Chapter 8
Printing an Image

8.1 Subtractive Printing

To make permanent prints of digital images on paper, the technology is drawn from the printing trades [1]. Optically, printing inks are transparent films, which act as filters to subtract (absorb) bands of wavelengths from the incident light. Thus, a cyan 'not-red' ink absorbs the red long wavelengths and transmits the green middle and blue short wavelengths; a magenta 'not-green' ink absorbs green and transmits red and blue; and a yellow 'not-blue' ink absorbs blue and transmits red and green (see Chap. 1, Section Printing). Available cyan magenta and yellow (CMY) inks are deficient in various ways, particularly in not making a good black when all three are overprinted. A black ink K, which absorbs all wavelengths and transmits none, is used to replace equal densities of CMY overprints ('undercolour-removal'). The incident light which survives the filtering of the ink layers is reflected by the white paper. Figure 8.1 shows the subtractive combinations of CMYK inks when printed solid.

But printing ink on paper is an essentially binary process. Each location of the master plate can either deposit ink or leave the paper showing the intensity of the ink deposit cannot be varied. Halftoning of one kind or another is the way around this limitation that has been used since the beginning of printing (see Chap. 6, Section Halftone Palettes). Hatched lines or small dots of solid ink are spaced out to appear as a range of intensities, in effect diluting the ink with the white paper. Digital halftoning [2, 3] is an important aspect of printing digital images, by either four-colour or black-only processes. A black-only halftone image can also be displayed on an additive sRGB screen.

Thus, printing uses a *CMYK colour space* [4], which is inverse to the sRGB space: instead of red we have cyan, instead of green magenta, instead of blue yellow and instead of equal intensities of red green and blue we have black. Figure 8.2a shows the four ink colours, and Fig. 8.2b shows the gamut of print colours, which is noticeably different from the sRGB gamut. Figure 8.3 shows a cube model of the CMYK space, front and back.

A. Parkin, *Computing Colour Image Processing*,
https://doi.org/10.1007/978-3-319-74076-8_8

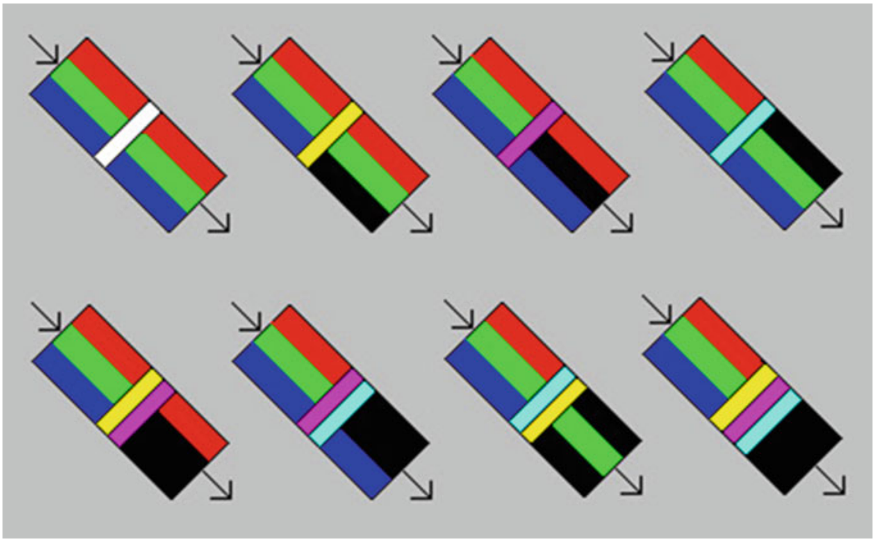

Fig. 8.1 Subtractive-colour filtering. Top row: **a** No ink passes all three wavelength bands of incident light and stops none. **b** Yellow ink passes red and green, stops blue. **c** Magenta ink passes red and blue, stops green. **d** Cyan ink passes green and blue, stops red. Bottom row: **e** Yellow and magenta inks together pass red. **f** Magenta and cyan inks together pass blue. **g** Cyan and yellow inks together pass green. **h** Ideal yellow magenta and cyan inks together would stop all light and pass none, to show black. Practical inks need a black-ink booster to show a good black

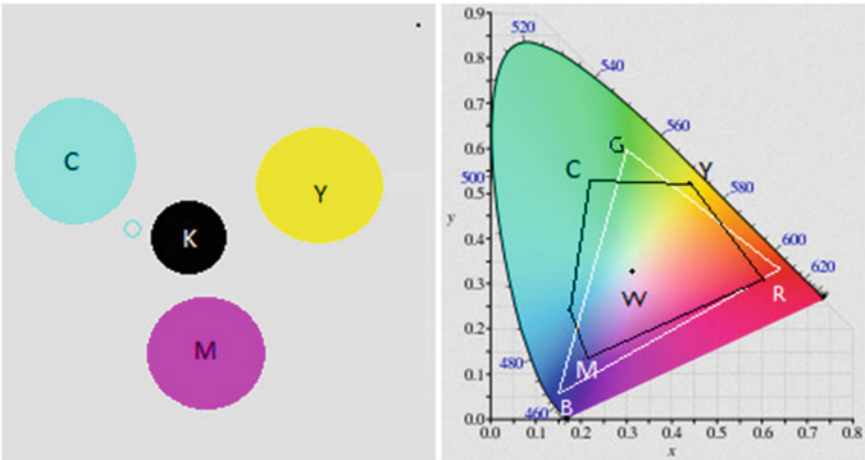

Fig. 8.2 The CMYK inks and their gamut of CIE hues. **a** Cyan magenta yellow and black inks. **b** The subtractive gamut of typical inks, compared to the sRGB additive gamut

