Transformation between *absolute LAB** (CIELAB) and device dependent *relative lab** data

Prof. Dr. Klaus Richter

Federal Institute for Materials Research and Testing (BAM)
Working Group VIII.34, Visual Methods and Image Reproduction

Unter den Eichen 87, D-12205 Berlin

Tel. +49 30 8104 1834; Fax +49 30 8104 1807

klaus.richter@bam.de

http://www.ps.bam.de

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Title

Method and equations for the transformation between the device independent *absolute* coordinates ***LAB**** (CIELAB) and the device dependent *relative* colorimetric coordinates ***olv**** and ***cmy**** in both directions based on eight device colours CMYOLVNW

Scope

This International Technical Report describes a method and equations for the transformation between the family of device independent *absolute* colorimetric coordinates ***LAB**** (CIELAB) and the family of device dependent *relative* colorimetric coordinates ***lab**** in both directions, for example *olv*, cmy*, and nce* (n* = blackness, c* = chromaticness, e* = elementary hue)*. For the 16 step colour scales used in the ISO/IEC-test charts according to ISO/IEC 15775 and for any device a *linear* relationship is produced between the ***LAB**** data of the colours and the ***lab**** data which are used for example in the *PostScript* or *PDF* file. The calculations are based on the CIELAB data of eight colours CMYOLVNW of any input or output device system.

NOTE: The device dependent *relative* colorimetric coordinates ***lab**** are appropriate to produce colours of constant hue and constant *relative* chromaticness and *relative* lightness of the CIELAB space on different devices *(compare Fig. 3).*

Purpose and justification

The eight standard offset colours CMYOLVNW printed on standard offset reference paper according to ISO/IEC 15775 define the Offset Reflective System ORS18 with the lightness *L**=18 for black N (=noir), compare also ISO/IEC TR 24705. The eight *LAB** (CIELAB) data of the system ORS18 are used to define the device dependent relative colorimetric coordinates *olv** and *cmy** which are applied in image technology according to ISO/IEC 15775.

This International Technical Report describes a method and equations for the transformation between the family of device independent *absolute* colorimetric coordinates ***LAB**** (CIELAB), for example *LAB*LAB = L*, a,*, b** and *LAB*LCH = L*, C*ab, H** and the family of device dependent *relative* colorimetric coordinates ***lab*,*** for example *lab*olv = olv**, *lab*cmy = cmy**, *lab*nce = nce** with blackness *lab*n = n**, chromaticness *lab*c = c**, and elementary hue *lab*e = e** and others in both directions *(compare examples in Fig. 4)*

The device dependent *relative* colorimetric coordinates ***lab****, for example *olv*, cmy*, nce** and others have a *linear* relationship to the device independent *absolute* colorimetric coordinates ***LAB**** (CIELAB) *(compare Fig. 3 and 4).*

The following *notes* list some possibilities how to apply the method and the equations for the transformation between ***LAB**** and ***lab**** in both directions. The scope of this International Technical Report is limited to the above transformation equations.

NOTE1: Nearly all colorimetric colour order systems are defined for the CIE standard illuminant D65 and this illuminant is used in ISO/IEC 15775 for colour copiers. Any colour order system uses three coordinates out of a variety of many coordinates, such as lightness, chromaticness, hue, blackness, elementary hue, whiteness, deepness and others. This variety produces families of colorimetric coordinates either defined by *absolute* or *relative* colorimetric coordinates ***LAB**** and ***lab*.*** For example *absolute* ***LAB**** data *(LCH*)* are used for the about 1700 samples of the *RAL Design Colour Atlas* and *relative* ***lab**** data *(nce*)* are used for the about 1700 samples of the *NCS Natural Colour System (compare Fig. 1).*

NOTE2: The different colorimetric coordinates used for example in information technology, in design, in industrial applications, and in colour order systems will be connected by *linear* equations between the device dependent *relative* colorimetric coordinates ***lab****, for example *olv**, *cmy**, *nce** and the device independent *absolute* ***LAB**** measurement data.

