Colorimetric Tone Value (CTV)
A Proposed Single-Value Measure for Presswork

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Rationale

Traditionally, most of the measures used for calibration and process control in the pressroom are based on density. Solid ink density (SID), tone value increase (TVI), and print contrast are all density-based measures. Colorimetry has now become a useful common measure for characterizing a printing process. Bringing colorimetry into the pressroom presents difficulties for the press operator. Suppose that a solid ink target value is specified by its colorimetric Lab values, as in ISO 12647-2. That measure consists of three numbers. The press operator can only adjust the ink keys up or down to increase or decrease the ink lay. But the operator cannot hit the three-valued target, except by chance, or by changing the color of the inks. A single-value colorimetric measure of tone value is needed in the pressroom.

Potential Single-Value Colorimetric Measures

L-value

For measuring black ink, the L-value could be used. This value varies between 100 (perfect white) and 0 (perfect black), and is a uniform visual measure. Typical values for a #1 coated sheet are 95 (paper white) to 15 (solid black).

Unfortunately, the L-value is a poor solution for measuring colors. For example, typical yellow values are 95 (paper white) to 90 (solid yellow). The yellow property of the ink is simply not captured by the L-value, as it is based entirely on the y-measure.

Chroma

For colored inks, chroma looks like a reasonable measure. But there are anomalies when measuring certain colors, like magenta. For instance, the chroma of a "pure" magenta will be greater than a "dirty" magenta, even though the visual perception of tone is reversed. The dirtier the magenta ink becomes, the less its chroma value.

ΔE

A better solution is to use the ΔE between the color being measured and the paper white. This value will range from 0 (paper white) to 100 for neutrals (perfect black on perfect white). In some cases (e.g. yellow) the value can exceed 100. Most instruments already provide this measure, and it can be easily computed from Lab data.

But ΔE is derived from Lab differences, and the anomalies of the chroma measure are still present.

Colorimetric Tone Value – CTV

Colorimetric Tone Value (CTV) is similar to the ΔE measure, but avoids the chroma anomalies. It makes use of the linearizing function employed in the conversion of xyz to Lab. This makes CTV a visually uniform measure.

The CTV measurement is normally relative to paper white. Paper white has a CTV of 0, and a perfect black on perfect white paper has a CTV of 100. For neutrals, CTV and ΔE are identical measures. For colors, the CTV measures will be less than ΔE.Here is the math for *CTV*, starting with *xyz* values. The calculations are very similar to those for Lab. See Annex H of ANSI CGATS.5-2003.

$$f_x = \begin{cases} \sqrt[3]{x_r} & x_r > \varepsilon \\ \dfrac{\kappa x_r + 16}{116} & x_r \le \varepsilon \end{cases} \qquad \begin{aligned} \varepsilon &= 216/24389 \cong 0.008856 \\ \kappa &= 24389/27 \cong 903.3 \end{aligned}$$

$$f_y = \begin{cases} \sqrt[3]{y_r} & y_r > \varepsilon \\ \dfrac{\kappa y_r + 16}{116} & y_r \le \varepsilon \end{cases}$$

$$f_z = \begin{cases} \sqrt[3]{z_r} & z_r > \varepsilon \\ \dfrac{\kappa z_r + 16}{116} & z_r \le \varepsilon \end{cases}$$

From the intermediate values (f_x, f_y, f_z) above, we compute L_x, L_y, L_z:

$$L_x = 116 f_x - 16$$

$$L_y = 116 f_y - 16$$

$$L_z = 116 f_z - 16$$

Using the paper white measurements, L_{xp}, L_{yp}, L_{zp}:

$$CTV = \sqrt{\frac{(L_{xp} - L_x)^2 + (L_{yp} - L_y)^2 + (L_{zp} - L_z)^2}{3}}$$

CTV can be made absolute simply by setting the paper white values (L_{xp}, L_{yp}, L_{zp}) to 100.

Most graphic arts color measurements are made in Lab.

To convert from Lab to $L_xL_yL_z$:

$$L_y = L$$

$$L_x = L + \frac{116a}{500}$$

$$L_z = L - \frac{116b}{200}$$

To convert from $L_xL_yL_z$ to Lab:

$$L = L_y$$

$$a = \frac{500(L_x - L_y)}{116}$$

$$b = \frac{200(L_y - L_z)}{116}$$

To compute CTV from Lab values, first convert the Lab values to $L_xL_yL_z$, then evaluate CTV:

$$CTV = \sqrt{\frac{(L_{xp} - L_x)^2 + (L_{yp} - L_y)^2 + (L_{zp} - L_z)^2}{3}}$$

Properties of CTV

- Single-valued tone measure
- Computed from Lab or xyz values
- No RGB filter response to choose
- Works for both process and spot colors
- Inherently achieves the “best match” to an Lab value
- Visually uniform measure
- Absolute or relative to paper white

Geometric Interpretation

CTV has a simple geometric interpretation. CTV is proportional to the length of the vector from paper white to the color being measured in $L_xL_yL_z$ space (as defined above).

CTV in the Pressroom

Pressmen use tone measurements to set up and monitor their work. The measure currently used for this purpose is density. Density measurements are based on the spectral characteristics of gelatin color separation filters in combination with photomultiplier tubes. But recent print standards, such as ISO 12647-2, use colorimetry to specify solid ink color. Colorimetry and density are incompatible measures. Although they can each be derived from spectral data, it is impossible to convert density to colorimetry or vice versa.

A press operator attempting to set up according to ISO 12647-2 must use a colorimeter to measure the solid ink colors. The target color is specified as an Lab value. Unfortunately, the operator will not be able to achieve the exact target value, except by chance. Instead, they must adjust for minimum ΔE, with the distinct possibility that the allowable tolerance may not be achievable. This places the press operator in the difficult situation of not knowing when the closest match to the target has been achieved.

CTV solves this problem by providing the operator with a single-valued measure derived from colorimetry. The CTV target values are computed directly from the Lab targets. Ink lay is adjusted to achieve those values exactly. That is an easy and familiar task for the pressman. The end result is almost exactly the same as minimizing ΔE.

Effect of Paper on Solid Ink Color

Using CTV in this way overcomes another problem, which is the effect that paper has on the solid ink colors. The Lab values in ISO 12647-2 are based on specific paper types. In reality, paper is a variable in commercial printing, and the choice of paper will affect the color of solid inks. It is very doubtful that printers will reformulate their inks for different paper stocks.

This effect of paper on ink color is an unresolved standards issue. For now, a common sense solution is to specify ink lay using CTV. Since CTV is relative to paper white, this approach will maintain a consistent visual appearance.