Technical Report BAM(8650/8750/8870/8880/8890)E

Colour Hexagon Transformations between the CIELAB and the *cmyw**, *olvn**, *nru** coordinates of the Offset Reflective System (ORS) using *L**=18, 14, 10, and 0 for Black *N*

Author: Prof. Dr. Klaus Richter

Federal Institute of Materials Research and Testing (BAM)
Head of Project Group: Visual Methods and Image Reproduction for NDT
Unter den Eichen 87

D-12200 Berlin, Germany

email: klaus.richter@bam.de
Internet: www.ps.bam.de or http://o2.ps.bam.de
Tel. +49-30-8104-1834 or 3587/8/9
Fax +49-30-8104-1837

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This BAM Technical Report exists as pdf- and html-file. Click for change to the other version:

http://o2.ps.bam.de/INFVM03/8650/BAM8650E.PDF

http://o2.ps.bam.de/INFVM03/8650/BAM8650E.HTM

Data and URL addresses:

The Technical Reports 8650, 8750, 8870, 8980, and 8890 transform *LAB** coordinates into *cmy*, olv*,* and *nru** data. In most cases16-step equally spaced colour series in *linear LAB** arrangement are transformed. But also the *LAB** coordinates of the CIE-test colours are transformed.

The *CMYOLVNW* colour space of printing (PR) or television (TV) is defined by 8 CIELAB colour coordinates in a 3-dimensional space. Both spaces look like a double pyramid with White *W* at the top and Black *N* at the bottom and an colour hexagon of the 8 colours CMYOLV roughly perpendicular to the achromatic axis *N-W.* If we use absolute coordinates *LAB** (identical to the 3 coordinates *L*a*b** of CIELAB colour space) then the space looks irregular but in relative coordinates (*lab**, small letters) the space is a regular double pyramid with a regular hexagon as basis. The following two figures shown this regular spacing in two dimensions with the colours between White *W* and the hexagon CMYOLV (the whitish colours *w*) or the colours between Black *N* and the hexagon CMYOLV (the blackish colours *n*)

http://o2.ps.bam.de/INFVM03/8370/E4370-2N.PDF

http://o2.ps.bam.de/INFVM03/8370/E4370-3N.PDF

Reference systems for the calculations:

The Standard PRint system (SPR) contains the 8 colours *CMYOLVNW(PR)* defined in ISO/IEC 15775. The lightness range is in the standard defined between *L**=18 and *L**=95. One may call this SPR(*L**=18-95) = PR18. The photographic test chart no. 1 in continuous tone has according to ISO/IEC 15775 a lightness range between *L**=10 and *L**=94. One may call this DPR(*L**=10-94) = DPR10-94 (D=Device)

Other systems used here are DPR (*L**=14-95) = PR14, DPR (*L**=10-95) = PR10, DPR (*L**=0-95) = PR0, and DPR (L*=0-100) = CPR. The last one with the limits *L**=0 and *L**=100 for Black *N* and White *W* is of special colorimetric interest and is called here the colorimetric print system (CPR). PR18 and CPR are the important ones here.

The Standard Television system (STV) contains the 8 colours *CMYOLVNW*(TV) tabled in ISO/IEC 15775. The lightness *L** normalisation for White *W* is the same as for offset colours according to the standard. In offices with daylight illumination actual Black *N* on a screen is far from *L**=0 mainly because of the about 4% surface reflection on the screen surface which is very much depending on the device. One may choose *L**=18 as in SPR for simplicity of the calculations. This system is called STV(*L**=18-95) = TV18.

Others systems used here are DTV (*L**=10-95) = TV10 (D=Device), DTV (*L**=0-95) = TV0, and DTV (*L**=0-100) = CTV. TV18 and CTV are the important ones here.

System and device adaptation (sa and da) for the calculations.

A system adaptation (sa) and/or a device adaptation (da) to CIE illuminant D65 is used. According to ISO/IEC 15775 the 8 colours *CMYOLVNW* defining the system output show for television (TV) zero CIELAB coordinates for both

Black *N* and White *W* but not for printing (PR). Therefore for printing (PR) a chromatic adaptation is necessary for the system coordinates. Any device output may deviate from zero CIELAB coordinates for both Black *N* and White *W*. For comparison of coordinates both a system adaptation and a device adaptation may be necessary.