NOTE3: Up to now image technology uses often device dependent coordinates *rgb (olv)* and *cmy* which have **No** linear relationship (indicated by *cmy* instead of *cmy**) to the colour coordinates used in every day life in design, architecture, and art, and to the ***LAB**** measurement data of industrial colour products and colour surfaces. However, the device dependent *relative* colorimetric coordinates *olv**, *cmy*, nce** and others of this International Technical Report have a *linear* relationship to the *absolute* ***LAB**** data, for example of a printer system. For achromatic colours the *sRGB* coordinates of the standard IEC 91966-2-1 have approximately a linear relationship to the lightness *L** of CIELAB.

NOTE4: If the analog ISO/IEC-test charts are taken by new CIELAB cameras or scanners then the pixels are defined by ***LAB**** (CIELAB) data. The ***LAB**** (standard CIELAB) images can often not be viewed. A transformation from the ***LAB**** data to the ***lab**** data, for example *olv** and *cmy** data is necessary *(compare Fig. 2).*

NOTE5: For two different device spaces, for example the input space TLS18 (Television Luminous System) and the output space ORS18 (Offset Reflective System) (both with black lightness L^*_N=18, compare space names in ISO/IEC TR 24705), the equally spaced 5 step colour scales are connected by linear equations *(compare Fig. 3)*.

NOTE6: If a user describes a 5 step digitally equally spaced colour series by the three coordinates *nce** and both blackness and elementary hue is constant (for example *n**=0, *e**=0.8) then the variable *c** = 0, 0.25, 0.50, 0.75, 1 describes the 5 step colour series between White W and Cyan blue C which is equally spaced in CIELAB on any device, for example on the two devices ORS18 and TLS18 *(compare Fig. 3 and 4)*.

NOTE7: Each line in *Fig. 4* lists three equivalent colorimetric data sets *LAB*LAB, lab*cmy* and *lab*olv* which are connected by the colorimetric transformation equations between ***LAB**** and ***lab****. The transformations are the basis for a Colorimetric Image Technology (CIT) which produces the same output for many equivalent colorimetric data *(compare the two reference papers)*.

NOTE8: In application some measured ***LAB**** (CIELAB) output colours may be located outside the hue triangles which are for example shown in *Fig. 3*. Then some of the relative colorimetric data of the ***lab**** family may be outside the range 0 to 1. For many applications the reverse transformations are necessary and it is appropriate to get back the original data. Therefore it is appropriate to allow calculations within the digital range -0.5 to +1.5 instead of 0 to 1 in both directions and for all data without clipping. The range -0.5 to +1.5 seem to cover all colours of any printer and monitor device system. The colour gamut for the range -0.5 to +1.5 is four times larger compared to the range 0 to 1.

NOTE9: For colour management applications a linearization method is appropriate, for example the method given in ISO/IEC TR 19797. However, in application often very *non* linear look up tables between *cmy* (or *rgb)* input data in a file and ***LAB**** (CIELAB) output data of the measured colours are produced, for example by some printer systems. The methods and equations of this International Technical Report define *linear* look up tables between *cmy** data and ***LAB**** (CIELAB) data in both directions for any device. If both look up tables *cmy** – ***LAB**** and *cmy* – ***LAB**** are known for the **intended** ***LAB**** output then a new produced and applied look up table *cmy** – *cmy* (user required input data and necessary input data to produce the intended ***LAB**** output) solves the problem of output linearization and gives an additional method compared to ISO/IEC TR 19797. In this case the analytical method of ISO/IEC TR 19797 is replaced by a look up table method but also a combination of both methods is possible.

NOTE10: For hex coding 8 bits may be used for the range -0.5 to +1.5 and then 7 bit are remaining for the achromatic standard range between 0.0 to 1.0. This allows the encoding and decoding called 7/8bits for at least 128 equally spaced grey steps in the CIELAB standard lightness range *L**=18 to *L**=95. Observers can usually not distinguish more then 64 grey steps and only 16 steps are produced in the ISO/IEC-test charts for office applications. Therefore the encoding and decoding of 8/8bits with 256 possible grey steps is not economical and efficient. In case of a very *non linear* (cubic) relationship for the device look up table *cmy** – *cmy* then up to 16 bits may be appropriate for the device data *cmy* but 7 bits are still sufficient for the colorimetric coordinate *cmy**.

