Technical Report BAM(6110/20/30/40/50)E

CIE colorimetric definition of Standard, Mean, and Wide Gamut colour code (SGcode, MGcode, and WGcode) compatible with CIELAB, ISO/IEC 15775 and DIS ISO/IEC 19839-1 to 4 for colour management and communication - Corresponding colours in different chromaticity diagrams

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Creation date: 2000-09-16
Revision date: 2000-09-28

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http://o2.ps.bam.de/INFVM03/6110/BAM6110E.PDF

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The most important diagrams are used in a paper

http://o2.ps.bam.de/CISO08.PDF

Data and URL addresses:

The Technical Reports 6110/20/30/40/50/50 transform the *(x,y)* chromaticity coordinates of colours in the CIE standard chromaticity diagram into different chromaticity coordinates. Most useful for the application of Wide Gamut color spaces are the *(a‘,b‘)* chromaticity coordinates which have been defined for the CIELAB 1976 color space for illuminant D65 (see Richter, K.laus,1980, Cube root color spaces and chromatic adaptation, Color Research and Application 5, no. 1, pages 24-45, with *OSA* and *Munsell* samples in the *(x,y)* and *(a‘,b‘)* chromaticity diagrams in colour) and for definitions the URL:

http://o2.ps.bam.de/INFVM03/8270/E4270-3N.PDF

and for *OSA* and *Munsell* examples the URL:

http://o2.ps.bam.de/INFVM03/8270/A4Q8270E.PDF

***CMYOLVNW* colours of printing (PR) or television (TV) in CIELAB colour space**

The *CMYOLVNW* colours of printing (PR) or television (TV) are defined by a set of 8 CIELAB colour coordinates in the 3-dimensional CIELAB colour space. Both sets look like a double pyramid with White *W* at the top and Black *N* at the bottom and a colour hexagon of the 6 colours CMYOLV 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 formed by the set 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 show a model of 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

There are different reference systems for the calculations. For this see the Tables 1 to 6 given in the **additional** technical report (compare near the end of this paper)

Definition of Standard and Wide Gamut colour spaces

The 8 standard printing colours including the colour of the white standard paper form in the CIELAB color space an irregular hexagon with the white colour at the top and the black colour at the bottom. This irregular hexagon can be transformed to a regular hexagon with white at the top and black at the bottom using the *relative* CIELAB coordinates for all series, e. g. between white and cyan. The corresponding colours of the different series are produced in the analog ISO/IEC-test charts according to ISO/IEC 15775. ISO/IEC-test chart productions are available from the German Standard Organisation (DIN, see DIN 33866-1 to 5) and the Japan Business Machines Makers Association (JBMA).

The Standard Gamut color code of Printing (PR) uses 8bit in *color (perceptive color) space. If the CIELAB hexagon is extended by a factor 1.5 or 2.0 then new extended hexagons are defined which allow a 7bit or the 6bit colour code for the colour series *N–W* instead of the 8bit code for the gray colours. The hexagon size is only proportional by the factors 1.5 and 2.0 in the *(a‘,b‘)* chromaticity diagram and not in the *(x,y)* chromaticity diagram. The extended hexagons are the basis for the Wide Gamut 8bit colour code useful for a new colorimetric colour management and for colour communication.

The extension can be by a factor 2 (256/128) or 4 (256/64) in one dimension and this defines a factor 3.82 (1.5x1.5x1.5) or 8 (2x2x2) in three dimensions. Any other factor lower or larger compared to the factor 1 is also possible and can be defined according to the application or the colorimetric colour content of the image.

There may be some additional *L** range information coming with the image data or used in the transfer function (e. g. *Adobe Photoshop* or equivalent) or the settransfer function (e. g. *PostScript, PDF* or equivalent) in front of the image data. This additional *L** range information may include:

1. The gray *L** range of the actual scene, e. g. the offset range *L**=18 and *L**=95 if one takes the analog ISO/IEC-test chart according to ISO/IEC 15775.