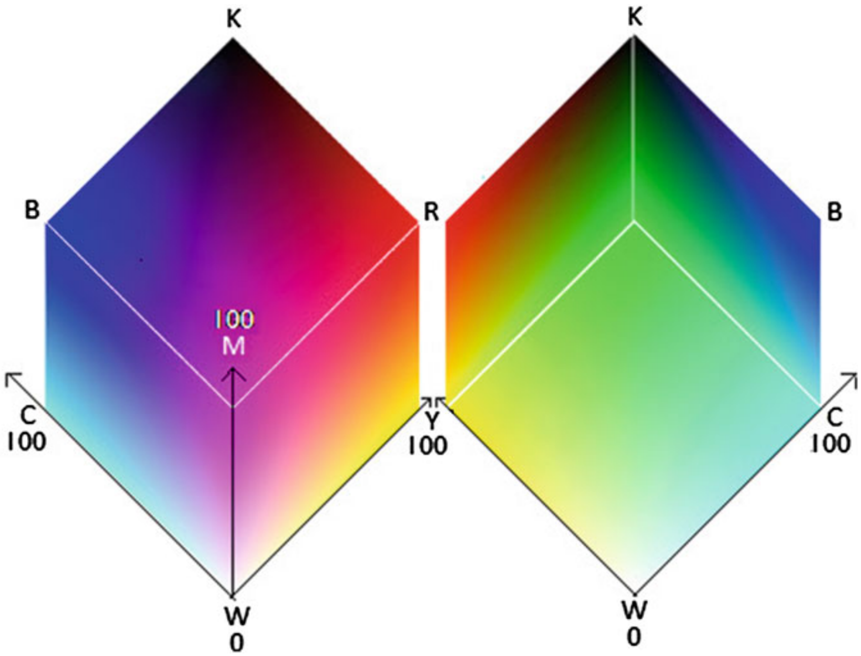

Fig. 8.3 CMYK colour space. Cube model, front and back, inverse to sRGB space. The origin is W white, with axes Y yellow, M magenta and C cyan, each axis calibrated 0–100%. K black ink replaces neutral combinations (C = M = Y)

8.2 Location Resolution

Numerically, an inkjet printer has:

Fixed line length $L*$ in.
Fixed page length $M*$ in.
Fixed dot pitch $N*$ dots per inch (dpi) (or dots per millimetre (dpmm)).
In each pixel, cyan magenta yellow and black dot densities 0–100%.

A typical A4 printer has a fixed line length of 8 in and a fixed page length of 11 in. The fixed dot pitch is usually 600 dpi for an inkjet printer, or 600–1200 or higher for a laser printer. So, an A4 600 dpi printer has a print extent of fixed width $W* = 8 \times 600 = 4800$ dots and a fixed height of $H* = 11 \times 600 = 6600$ dots. The printer software allocates a square of (say) 6×6 dots per pixel, so the extent of the printed page is $E* = 4800/6 \times 6600/6 = 880000$ px, about the same as an A4 display screen.

The computations for converting an sRGB image to CMYK colour space, and for halftoning the colours, are supplied in the printer manufacturer's driver software. The basic calculations are described in [3].

8.3 Colour Resolution

Compared to a screen display at 100 pixels per inch, a printer can thus allocate 6 $\times$ 6 dots per pixel. Each dot is an unvaried intensity of yellow magenta cyan or black ink. The dots are variably spaced by halftoning percentage from 0 to 100. At normal viewing distance, the dots combine subtractively and additively to give an approximate match to the additive display colours.

A CMYK printed image thus has four ink colours, each in 100% halftones, colour diversity $D = 100^4 = 100$ million apparent colours. Clearly, halftoning to say four levels would provide $D = 4^4 = 256$ colours, $COLRES = 1/256$, sufficient for most purposes.

8.4 Viewing Environment

We view an image printed on paper at a suitable distance and under suitable ambient lighting. Figure 8.4 shows the trigonometry of the situation. Best viewing distance is usually reckoned as the diagonal of the image. As shown in Chap. 7, a pixel can easily be seen by a normal Snellen 20/20 eye. But in a printout, a pixel is formed of (say) 6 $\times$ 6 dots, which are well below the threshold of normal visibility. A printout thus appears as a continuous-tone image with no visible pixel structure.

Since a printout depends on filtering out some parts of the incident light, it will always need bright incident light to match the 80–100 cd/m^2 recommended for an additive screen [3]. But the eye is remarkably adaptive to lighting conditions, and involuntarily compensates for differences of incident and reflected light [5].

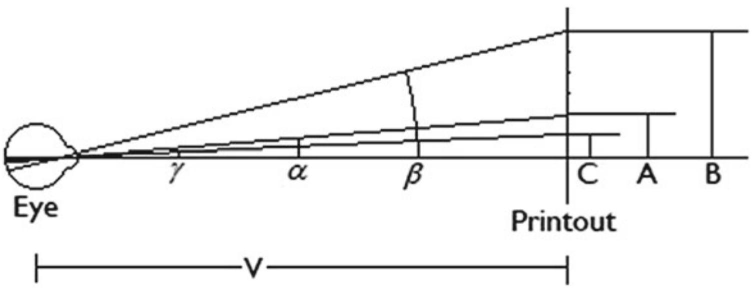

Fig. 8.4 Viewing a printout. α is 1 arc-minute, and A is the smallest detail resolved by a normal Snellen 20/20 eye. β is 3 arc-minutes, the angle subtended at the eye by one pixel at near viewing distance $V = 10$ in. γ is 0.5 arc-minute, the angle subtended at the eye by a typical printer dot C: too small to resolve

References

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