Relevant documents to be considered

ISO/IEC 15775:1999, ISO/IEC 15775:1999/Amd 1:2005, ISO/IEC TR 19797:2004, ISO/IEC 24705:2005 (under publication), CIE Publ. 15: 2004 (Colorimetry), IEC 61966-2-1:1999, ISO 22028-1:2004

For further information see the two papers:

K. Richter, 2005, Natural Colour Connection Space (NCCS) between input and output for office systems, see the URL (1.0 MByte, 20 pages)

http://www.ps.bam.de/BAMAG1.PDF

K. Richter, 2005, Linear Relationship between CIELAB and Device Coordinates for a new Colorimetric Image Technology (CIT), see the URL (140 kByte, 6 pages)

http://www.ps.bam.de/CIE05.PDF

Cooperation and liaison

CIE Div. 8, CIE Div. 1 (TC1-57), ISO TC 42, ISO TC 130, ISO TC 159/SC4, ISO TC 171, IEC TC 100 TA2

Market Requirements

There is a need to connect the different colorimetric coordinates used for example in information technology, in design, in industrial applications, and in colour order systems. New *linear* equations between the device dependent *relative* colorimetric coordinates ***lab*,*** for example *olv**, *cmy**, *nce** and the device independent *absolute* ***LAB**** measurement data solve parts of this problem.

The new analog ISO/IEC-test charts according to ISO/IEC 15775:1999/Amd 1:2005 will be used to test the calculations and to show visually the relationships to colour order systems.

Completion/Maintenance of current standards

This report defines extensions of the coordinates *olv** and *cmy** which are used in ISO/IEC 15775:1999 and in ISO/IEC TR 19797:2004 for copier and printer systems. The new analog ISO/IEC-test charts according to ISO/IEC 15775:1999/Amd 1:2005 will be used to test the calculations. The different coordinates ***lab**** and ***LAB**** may serve for a new look up table method for output linearization of printers, which is an alternative to the method given in ISO/IEC TR 19797.

For the many BAM-, DIN-, CEN-, ISO-, IEC-, and ISO/IEC-test chart files see the URL

http://www.ps.bam.de

A PDF file with many other equivalent colorimetric coordinates for colours of eight different hues is at the URL (3 pages, 70 kByte)

http://www.ps.bam.de/LE36/10L/L36E00NP.PDF

Many additional and similar diagrams one may find in the paper (20 pages, 1 Mbyte)

http://www.ps.bam.de/AWG05.PDF

Fig. 1 to 4 may help to understand the relationship between *absolute* ***LAB**** and *relative* ***lab**** coordinates and the special importance for many applications.

Application of colour in daily life or in Information Technology (IT):

Design, architecture, art, industrial products
Measured for CIE standard illuminant D65

colour order system: name and coordinates

RAL Design Colour System (CIELAB):
LCH*, lightness, chroma, hue

Munsell Colour System:
VCH*, lightness (Value), Chroma, Hue

Natural Colour System (NCS):
nce*: blackness, chromaticness, elementary hue

Information technology of printers
Measured for CIE illuminants D65 or D50

Device system name and coordinates:

Printer system (illuminant D65 or D50):
cmy, content of "cyan", "magenta", "yellow"

Display system (standard illuminant D65):
rgb/sRGB, content of "red", "green", "blue"

IT colour coordinates confuse the users!
Nearly no connection to colour order systems!

New: Application connection by coordinates *olv, *cmy**, *nce**, ... and linear relation to *LAB****

CIELAB: ***LAB**** : lightness, red-green and yellow-blue chroma; ***LCH**** : lightness, chroma, hue

