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Information technology — Office machines — Device output of 16 colour scales, output linearization method (LM) and specification of the reproduction properties

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Technologies de l'information — Machines de bureau — Sortie de dispositif des échelles 16 couleurs, méthode linéaire de sortie (LM) et spécification des propriétés de reproduction

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Foreword

ISO (the International Organization for Standardization) and IEC (the International Electrotechnical Commission) form the specialized system for worldwide standardization. National bodies that are members of ISO or IEC participate in the development of International Standards through technical committees established by the respective organization to deal with particular fields of technical activity. ISO and IEC technical committees collaborate in fields of mutual interest. Other international organizations, governmental and non-governmental, in liaison with ISO and IEC, also take part in the work. In the field of information technology, ISO and IEC have established a joint technical committee, ISO/IEC JTC 1.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of the joint technical committee is to prepare International Standards. Draft International Standards adopted by the joint technical committee are circulated to national bodies for voting. Publication as an International Standard requires approval by at least 75 % of the national bodies casting a vote.

In exceptional circumstances, the joint technical committee may propose the publication of a Technical Report of one of the following types:

— type 1, when the required support cannot be obtained for the publication of an International Standard, despite repeated efforts;

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— type 2, when the subject is still under technical development or where for any other reason there is the future but not immediate possibility of an agreement on an International Standard;

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— type 3, when the joint technical committee has collected data of a different kind from that which is normally published as an International Standard ("state of the art", for example).

Technical Reports of types 1 and 2 are subject to review within three years of publication, to decide whether they can be transformed into International Standards. Technical Reports of type 3 do not necessarily have to be reviewed until the data they provide are considered to be no longer valid or useful.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO and IEC shall not be held responsible for identifying any or all such patent rights.

ISO/IEC TR 19797, was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC 28, *Office equipment.*

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Introduction

Purpose and justification

The method in this Technical Report produces a linear relationship between the linear digital input data and the output data produced for a visual relative CIELAB scale. Using this method for a digital input value of 0.5 a mean grey of 0.5 on a visual scale is produced. On the visual scale the values for white and black are 0 and 1 in relative CIELAB space. The method has been already developed (there was a SC28 study period of one year, Project 18 of the SC28 Berlin 2000 Plenary). Example files are on the Internet in various file formats (see SC28 Document j28N493). The output will be within a visual tolerance of 6 CIELAB units independent of the file format used (see graphs on page 13–15 and on BAM-Internet addresses listed in Annex B). For a given file format the CIELAB values of the first output must be measured. The measured CIELAB data are included in a modified output file which produces the linearized output which will be equally spaced in CIELAB. Various cases are given below:

1. PS (PostScript) file on a PS printer then the new PS output file on the PS printer produces the 16 step equally spaced output.

2. PDF file on any printer then the new PDF output file is produced by the software *Adobe Acrobat Distiller or equivalent* from a PS file. The PDF output file produces the 16 step equally spaced output.

3. GIF file on any printer then the new GIF output file is produced by the software *Adobe Illustrator or equivalent* from a PS file. The GIF output file produces the 16 step equally spaced output.

The method is similar for other file formats and the output result is within a visual tolerance of 6 CIELAB units independent of the file format used.

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Advantages: If the CIELAB data of the first output are used then the linearization method (LM) leads to the same relative CIELAB output within visual tolerances of 6 CIELAB values (1 step of 16 steps, see graphs on pages 13–15) independent of e. g. application software, file format, printer driver and paper.

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Remark: If the intended output is linearly spaced in relative CIELAB space (see ISO/IEC 15 775) then in most cases the colour differences between the first and the linearized output and the intended output are reduced by a factor 3 to 6.

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Information technology — Office machines — Device output of 16 colour scales, output linearization method (LM) and specification of the reproduction properties

1. Scope

A digital file is used to produce 16 step colour scales on a colour printer between the white paper and the 6 chromatic colours and black. The intended 16 step colour scales are defined in figures B4 and D4 of the ISO/IEC-test charts for colour copiers according to ISO/IEC 15775. The digital file format may be PostScript (PS), Portable document (PDF), GIF, HTM or equivalent. Within the different file formats the 16 step colour scales are defined by 16 digital values between 0 and 1, e. g. by 0, 1/15, 2/15 to 15/15 in CMY coordinates. The first output is measured and by the linearization method (LM) of this Technical Report, a visually equally spaced output is produced in relative CIELAB units, e. g. between the white paper and the six device colours and black. There is a table of output values and a graph for the first and linearized output. This method produces a linear relationship between the linear digital input data and the output data on a visual relative CIELAB scale for the colour primaries. The visual uniformity of overprint scales can be improved by this method. The method is applicable for systems that do not have colour management or as a linearization method for devices that could be used as a setup_state for colour management. The aim of this method is to produce equal CIELAB spacing. The equal spacing of the steps achieved in the linearization method may be adapted to various purposes. The accuracy and repeatability of this method is expected to be within 6 CIELAB units. Other methods may be appropriate for applications requiring greater accuracy.