2. The (larger) *L** range which include all the scene colours including the achromatic and chromatic highlights and darklights, e. g. the colorimetric range *L**=0 to *L**=100 may include all this colours

3. The (larger) *L** range used for coding, e. g. *L**=-50 to *L**=150 for 7bit gray code of 8 bit Wide Gamut code (WGcode) or *L**=-150 to *L**=250 for 6bit gray code of 8bit Wide Gamut code (WGcode).

Remark: The negative *L** values and the *L** values larger 100 are often appropriate, e. g. the violet-blue chromatic color may change by a factor two for darker or lighter colours **compared** to the standard colours in television or printing.

WGcode for colour management and colour communication

The most important **intention** for colour management and colour communication is **to include both all real colours of offset printing (PR) and all real colours of television (TV) in one universal Wide Gamut colour code** for three channels (*olv** or *cmy**). Then this Wide Gamut code (WGcode) can be used for colour management and colour communication. There is a colorimetric solution for this intention. For the offset gray scale with the CIE lightness range *L**=18 to *L**=95 there remain approximately 64 steps within the 8bit (256 steps) WGcode. This will be shown by different *(a‘,b‘)* chromaticity and *(x,y)* chromaticity diagrams in the following.

The figures include the 6 chromaticities of the chromatic standard printing (PR) and television (TV) colours. The 16-step colour series equidistant in CIELAB colour space between White *W* and the 6 chromatic colours *CMYOLV* are also reproduced.

An extended hexagon of the standard printing colours touches the television hexagon at the Violet-blue color V if a factor 2 is used for the extension. The following list shows four different normalizations for the White W of the television colours with the three television primaries called red, green, and blue:

1. CIE luminance factor *Y*=100 (CIE lightness *L**=100), see e. g. IEC 61966-2-1:1999-10

2. CIE luminance factor *Y*=88.60 (CIE lightness *L**=95), see e. g. ISO/IEC 15775:1999-12

3. CIE luminance factor *Y*=76.15 (CIE lightness *L**=90), see e. g. DIN 6169-6:1979

4. CIE luminance factor *Y*=76.56*0.5869 (CIE lightness approximately *L**=80), see e. g. DIN 6169-7:1976

Case 1: This is a theoretical colorimetric solution.

Case 2: This is an appropriate adjustment when taking real pictures. If one takes a real picture with a television or digital camera then the scene white is in this case the paper white of the analog ISO/IEC-test charts according to ISO/IEC 15775. Then the signals are normalized to one for this White *W* and to zero for the Black *N* of the ISO/IEC-test charts with the CIE lightness *L**=18.

Case 3: This is an appropriate adjustment when taking real pictures. If one takes a real picture with a television or digital camera then the scene white is in this case the white sample *Value* 8 (*Y*=76.15, *L**=90) of the *Munsell* colour system. Then the signals are normalized to one for this white. The CIE-test colours (originally special samples of the *Munsell* colour system) define for this white of *Value* 8 (*Y*=76.15, *L**90) a natural environment. Reflective CIE-test colours according to CIE Publ. 13.3, ISO/IEC 15775:1999-12, and DIN 6169-6 with high stability are available for practical tests by the BAM and others. The BAM samples are produced by automotive paints and the typical size is 5cm x 5cm.

Case 4: This is an appropriate adjustment when scanning real pictures in transparent mode with a film scanner in colour television. The transmission of the film material to be scanned is assumed to have 60% transmission in the white areas. The luminance factor *Y*=60 is reduced compared to the luminance factor *Y*=100 of the open gate (window) of the film scanner. If one takes this film pictures with the scanning equipment of colour television or a digital camera then the scene white is in this case the white sample with the CIE luminance factor Y=76.15*0.5869 (CIE lightness L^*=80?). Then the signals are normalized to one not for the so called open window but for this film white. Transparent CIE-test colours according to DIN 6169-7 with high stability are available for practical tests by the BAM.

The CIE chroma C^* in the CIELAB color system is approximately reduced proportional to CIE lightness L^* (this is true exactly in the CIELUV 1976 system, compare the above equations for the color space CIELAB 1976). Therefore in the cases 2, 3, and 4 there is approximately a chroma reduction by 5, 10, or 20 percent compared to the case 1.