Definition of device coordinates similar to coordinates of colour order systems

lch*: relative lightness, chromaticness, hue

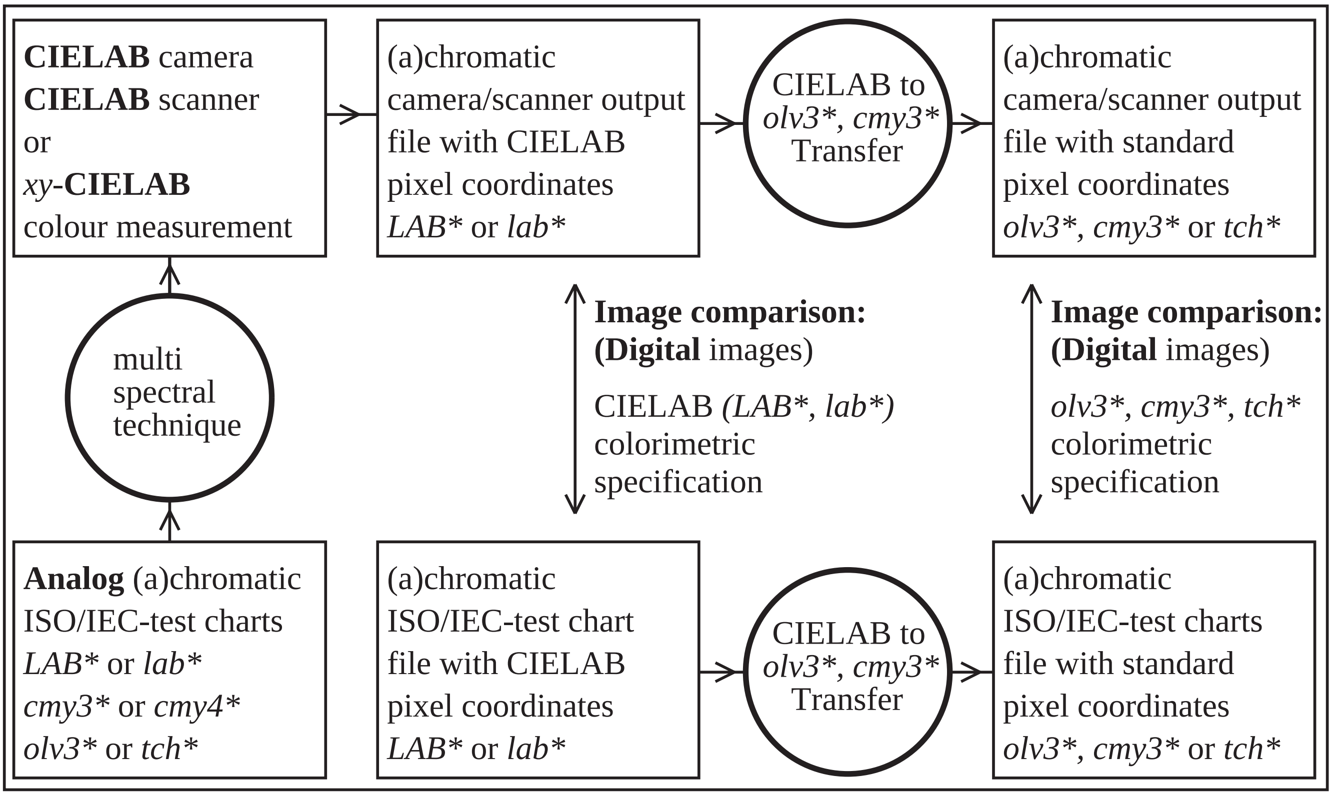
tch**, *tce*: triangle lightness, chromaticness, hue or elementary hue

nce*: blackness, chromaticness, elementary hue

LE430−3, Application connection with coordinates *olv**, *cmy**, *tch**, *tce**, *nce**, ... and linear relationship to *LAB**