Note: Any first output can be used for this linearization method (LM) even though the first output depends e. g. on application software, file format, printer driver, paper and other parameters.

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2. Normative References

The following referenced documents are indispensable for the application 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.

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ISO/IEC 15775: 1999, *Information technology – Office machines – Method of specifying image reproduction of colour copying machines by analog test charts – Realisation and application*

ISO/CIE 10526:1991, *CIE standard colorimetric illuminants*

ISO/CIE 10527:1991, *CIE standard colorimetric observers*

CIE-pub. 15.2:1986, *Colorimetry*

ITU-R BT.709-2:1995, *Parameter Values for the HDTV Standards for Production and International Program Exchange*

IEC/CIE 17.4:1987, *International lighting vocabulary, 4th edition, Joint publication IEC/CIE*

DIN 33866-1 to -5:2000, *Information technology – Office machines – Colour image reproduction devices,* Part 1: *Method of specifying image reproduction of colour devices by digital and analog test charts*

3. Terms and Definitions

3.1 Definitions

For the purposes of this document, the following terms and definitions apply.

NOTE The definitions are taken from ISO/IEC 15775 and IEC/CIE 17.4. The definitions are adapted to the ISO/IEC Directives Part 2. The CIE/IEC definitions are adapted slightly to agree with the ISO/IEC Directives.

3.1.1
standard tristimulus values *X, Y, Z* and colorimetric parameters *L*a*b**
describe the psychophysical colour

NOTE 1 Standard tristimulus values *X, Y, Z* are mostly obtained as an immediate result of a colour measurement.

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NOTE 2 As standard tristimulus values X, Y, Z only allow statements referring to equality of two colours, for statements made beyond that, e. g. concerning the kind and size of colour differences, non-linear transformations of X, Y, Z into other colorimetric parameters systems preferably into the colorimetric parameters L*, a*, b* are necessary (compare CIE publ. 17.4)

NOTE 3 Within this Technical Report the abbreviation **LAB*** for the colorimatric parameters **L*a*b*** is used. For *relative* CIELAB coordinates the abbreviation **lab*** is used.

3.1.2
colour difference ΔE^*_{ab}
specifies the size of the difference between two colour stimuli

3.1.3
***-image ("star-image")**
includes colours defined by the colorimetric parameters L*a*b* of the CIELAB colour system.

NOTE The *-image ("star-image") includes colours (of the colour pixels or areas) which are defined either in absolute (LAB*) or relative (lab*) coordinates.

3.1.4
***'-image ("star-prime-image")**
includes colours produced by a standard reproduction process of a colour device and is different than the *-image.

NOTE The *'-image ("star-prime-image") has different colorimetric parameters L*'a*'b*' (*'-coordinates) compared to the *-image ("star-image") with L*a*b* parameters defined either in absolute (LAB*) or relative (lab*) coordinates.

3.1.5
'*-image ("prime-star-image")
is produced by the standard reproduction process of a colour device and is different than the *-image ("star-image").

NOTE The '*-image ("prime-star-image") is called the inverse image and includes L'*a'*b'* parameters defined either in absolute (LAB*) or relative (lab*) coordinates.

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3.1.6
standard image transformation
changes a *-image ("star-image") into a *'-image ("star-prime-image") (Fig. 1) or changes a '*-image ("prime-star-image") into a *-image ("star-image") (Fig. 2)

3.1.7
inverse image transformation
changes a *-image ("star-image") into a '*-image ("prime-star-image") (Fig. 2) or changes a *'-image ("star-prime-image") into a *-image ("star-image") (Fig. 1)