This kind of normalization (with chroma reduction) decreases **not** the TV-chromaticity hexagon by 5, 10, or 20 percent. The coordinates of the *(a‘,b‘)* chromaticity diagram describe the colours in luminance units. So we can plot the chromaticity of the colours of the **same CIE luminance factor** (same CIE lightness L^*) which are 5, 10, or 20 percent less chromatic (chroma reduction) and this defines a TV-chromaticity hexagon which is 5, 10, or 20% smaller.

In theory there are the two possibilities to decrease the TV-chromaticity diagram by a factor 2.0 (0.5 in absolute values) to touch the PR-chromaticity diagram or to increase the TV-chromaticity diagram by a factor 1.5 to include the PR-chromaticity diagram in the blue-green area.

The normalisation of case 2 according to ISO/IEC 15775: 1999-12 may be the most appropriate for practical tests. Here we have the **analog ISO(IEC-test charts for calibration**, see also the paper:

http://o2.ps.bam.de/CISV06.PDF

Series 6110 to 6150

The colour series 6110 to 6150 show the six colours CMYOLV of printing (PR) and television (TV) in 16 different chromaticity diagrams. The figures 1 and 3 on the left side show the CIE *(x,y)* and the *(a‘,b‘)* chromaticity diagram and the figures 1 and 2 at the right side show the CIE (*u,v)* and (*u‘,v‘)* chromaticity diagrams. The definitions of the coordinates of the different diagrams are given in the figures.

The *(a‘,b‘)* chromaticity diagrams of the three different LABHNU color spaces show a higher correlation with visual scaling experiments. One leading manufacturer of colour printers use since 20 years within the printer the LABHNU colour space for the calculation and the output of the device colour test charts. The (*a”,b”)* chromaticity diagrams are used to describe colour threshold data, e. g. *MacAdam* threshold ellipses.

The series 6120 and 6130 show additionally a PR-hexagon magnified by the factor 1.5 or 2.0. The *(a‘,b‘)* chromaticity diagram which belongs to the CIELAB colors space is used and the *(a‘,b‘)* chromaticity coordinates are used to calculate the CIE *(x,y)* chromaticity coordinates.

The series 6140 and 6150 show additionally a TV-hexagon magnified or reduced by the factor 1.5 or 0.5.

One must have in mind that the calculated chromaticities will not change the chromaticity of any sample. The new calculated hexagon chromaticities show always a colour of the same luminance factor compared to the reference luminance factor. But the calculated colours are by a factor 1.5 or 2.0 more chromatic and they are located in a 3-dimensional colour space by a factor 1.5 or 2 outside the reference colour space. We can choose 8bit to describe all colours within the reference colour space. If we use 8 bit for a space magnified by a factor 1.5 then we have only about 7bit for the scale *N–W* and all other colours within the reference space. If we use 8 bit for a space magnified by a factor 2.0 then we have only about 6bit for the scale *N–W* and all other colours within the reference space.

A magnifying factor of 2.0 (exact value 2.36 depending on normalization of TV-colours) for the PR-hexagon approximately includes all colours of the TV-hexagon. More accurate calculations in the three dimensional space seem to verify that a factor 2 include all TV-colours normalized to the above case 2 (offset range L^*=18 to L^*=95). The factor 2.1 include all TV-colours normalized to the above case 1 (colorimetric range L^*=0 to L^*=100).

Therefore one of this by 5% different Wide Gamut codes (WGcodes) can be used for colour management and colour communication. The WGcode based on the PR-colours can be calculated for any colour defined by any CIELAB coordinates. Some spectral colours in the saturated green and purple area of the chromaticity diagram still may give negative values in the WGcode. But we know that all real colours of the standard printing and television area will give 3 code values between 0 and 255 for *olv** or *cmy**.