For the printing system (PR) then Black N (*A**CIE=0.5, *B**CIE=-0.46) and White *W* (*A**CIE=-0.98, *B**CIE=4.76) and all gray colours get the coordinates *A**CIE=0.0, *B**CIE=0.0)

Similar for any output device then Black *N* (*A**CIE=0.5, *B**CIE=-0.46 or other values) and White W (*A**CIE=-0.98, *B**CIE=4.76 or other values) and all gray colours in CIELAB space linear between Black *N* and White *W* get the coordinates *A**CIE=0.0, *B**CIE=0.0). Within a tolerance of 1 of the 16 gray steps (5.2 CIELAB units) a linear shift in CIELAB space depending on lightness *L**CIE is used for the transformations.

For a 16 step gray colour series in offset printing with device colours PR18 (*L**=18 to 95 and Black *N* with *A**CIE=0.5, *B**CIE=-0.46 and White *W* with *A**CIE=-0.98, *B**CIE=4.76) in system PR18sa (*L**=18 to 95 and for both Black *N* and White *W* with *A**CIE=0.0, *B**CIE=0.0) see the simple *colour data by the URL:

http://o2.ps.bam.de/INFVM03/7130/E3130-3N.PDF

http://o2.ps.bam.de/INFVM03/7130/E3130-3N.EPS

http://o2.ps.bam.de/INFVM03/7130/E3130-7N.PDF

http://o2.ps.bam.de/INFVM03/7130/E3130-7N.EPS

Absolute measurement or theoretical *colour data in CIELAB colour space are called *L**CIE, *A**CIE, *B**CIE and device adapted (da) *colour data are called *L**CIEda, *A**CIEda, *B**CIEda.

Relative measurement or theoretical *colour data in CIELAB colour space are called *l**CIE, *a**CIE, *b**CIE and device adapted (sa) *colour data are called *l**CIEda, *a**CIEda, *b**CIEda.

Calculations of *olv*, cmy** and *nru** data are based on relative data *l**CIEda, *a**CIEda, *b**CIEda.

Series 8650

The PostScript files of this report include *LAB** coordinates of standard offset colours *CMYOLVNW* as input

1. Standard offset colours *CMYOLVNW* (PR18) in system PR18sa (*L**=18-95) (E8650-3N.EPS)
2. Standard offset colours *CMYOLVNW* (PR18, *n**=0.25) in system PR18sa (*L**=18-95) (E8650-7.EPS)
3. Standard offset colours *CMYOLVNW* (PR18, *w**=0.25) in system PR18sa (*L**=18-95) (E8651-3N.EPS)
4. Standard offset colours *CMYOLVNW* (PR18, *n** and *w**=0.25) in system PR18sa (*L**=18-95) (E8651-7N.EPS)

All four are found in:

http://o2.ps.bam.de/INFVM03/8650/A4Q8650E.PDF

http://o2.ps.bam.de/INFVM03/8650/A4Q8650E.PS

Series 8750

The PostScript files of this report include *LAB** coordinates of standard offset colours *CMYOLVNW* and CIE-test colours as input.

1. Standard offset colours *CMYOLVNW* (PR18) in system CPRsa (Colorimetric PRint *L**=0-100) (E8750-3N.EPS)
2. Standard offset colours *CMYOLVNW* (PR18, *n**=0.25) in system CPRsa (*L**=0-100) (E8750-7.EPS)
3. Standard CIE-test colours *(i*=0 to 7) in system PR18sa (*L**=18-95) (E8751-3N.EPS)
4. Standard CIE-test colours *(i*=8 to F) in system PR18sa (*L**=18-95) (E8751-7N.EPS)

All four are found in:

http://o2.ps.bam.de/INFVM03/8750/A4Q8750E.PDF

http://o2.ps.bam.de/INFVM03/8750/A4Q8750E.PS

Series 8870

The PostScript files of this report include *LAB** coordinates of standard offset colours *CMYOLVNW* and CIE-test colours as input.

1. Standard offset colours *CMYOLVNW* (PR14) in system PR14sa (*L**=14-95) (E8870-3N.EPS
2. Standard offset colours *CMYOLVNW* (PR14, *n**=0.25) in system PR14sa (*L**=14-95) (E8870-7.EPS)
3. Standard CIE-test colours *(i*=0 to 7) in system PR14sa (*L**=14-95) (E8871-3N.EPS)

4. Standard CIE-test colours *(i*=8 to F) in system PR14sa (*L**=14-95) (E8871-7N.EPS)

All four are found in:

http://o2.ps.bam.de/INFVM03/8870/A4Q8870E.PDF

http://o2.ps.bam.de/INFVM03/8870/A4Q8870E.PS

Series 8880

The PostScript files of this report include *LAB** coordinates of standard offset colours *CMYOLVNW* and CIE-test colours as input.