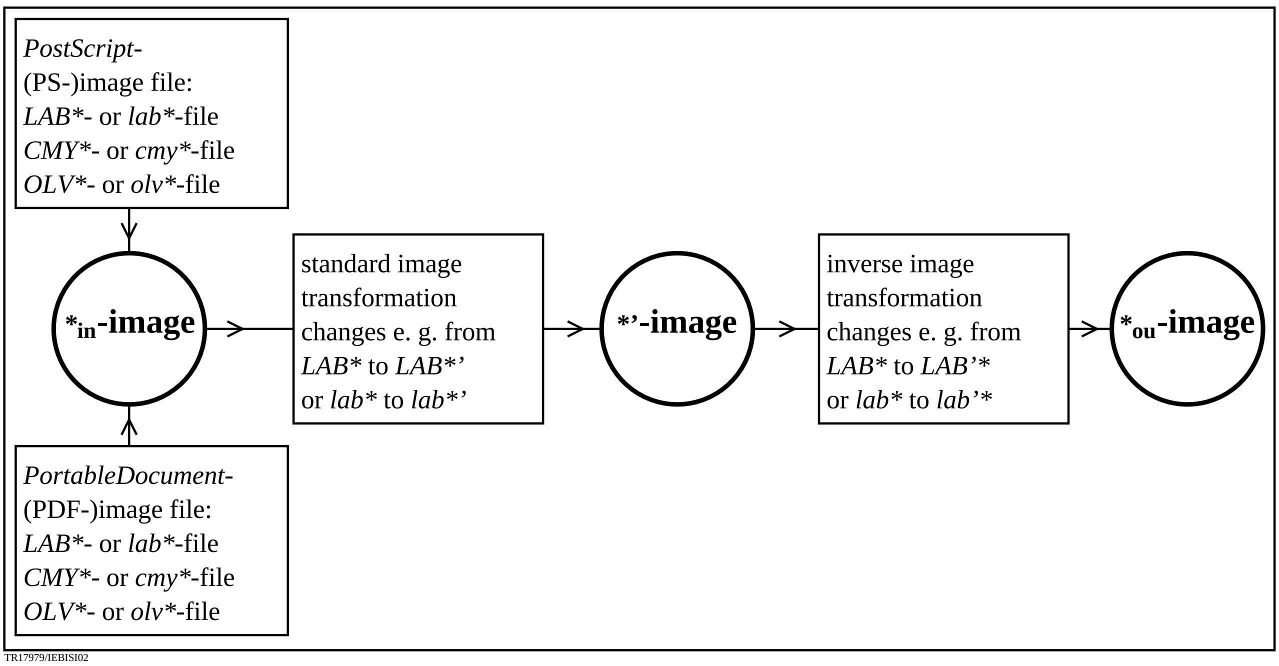

Figure 1: Standard and inverse image transformation

Fig. 1 shows that the standard image transformation changes a *-image ("star-image") into a *'-image ("star-prime-

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image“) and that the inverse image transformation changes a *’-image (“star-prime-image“) into a *-image (“star-image“)

