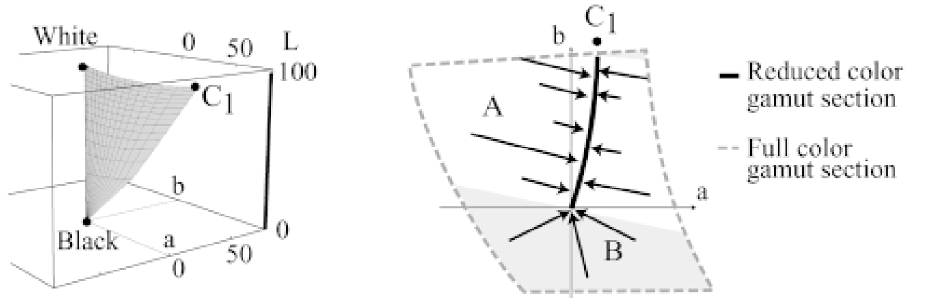
Techniques for color-gamut reduction

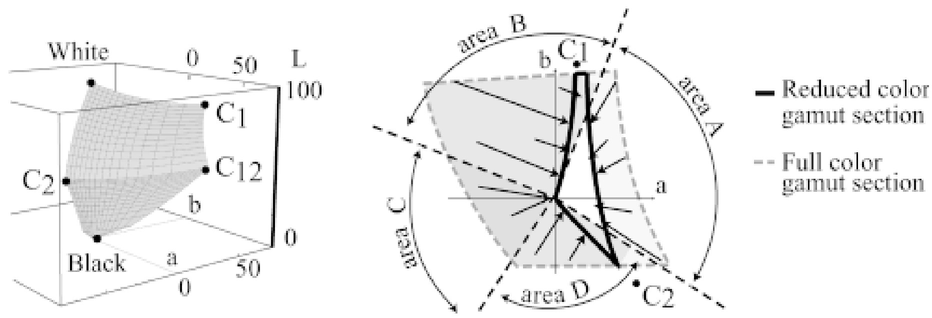
Printing with custom inks[1-3] is a widespread technique for protecting documents against counterfeiting attempts. Banknotes are often printed with a limited set of custom inks. In such banknote designs, the color gamut defined by the custom inks is severely reduced compared with the gamut defined by the standard cyan, magenta and yellow. In the context of banknote and artistic design, it would be very valuable to have a flexible tool able to carry out gamut reduction in order to map a color input image to an image with colors located within the reduced gamut offered by the set of one, two, or three custom inks: generally without the black.

The problem of color-gamut reduction distinguishes itself considerably from the well-known problem of gamut mapping.[4] This is especially the case when the grey axis is not part of the reduced target gamut. The gamut reduction problem consists in creating a mapping between an original “full” color gamut—e.g. the color gamut of a CRT monitor—and the reduced gamut defined by a given set of custom inks. The proposed mapping should preserve color continuity and, whenever possible, smoothness, i.e. a continuous color wedge located in the original color space should be mapped into a continuous color wedge located in the reduced target gamut. In addition, among different possible mappings, those preserving the original colors to at least a certain extent should be preferred. For example, hues of original colors should be preserved as much as possible, and saturated colors located in parts of the color space common to both the input and target gamuts should remain as close as possible.



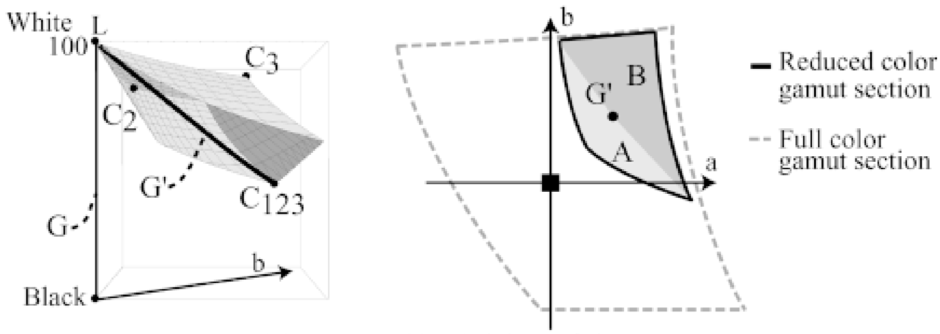
(a) Target gamut (CIE-Lab). (b) Projection of colors into the target gamut.

Figure 1. Reduced color gamut with custom ink C_1 and black.



(a) Target gamut (CIE-Lab). (b) Mapping colors into the target gamut.

Figure 2. Reduced color gamut with two custom inks C_1, C_2, and black.



(a) Target gamut with pseudo-gray axis G'. (b) Division of the target gamut into regions A and B.

Figure 3. Reduced color gamut with three custom inks C_1, C_2, and C_3.

Gamut reduction for custom inks including the black ink

If the paper is white and the selected set of inks includes black, the grey axis of the reduced target color gamut is identical or very close to the original grey axis. A linear mapping is adequate for mapping original lightness levels to target lightness levels. When, in addition to black, a single color C_1 is selected in order to give to a design a monochromatic aspect, the proposed gamut mapping method maps the original colors onto the gamut surface *White*-C_1-*Black* (see Figure 1). The points located in area *A* are orthogonally projected onto the surface. Colors with hues far from the hue of color C_1 will therefore be more desaturated, i.e. closer to grey than colors with hues close to that of C_1. All the color points in area *B* are mapped onto the grey axis by keeping their relative lightness values constant.

With two custom inks, printable hues are located between those of inks C_1 and C_2. Area *A* is where the hues are kept as close as possible to the original (Figure 2b). Original colors with hues located in areas *B* and *D* are mapped onto areas at the border of printable area *A* and colors with hue located in area *C* are mapped onto the grey axis. The same method is applicable in the case where three or more custom inks cover less than a 180˚ hue range.

When printing with a set of custom inks not including black, the input color gamut needs to be mapped into a reduced gamut that either does not include the grey axis at all or includes only a part of it. Again, we try to preserve the saturated colors located inside the reduced target gamut as much as possible and map hues

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Special Issue on:

Gamut Mapping

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outside it onto de-saturated pseudo-grey colors. Since the grey axis cannot be printed with the chosen set of inks, we map it onto the target gamut as a continuous smooth curve ensuring that continuous original grey values are mapped into continuous values of lightness, saturation and hue. A smooth curve, which by definition remains within the target gamut, is the curve representing equal coverage of inks C_1, C_2 and C_3. With this pseudo-grey axis, we divide the target gamut into two distinct regions: one on its de-saturated side (area *A*, Figure 3b) and one on its saturated (area *B*, Figure 3b). Input gamut colors with hues that are not part of the target gamut are mapped into colors located on the de-saturated side of the pseudo-grey axis. Colors within the set of printable hues remain within the target color gamut and retain their original hue and saturation as much as possible.

More information and images illustrating our results can be found at:
http://diwww.epfl.ch/w3lsp/research/colour/

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