Possible interpretation of the data:

The factors1.5 and 2.0 produce larger chromaticity hexagons for the PR-colors in the *(a‘,b‘)* chromaticity diagram. The factor 2 includes in the violent-blue region and all other region the chromaticity hexagon of the PR-colors. More exact calculations have shown that a factor 2 is sufficient for the normalisation according to case 2 with Y=88.60 for white, see the URL:

http://o2.ps.bam.de/INFVM03/7290/E3291-7N.PDF

or

http://o2.ps.bam.de/INFVM03/7420/E3420-3N.PDF

A factor 2.07 is sufficient for the normalisation according to case 2 with *Y*=100 for white, see the URL:

http://o2.ps.bam.de/INFVM03/7390/E3391-7N.PDF

Implementation of the transformations in software products:

The hexagon in based on 6 chromaticity triangles. The chromaticity of White *W* and of two neigboring colours, e. g. Orangered *O* and Yellow *Y,* have to be used for the calculations. For the colorimetric calculations a software program must decide first which one of the 6 triangles to be used. Then the colorimetric calculations must be done with these 3 colours in CIELAB colour space instead of the CIEXYZ colour space as usual. All the figures of the series 7XY0 (X=1, 2, 3, 4; Y=1, 2, etc. ,9) include such transformations in *PostScript* code.

Near line 70 the CIELAB coordinates of the system (PR, TV of different normalisation) are defined, near line 250 the CIELAB coordinates of the colours (PR, TV, CIE, RAL) are defined. The so called *Ostwald* triangle coordinates *olv** or *cmy** are calculated form the CIELAB data of the input colours. The reverse transformations are very simple. It is always an additive mixture in CIELAB space of the three colours of one triangle or 4 colours (two chromatic and Black and White) in a 3-dimensional space. Compare the technical report by the URL:

http://o2.ps.bam.de/INFVM03/8640/BAM8640E.PDF

http://o2.ps.bam.de/INFVM03/8640/BAM8640E.HTM

Remark for additional Technical Reports

There are **additional** Technical Reports 7310/20/30/40/50/50/70/80/90 which describe how to make the real transformations for single colours. The *LAB** coordinates are transformed into coordinates *cmy*, olv** and *rtu** in Systems *CTV* and *CTVw* and the data *rtu** and *RGB* and *R'G'B'* of the *sRGB* color space according to IEC 61966-2-1:1999-10 are calculated.

Remark: One can read the PostScript code of the figures within the EPS files. Near line 60 in the EPS files the CIELAB data of the system *(CTV, CTVw, CPR)* are defined for the calculations and near line 250 the CIELAB data of the 8 colours *(CTV, CTVw, CPR, CIE, RAL)* are defined as input for the figures.

Standard printing colours (Series 7310) and colours of the RAL atlas of the four different hues green (Series 7320/30), red (7340/50), yellow (7360/70) and blue (7380/90) (CIELAB hue angle 180, 360, 90 and 270) are used. The CIELAB coordinates of real RAL colours of the RAL colour atlas are transformed to the SGcode and WGcode of both the Television (Series 7320/40/60/80) and the Printing (Series 7330/50/70/90) colour spaces.

This **additional** BAM Technical Report exists as pdf- and html-file. Click for change to the other version (click to go!):

http://o2.ps.bam.de/INFVM03/7310/BAM7310E.PDF

http://o2.ps.bam.de/INFVM03/7310/BAM7310E.HTM

The Technical Reports 7110, 7120, 7130, 7140, 7150, 7160, 7170, 7180, 7190 include similar data. The SGcode (Standard Gamut) *olv*, cmy*, nru** and WGcode (Wide Gamut 88-166) *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 7210, 7220, 7230, 7240, 7250, 7260, 7270, 7280, 7290 include similar data. The SGcode (Standard Gamut) *olv*, cmy*, nru** and WGcode (Wide Gamut 88-166) *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/INFVM03/7210/BAM7210E.PDF

or one example;

http://o2.ps.bam.de/INFVM03/7210/A4Q7210E.PDF http://o2.ps.bam.de/INFVM03/7210/A4Q7210E.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 7210 to 7290 show transformations to the *sRGB* tristimulus value and the *sRGB** perceptive *colour space.

The Technical Reports 8650,8750,8870,8880,8890 include similar. 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/INFVM03/8650/BAM8650E.PDF

or one example;

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

http://o2.ps.bam.de/INFVM03/8600/A4Q8650E.PS

These technical reports include transformations in colour systems PR18sa (*L**=18-95), PR14sa (*L**=14-95), PR10sa (*L**=10-95), PR0sa (*L**=0-95)

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)