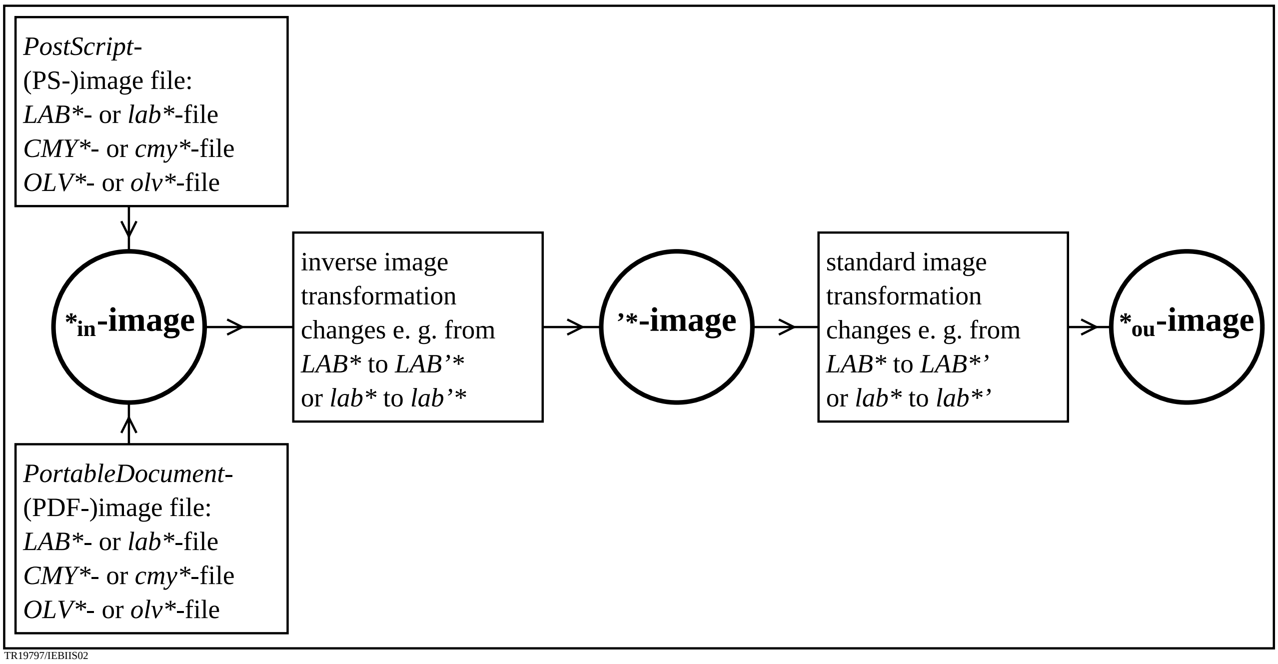

Figure 2: Inverse and standard image transformation

Fig. 2 shows that the inverse image transformation changes a *-image (“star-image“) into a ‘*-image (“prime-star-image“) and that the standard image transformation changes a ‘*-image (“prime-star-image“) into a *-image („star-image“)

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4. Overview: Six chromatic reproduction colours and 128 standard colours

There is a variety of colour spaces which can be used for input and output. Any user has to spend a lot of time to learn about the different spaces and to learn the relationship of the different spaces which depends on application.

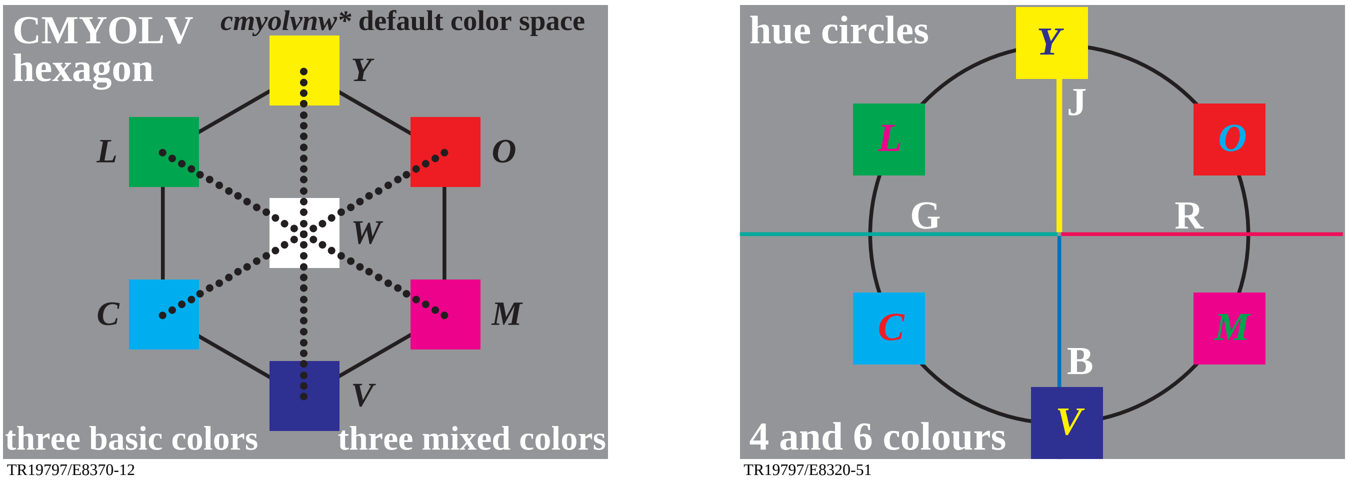

Figure 3: Six reproduction colours CMYOLV and four unique hue colours RJGB

Fig. 3 shows the six chromatic colours **CMYOLV** and Black **N** (=noir) and White **W** of standard offset printing (left). The four unique hue colours **RJGB** are different from the six reproduction colours. Standard non fluorescent offset paper was used to produce the **analog ISO/IEC-test charts which are equally spaced in CIELAB coordinates.** There are productions by DIN and JBMIA (see Annex B.) in reflective and transparent mode. The German DIN-test charts have been measured with the 45/0 measuring geometry for standard illuminant D65 and the CIE 1931 standard observer at BAM *(Laboratory S.13)*. The mean colour difference of CMYOLV compared to the standard data is 2.5 CIELAB, (see the standard DIN 33866-X and the International Standard ISO/IEC 15775).