1. Standard offset colours *CMYOLVNW* (PR10) in system PR10sa (*L**=10-95) (E8880-3N.EPS

2. Standard offset colours *CMYOLVNW* (PR10, *n**=0.25) in system PR10sa (*L**=10-95) (E8880-7.EPS)

3. Standard CIE-test colours *(i*=0 to 7) in system PR10sa (*L**=10-95) (E8881-3N.EPS)

4. Standard CIE-test colours *(i*=8 to F) in system PR10sa (*L**=10-95) (E8881-7N.EPS)

All four are found in:

http://o2.ps.bam.de/INFVM03/8880/A4Q8880E.PDF

http://o2.ps.bam.de/INFVM03/8880/A4Q8880E.PS

Series 8890

The PostScript files of this report include *LAB** coordinates of standard offset colours *CMYOLVNW* and CIE-test colours as input.

1. Standard offset colours *CMYOLVNW* (PR0) in system PR0sa (*L**=0-95) (E8890-3N.EPS

2. Standard offset colours *CMYOLVNW* (PR0, *n**=0.25) in system PR0sa (*L**=0-95) (E8890-7.EPS)

3. Standard CIE-test colours *(i*=0 to 7) in system PR0sa (*L**=0-95) (E8891-3N.EPS)

4. Standard CIE-test colours *(i*=8 to F) in system PR0sa (*L**=0-95) (E8891-7N.EPS)

All four are found in:

http://o2.ps.bam.de/INFVM03/8890/A4Q8890E.PDF

http://o2.ps.bam.de/INFVM03/8890/A4Q8890E.PS

Technical Calculations:

Colour triangle equation

Wilhelm Ostwald (1853 to 1932) defines a

Colour triangle equation: blackness + whiteness + (radial) chromaticness =1

n* + w* + r* = 1

In the Swedish Natural Colour System (NCS) the relative coordinates blackness *n** and radial chromaticness *r** together with the coordinate unique hue *u** have been used to describe colours in a user friendly way.

The six offset colours form a hexagon perpendicular to the achromatic axis. This hexagon in the CIE chromaticity diagram shows

http://o2.ps.bam.de/INFVM03/8550/E4551-4N.PDF

Two regular hexagons show the whitish *(w)* and blackish *(n)* colours *cmyolv*$_w$* and *cmyolv*$_n$*

http://o2.ps.bam.de/INFVM03/8370/E4370-2N.PDF

http://o2.ps.bam.de/INFVM03/8370/E4370-3N.PDF

Colour hexagon equation

For a 3-dimensional sector (with Black *N,* White *W* and two neighbouring colours at the corners, e. g. Magentared *M* and Orangered *O*) the radial chromaticness *r** is calculated instead from one colour by the two neighbouring chromatic colours.

This leads to one of six **colour hexagon equations:**

n* + w* + a o* + (1-a) m* = 1 (0< = a <= 1)

The CIELAB coordinates (absolute data: abbreviation *LAB**) of any given colour may be defined as L^*_{color}, a^*_{color}, b^*_{color}. Together with the standard CIELAB coordinates of the offset printing process (*L*, a*, b** of Black *(index N)*, White *(index W)*, Magentared *(index M)* and Orangered *(index O)* (compare ISO/IEC 15775) there are 4 equations with 4 unknown constants:

$n^* + w^* + o^* + m^* = 1$

$L^*_N\, n^* + L^*_W\, w^* + L^*_O\, o^* + L^*_M\, m^* = L^*_{color}$

$a^*_N\, n^* + a^*_W\, w^* + a^*_O\, o^* + a^*_M\, m^* = a^*_{color}$

$b^*_N\, n^* + b^*_W\, w^* + b^*_O\, o^* + b^*_M\, m^* = b^*_{color}$

n, w*, o*, m** may be calculated using the 4x4 and 3x3 determinants **D** of the known form:

$n^* = \mathbf{D}_{331} / \mathbf{D}_{44},\ w^* = \mathbf{D}_{332} / \mathbf{D}_{44},\ o^* = \mathbf{D}_{333} / \mathbf{D}_{44},\ m^* = \mathbf{D}_{334} / \mathbf{D}_{44}$

The transformation from CIELAB to the coordinates of the Offset Reflective System (ORS)

A PostScript-program calculates these coordinates from CIELAB data. Input of any CIELAB colour data (L^*_{color}, a^*_{color}, b^*_{color}) lead to blackness *n**, whiteness *w** and the two chromatic data, e. g. *m** and *o**, of the two neighbouring colours of the offset colour hexagon.

