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Colorimetry —

Part 4: CIE 1976 L*a*b* colour space

Colorimétrie —

*Partie 4: Espace chromatique L*a*b* CIE 1976*

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by the International Commission on Illumination (CIE) in cooperation with Technical Committee ISO/TC 274, *Light and lighting*.

This first edition of ISO/CIE 11664-4 cancels and replaces ISO 11664-4:2008 | CIE 11664-4:2007, of which it constitutes a minor revision. The document has been editorially revised as per current ISO rules and the references have been updated.

A list of all parts in the ISO 11664 and ISO/CIE 11664 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The three-dimensional colour space produced by plotting CIE tristimulus values (*X*, *Y*, *Z*) in rectangular coordinates is not visually uniform, nor is the (x,y,Y) space nor the two-dimensional CIE (x,y) chromaticity diagram. Equal distances in these spaces do not represent equally perceptible differences between colour stimuli. For this reason, in 1976, the CIE introduced and recommended two new spaces (known as CIELAB and CIELUV) whose coordinates are nonlinear functions of *X*, *Y* and *Z*. The recommendation was put forward in an attempt to unify the then very diverse practice in uniform colour spaces and associated colour-difference formulae[1][2]. Both these more-nearly uniform colour spaces have become well accepted and widely used. Numerical values representing approximately the magnitude of colour differences can be described by simple Euclidean distances in the spaces or by more sophisticated formulae that improve the correlation with the perceived size of differences.

The purpose of this document is to define procedures for calculating the coordinates of the CIE 1976 L*a*b* (CIELAB) colour space and the Euclidean colour difference values based on these coordinates. This document does not cover more sophisticated colour-difference formulae based on CIELAB, such as the CMC formula[3], the CIE94 formula[4], the DIN99 formula[5], and the CIEDE2000 formula[6][7], nor does it cover the alternative uniform colour space, CIELUV[8].

Colorimetry —

Part 4:
CIE 1976 L*a*b* colour space

1 Scope

This document specifies a method of calculating the coordinates of the CIE 1976 L*a*b* colour space, including correlates of lightness, chroma and hue. It includes two methods for calculating Euclidean distances in this space to represent the perceived magnitude of colour differences.

This document is applicable to tristimulus values calculated using colour-matching functions of the CIE 1931 standard colorimetric system or the CIE 1964 standard colorimetric system. This document can be used for the specification of colour stimuli perceived as belonging to a reflecting or transmitting object, where a three-dimensional space more uniform than tristimulus space is required.

This document does not apply to colour stimuli perceived as belonging to an area that appears to be emitting light as a primary light source, or that appears to be specularly reflecting such light.

This document is applicable to self-luminous displays, such as cathode ray tubes, if they are being used to simulate reflecting or transmitting objects and if the stimuli are appropriately normalized.

Calculating the reverse transformation is shown in Annex A.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

CIE S 017, *ILV: International Lighting Vocabulary*

ISO/CIE 11664-1, *Colorimetry Part 1 — CIE Standard Colorimetric Observers*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in CIE S 017 apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

4 Symbols and abbreviated terms

X, Y, Z	tristimulus values of test stimulus calculated using the colour-matching functions of the CIE 1931 standard colorimetric system (also known as the CIE 2° standard colorimetric system)
X_n, Y_n, Z_n	tristimulus values of a specific white colour stimulus calculated using the colour-matching functions of the CIE 1931 standard colorimetric system
L^*	CIE 1976 lightness (CIELAB lightness)
a^*, b^*	CIELAB a^*, b^* coordinates
C^*_{ab}	CIE 1976 a,b chroma (CIELAB chroma)
h_{ab}	CIE 1976 a,b hue angle (CIELAB hue angle)
ΔL^*	CIELAB lightness difference
$\Delta a^*, \Delta b^*$	CIELAB a^*, b^* difference
ΔC^*_{ab}	CIELAB chroma difference
Δh_{ab}	CIELAB hue angle difference
ΔH^*_{ab}	CIELAB hue difference
ΔE^*_{ab}	CIELAB colour difference

If the character "Δ" is not available, it may be replaced by the character "D".