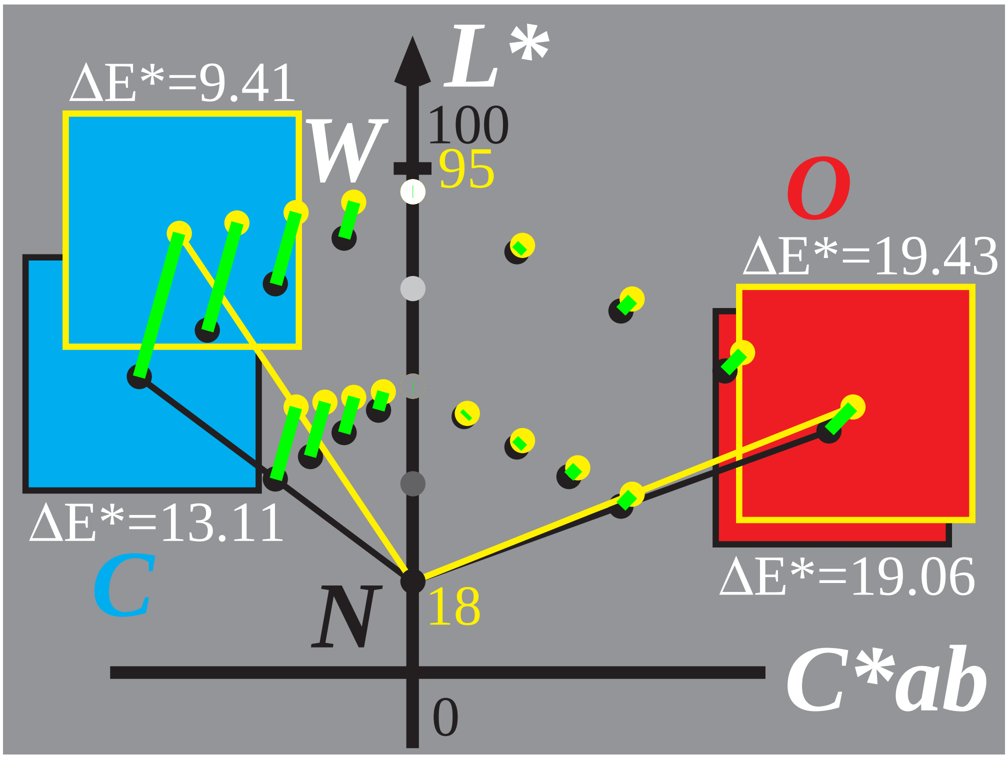
Figure 1: Linear relationship between *LAB and device coordinates *olv**, *cmy** and others**

Fig. 1 shows the *linear* relationship between ***LAB**** and device coordinates *olv**, *cmy** and others. The relations connect for example the coordinates of image technology and the coordinates of colour order systems used for many industrial applications.



LE430−7, Transfer from device independent data *LAB** to device dependent data *olv3**, *cmy3* and tch**

Figure 2: *LAB pixel data produced by CIELAB cameras and transfer**
Fig. 2 shows the ***LAB**** pixel data which are produced by CIELAB cameras. The transfer to device colorimetric coordinates *olv**, *cmy** is essential for the viewing of the images



ME321−41, Equal relative chromaticness and lightness: O-C

Figure 3: Equal relative chromaticness and lightness of hues O and C for two devices TLS18 and ORS18
Fig 3 shows equal relative chromaticness and lightness of hues O and C for two devices TLS18 and ORS18, compare ISO/IEC TR 24705:2005. The relative chromaticness *c** increases between 0 and 1 in steps of 0.25 compared to the maximum chroma in the $C^*_{ab} - L^*$ hue plane of CIELAB.

5 steps of colour series cyan blue - white (C - W)	Colour space, colour space coordinates and PostScript operator calculations according to ISO/IEC 15775:1999-12		
Linear mixture between cyan blue and white in CIELAB colour space	**CIELAB absolute *LAB*LAB = LAB** *LAB* setcolor***	**CIELAB relative *lab*cmy = cmy** *cmy* setcmykcolor***	**CIELAB relative *lab*olv = olv** *olv* setrgbcolor***
1,00 C + 0,00 W (cyan blue C)	58.62 -30.62 -42.74	1,00 0,00 0,00 0,00	0,00 1,00 1,00
0,75 C + 0,25 W	67.82 -23.21 -30.86	0,75 0,00 0,00 0,00	0,25 1,00 1,00
0,50 C + 0,50 W	77.02 -15.80 -18.98	0,50 0,00 0,00 0,00	0,50 1,00 1,00
0,25 C + 0,75 W	86.21 -8.39 -7.11	0,25 0,00 0,00 0,00	0,75 1,00 1,00
0,00 C + 1,00 W (white W)	95.41 -0.98 4.76	0,00 0,00 0,00 0,00	1,00 1,00 1,00

LE421−1, colorimetric relationship of *LAB**, *cmy**, *olv** for a 5 step scale: cyan blue − white

Figure 4: Relationship between *LAB (CIELAB) data and two device coordinates *cmy** and *olv****
Fig.4 shows the relationship between *LAB** (CIELAB) data and two device coordinates *cmy** and *olv** for the Offset Reflective System ORS18. The colorimetric coordinates *LAB**, *cmy** and *olv** in each line are called equivalent coordinates. For the ORS18 device the colour output will be equal for equivalent coordinates. The same 5 step colour series C – W is produced, independent of the colorimetric coordinates *LAB**, *cmy**, and *olv** used.