Additional calculations include:

1. CIE colour hue angle $H^*_{color} = \text{atan}\,(b^*_{color} / a^*_{color})$
2. CIE radial chromaticness $c^*_{color} = (a^{*2}_{color} + b^{*2}_{color})^{1/2}$
3. Relative (radial) chromaticness *r** (ORS)
4. Unique hue *u**, e. g. *b80r* (blue with 80% red) (ORS)
5. Whitish coordinates $cmyolv_w$* (ORS). *(*Remark: *cmy* without index is identical to cmy_w*)*
6. Blackish coordinates $cmyolv_n$* (ORS). (Remark: *olv* without index is identical to olv_n*)*

Instead of unique hue ***u*,*** blackness ***n**** and (radial) chromaticness ***r****, the unique hue ***U****, e, g, ***B80R*** (Blue with 80% perceived Red), **blackness *N**** = 100 *n** and (radial) chromaticness ***R**** (0<=R*<=100) may be used. These coordinates are then similar to the coordinates of the Natural Colour System NCS. **References for Blackness** *n**=0 or *N**=0 are defined by the colour series White *W* to the six colours *CMYOLV.*

Remark 1: Some of the coordinates *cmyolv** calculated from CIELAB data may become negative. Then the colour with the given CIELAB coordinates is located outside the 3-dimensional colour solid, defined by the colour hexagon *CMYOLV* and White *W* and Black *N* at the top and bottom.

Remark 2: There are simple reverse transformations from cmy_w* or olv_n* to CIELAB. This includes the case of some negative *cmyolv**-coordinates.

Remark 3: The three colour rectangles of the colour output based or *LAB*, cmy** and *olv** coordinates should look the same. There are different differences on every colour device (printers, monitors). This differences can be reduced to zero using the settranfer function *settransfer_LAB*cmy** which transfers from CIELAB *(LAB*)* coordinates to the default coordinates *cmy** or *settransfer_olv*cmy** which transfers from *olv** coordinates to the default coordinates *cmy**.

Remark 4: It is intended to make the colour output on every colour devices within 3 CIELAB units equal to the reference test charts of ISO/IEC 15775 independent of the software and the colour space used *(LAB*, cmy*, olv*, nru*)*. The colour difference of colours of an output can be measured with low cost colorimeters (starting with $500) if both the output and the reference test chart are measured with the same instrument. In many cases the reference test chart can be used to determine the *LAB** values of the output and no instrument is needed.

Similar data:

The Technical Reports 7110, 7120, 7130, 7140, 7150, 7160, 7170, 7180, 7190 include similar data. The SGcode (Standard Gamut) *olv*, cmy*, nru*, rtu** and WGcode (Wide Gamut 86-168) *olv*, cmy** is calculated for the device adapted coordinates *L**CIEda, *A**CIEda, *B**CIEda. See for instance the technical report:

See for instance the technical report:

http://o2.ps.bam.de/INFVM03/7110/BAM7110E.PDF

or one example;

http://o2.ps.bam.de/INFVM03/7110/A4Q7110E.PDF

http://o2.ps.bam.de/INFVM03/7110/A4Q7110E.PS

These technical reports include all important basic transformations in colour systems PR18sa (L*=18-95), TV18sa (L*=18-95), CPR (colorimetric PR, L*=0-100), and CTV (Colorimetric TV, L*=0-100). The series 7180 and 7190 show transformations to the *sRGB* tristimulus value and the *sRGB** perceptive *colour space.

The Technical Reports 8930,8940,8950,8950,8960,8970,8980,8990 include similar data. The SGcode (Standard Gamut) *olv*, cmy*, nru** and WGcode (Wide Gamut 77-177) *olv*, cmy** is calculated for the device adapted coordinates *L**CIEda, *A**CIEda, *B**CIEda. See for instance the technical report:

http://o2.ps.bam.de/INFVM03/8930/BAM8930E.PDF

or one example;

http://o2.ps.bam.de/INFVM03/8930/A4Q8930E.PDF

http://o2.ps.bam.de/INFVM03/8930/A4Q8930E.PS

The technical report 8930 include transformations in colour system PR18sa (*L**=18-95)

The technical reports 8940 to 8950 include transformations in colour systems PR18sa (*L**=18-95) for the 16 step colour series *W–C, N–C, W–M, N–M, W–Y, N–Y, W–N, N–W*

The technical reports 8960 to 8990 include transformations in colour systems TV18sa (*L**=18-95), TV14sa (*L**=14-95), TV10sa (*L**=10-95), TV0sa (*L**=0-95)