Applications Note

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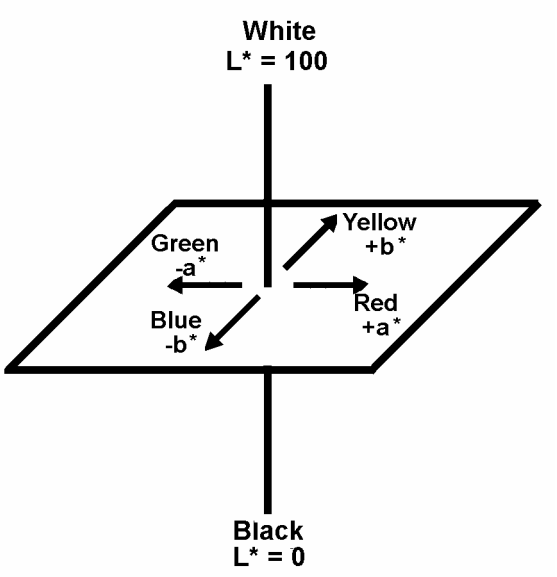
CIE L*a*b* Color Scale

Background

In 1976, the CIE recommended the CIE L*a*b*, or CIELAB, color scale for use. CIE Publication 15.2 (1986), Section 4.2, contains details on this color scale. It was intended to provide a standard, approximately uniform color scale which could be used by everyone so that color values could be easily compared.

The CIELAB color scale is an approximately uniform color scale. In a uniform color scale, the differences between points plotted in the color space correspond to visual differences between the colors plotted. The CIELAB color space is organized in a cube form. The L* axis runs from top to bottom. The maximum for L* is 100, which represents a perfect reflecting diffuser. The minimum for L* is zero, which represents black. The a* and b* axes have no specific numerical limits. Positive a* is red. Negative a* is green. Positive b* is yellow. Negative b* is blue. Below is a diagram representing the CIELAB color space.



There are delta values associated with this color scale. ΔL*, Δa*, and Δb* indicate how much a standard and sample differ from one another in L*, a*, and b*. These delta values are often used for quality

control or formula adjustment. Tolerances may be set for the delta values. Delta values that are out of the tolerances indicate that there is too much difference between the standard and the sample. The type of correction needed may be determined by which delta value is out of tolerance. For example, if Δa* is out of tolerance, the redness/greenness needs to be adjusted. Whether the sample is redder or greener than the standard is indicated by the sign of the delta value. For example, if Δa* is positive, the sample is redder than the standard.

The total color difference, ΔE*, may also be calculated. The ΔE* is a single value which takes into account the differences between the L*, a*, and b* of the sample and standard. It does not indicate which parameter(s) (L*, a*, and/or b*) are out of tolerances if ΔE* is out of tolerance. It may also be misleading in some cases where ΔL*, Δa*, or Δb* is out of tolerance, but ΔE* is still within tolerance.

In addition, there are two other delta values that are related to this scale, ΔC* and ΔH*. The ΔC* is the difference in chroma between the sample and standard as described in a polar coordinate system. The ΔH* is the difference in hue angle between the sample and standard as described in a polar coordinate system.

The CIELAB color scale may be used on any object whose color may be measured. It is used extensively in many industries. As was intended, it provides a standard scale for comparison of color values.

Conditions for Measurement

Instrumental: Any HunterLab color measurement instrument

Illuminant: Any

Standard Observer Function: 2 or 10 degree

Transmittance and/or Reflectance: Either.

Formulas

If X/X_n, Y/Y_n, and Z/Z_n are all greater than 0.008856, then

$$L^* = 116\sqrt[3]{Y/Y_n} - 16$$

$$a^* = 500\left(\sqrt[3]{X/X_n} - \sqrt[3]{Y/Y_n}\right)$$

$$b^* = 200\left(\sqrt[3]{Y/Y_n} - \sqrt[3]{Z/Z_n}\right)$$

If any of X/X_n, Y/Y_n, or Z/Z_n is equal to or less than 0.008856, then

$$L^* = 903.3\left(Y/Y_n\right)$$

$$a^* = 500\left[f\left(X/X_n\right) - f\left(Y/Y_n\right)\right]$$

$$b^* = 200\left[f\left(Y/Y_n\right) - f\left(Z/Z_n\right)\right]$$

where

X, Y, and Z are the CIE Tristimulus Values

X_n, Y_n, and Z_n are the tristimulus values for the illuminant

Y_n is 100.00

X_n and Z_n are listed in the tables below.

CIE 2 Degree Standard Observer

Illuminant	X_n	Z_n
A	109.83	35.55
C	98.04	118.11
D_{65}	95.02	108.82
F2	98.09	67.53
TL 4	101.40	65.90
UL 3000	107.99	33.91
D_{50}	96.38	82.45
D_{60}	95.23	100.86
D_{75}	94.96	122.53

CIE 10 Degree Standard Observer

Illuminant	X_n	Z_n
A	111.16	35.19
C	97.30	116.14
D_{65}	94.83	107.38
F2	102.13	69.37
TL 4	103.82	66.90
UL 3000	111.12	35.21
D_{50}	96.72	81.45
D_{60}	95.21	99.60
D_{75}	94.45	120.70

$f(X/X_n) = \sqrt[3]{X/X_n}$ when $X/X_n > 0.008856$

$f(X/X_n) = 7.87\left(\frac{X}{X_n}\right) + \frac{16}{116}$ when $X/X_n < 0.008856$

$f(Y/Y_n) = \sqrt[3]{Y/Y_n}$ when $Y/Y_n > 0.008856$

$f(Y/Y_n) = 7.87\left(\frac{Y}{Y_n}\right) + \frac{16}{116}$ when $Y/Y_n < 0.008856$

$f(Z/Z_n) = \sqrt[3]{Z/Z_n}$ when $Z/Z_n > 0.008856$

$f(Z/Z_n) = 7.87\left(\frac{Z}{Z_n}\right) + \frac{16}{116}$ when $Z/Z_n < 0.008856$

$\Delta L^* = L^*_{sample} - L^*_{standard}$ + ΔL^* means sample is lighter than standard
- ΔL^* means sample is darker than standard

$\Delta a^* = a^*_{sample} - a^*_{standard}$ + Δa^* means sample is redder than standard
- Δa^* means sample is greener than standard

$\Delta b^* = b^*_{sample} - b^*_{standard}$ + Δb^* means sample is yellower than standard
- Δb^* means sample is bluer than standard

$$\Delta E^* = \sqrt{\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2}}$$

$$\Delta C^* = C^*_{sample} - C^*_{standard}$$

where

$$C^* = \sqrt{a^{*2} + b^{*2}}$$ (this is called metric chroma)

$$\Delta H^* = \sqrt{\Delta E^{*2} - \Delta L^{*2} - \Delta C^{*2}}$$

Typical Applications

This color scale may be used for measurement of the color of any object whose color can be measured.

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