The phrase "CIE 1976 L*a*b*" and the term "CIELAB" may be used interchangeably.

Where tristimulus values are calculated using the colour-matching functions of the CIE 1964 standard colorimetric system (also known as the CIE 10° standard colorimetric system), a subscript 10 shall be added to all the above symbols.

5 Calculation method

5.1 Basic coordinates

The CIE 1976 L*a*b* colour space is a three-dimensional, approximately uniform colour space produced by plotting in rectangular coordinates, L^*, a^*, b^*, quantities defined by Formulae (1) to (3):

$$L^* = 116 f(Y/Y_n) - 16 \quad (1)$$

$$a^* = 500\left[f(X/X_n) - f(Y/Y_n)\right] \quad (2)$$

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

where

$$f(X/X_n)=(X/X_n)^{1/3} \quad \text{if } (X/X_n)>(6/29)^3 \tag{4}$$

$$f(X/X_n)=(841/108)(X/X_n)+4/29 \quad \text{if } (X/X_n)\leq(6/29)^3 \tag{5}$$

and

$$f(Y/Y_n)=(Y/Y_n)^{1/3} \quad \text{if } (Y/Y_n)>(6/29)^3 \tag{6}$$

$$f(Y/Y_n)=(841/108)(Y/Y_n)+4/29 \quad \text{if } (Y/Y_n)\leq(6/29)^3 \tag{7}$$

and

$$f(Z/Z_n)=(Z/Z_n)^{1/3} \quad \text{if } (Z/Z_n)>(6/29)^3 \tag{8}$$

$$f(Z/Z_n)=(841/108)(Z/Z_n)+4/29 \quad \text{if } (Z/Z_n)\leq(6/29)^3 \tag{9}$$

where

X, Y, Z are the tristimulus values of the test colour stimulus based on the CIE 1931 standard colorimetric system defined in ISO/CIE 11664-1;

X_n, Y_n, Z_n are the corresponding tristimulus values of a specified white stimulus.

In cases of simulated reflecting or transmitting objects produced on a self-luminous display, all the tristimulus values shall be first normalized by the same factor so that Y would be equal to 100 for an object with 100 % reflectance or transmittance.

If the angle subtended at the eye by the test stimulus is between about 1° and 4°, the tristimulus values X, Y, Z calculated using the colour-matching functions of the CIE 1931 standard colorimetric system should be used. If this angular subtense is greater than 4°, the tristimulus values X_{10}, Y_{10}, Z_{10} calculated using the colour-matching functions of the CIE 1964 standard colorimetric system should be used. The same colour-matching functions and the same specified white stimulus shall be used for all stimuli to be compared with each other.

When tristimulus values based on the CIE 1964 standard colorimetric system defined in ISO/CIE 11664-1 are used, a subscript 10 shall be added to all the symbols in Formulae (1) to (9).

If the tristimulus values X, Y, Z are obtained by spectrophotometry, the tristimulus values X_n, Y_n, Z_n of the specified white stimulus shall be calculated using the same method as used for the test stimulus (same colour-matching functions, same range and interval of wavelength, and same bandwidth). If the tristimulus values X, Y, Z are obtained by direct measurement using a tristimulus colorimeter, X_n, Y_n, Z_n shall be measured using the same tristimulus colorimeter and a white reflectance standard calibrated relative to a perfect reflecting diffuser.

NOTE 1 For real object colours, the specified white stimulus normally chosen for X_n, Y_n, Z_n is light reflected from a perfect reflecting diffuser illuminated by the same light source as the test object. In this case, X_n, Y_n, Z_n are the tristimulus values of the light source normalized by a common factor so that Y_n is equal to 100. For simulated object colours, the specified white stimulus normally chosen is one that has the appearance of a perfect reflecting diffuser, again normalized by a common factor so that Y_n is equal to 100.

NOTE 2 Examples of values of X_n, Y_n and Z_n for specific illuminants and specific calculation methods have been published[2].