Remarks: According to the International Standard ISO/IEC 15775 the letters ***j*** (=jaunne=yellow), ***r*** (red), ***g*** (green), and ***b*** (blue) are reserved for the unique hues and the letters ***olv**** (orange red, leaf green, violet blue) are used with a star to indicate the linear relationship to CIELAB. The ***olv**** coordinates are used for the reflective colours and are used in a similar way as the coordinates ***rgb*** of the luminous television colours. The ***cmy**** coordinates are alternate coordinates compared to ***olv**** (see Fig. 3 and Table 1 and 2).

All the 16 step colour series between white and the six chromatic colours CMYOLV (see Fig. 3) and black are equally spaced in the CIELAB colour space. Laser printers produce the six chromatic colours using between three and six colourants. The result is often similar to the six colours CMYOLV of the present analog ISO/IEC-test charts which have been produced by standard offset printing.

The halftone screening of laser printers (or of offset printing) produce colours which are approximately on a line, e. g. between White W and Cyan C in the CIELAB space. This is one basic assumption of the model colour space. In practice the 16 colours between White and Cyan may slightly deviate by less then 3 CIELAB units from the line in CIELAB space. This is much less than the 20 CIELAB unit spacing differences along the line W – C which printers often produce. For the office applications the aim was to reduce the spacing differences of the 16 step series C – W to below 3 CIELAB units. Then all Landolt-rings in the ISO/IEC-test chart output can be recognized. A non-critical user may require that along the line W – C only the cyan coordinate of *cmy** changes between zero and 1 in 15 digital steps of 1/15. The other coordinates are zero. In the alternate coordinate system *olv** the Orange red coordinate is zero and the other two change by equal amounts from zero to 1 in steps of 1/15 (see Table 2).

There were **goals**:
1) Linearization (equal CIELAB spacing) of the seven series W to CMYOLVN and
2) calculation methods to convert to coordinates *cmy** and *olv** from the CIELAB data of the standard (and the analog samples) and vice versa.

Both goals have been achieved by PostScript code called MTL (MTL = Measurement, Transfer and Linearization). If a device is linearized along the lines in CIELAB space then there are linear relationships between the coordinates *cmy*, olv*,* and *LAB** of the CIELAB colour space. The linear relations (and as a result a linear additive metric in CIELAB space in each of the six sectors of Fig. 3) are used in the PS MTL code. Either the ***olv*, cmy*,* or *LAB**** data can be used with an **ISO/IEC-test chart** file to get the **same** output on a printer or monitor.

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Table 1: Colour data of the 5 step colour series N – W for four input PS operators (N=noir=Black)

5 steps of grey series black - white (N - W)	Colour space, colour space coordinates and PostScript operator calculations according to ISO/IEC 15775:1999-12				
Linear mixture between black and white in CIELAB colour space	**CIELAB** ***LAB* (absolute)*** ***LAB* setcolor***	***l**** **CIE** ***w* = l**** ***setgray***	**CMYN (CMYK)** ***000n**** ***setcmykcolor***	**CMYN (CMYK)** ***cmy0**** ***setcmykcolor***	**OLV (RGB)** ***www**** ***setrgbcolor***
1,00 N + 0,00 W (black N)	18.01 0.50 -0.46	0,00	0,00 0,00 0,00 1,00	1,00 1,00 1,00 0,00	0,00 0,00 0,00
0,75 N + 0,25 W	37.36 0.13 0.84	0,25	0,00 0,00 0,00 0,75	0,75 0,75 0,75 0,00	0,25 0,25 0,25
0,50 N + 0,50 W	56.71 -0.24 2.15	0,50	0,00 0,00 0,00 0,50	0,50 0,50 0,50 0,00	0,50 0,50 0,50
0,25 N + 0,75 W	76.06 -0.61 3.45	0,75	0,00 0,00 0,00 0,25	0,25 0,25 0,25 0,00	0,75 0,75 0,75
0,00 N + 1,00 W (white W)	95.41 -0.98 4.76	1,00	0,00 0,00 0,00 0,00	0,00 0,00 0,00 0,00	1,00 1,00 1,00

TR19797/DESERCW2

Table 1 include four input *PostScript* (PS) operators which define the same achromatic colours black, three greys and white. Between one and four input data values are necessary for the complete definition of the achromatic colours depending on the colour space

Table 2: Colour data of 5 step colour series C – W for three input PS operators.

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** ***LAB* (absolute)*** ***LAB* setcolor***	**CMYN (CMYK)** ***cmy0* (relative)*** ***cmy0* setcmykcolor***	**OLV (RGB)** ***olv* (relative)*** ***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

TR19797/DESERCW1

Table 2 includes three input *PostScript* (PS) operators which define the same chromatic colour series between Cyan blue and White. There are ISO/IEC-test chart files which use the different PS operators of Table 1 and 2.

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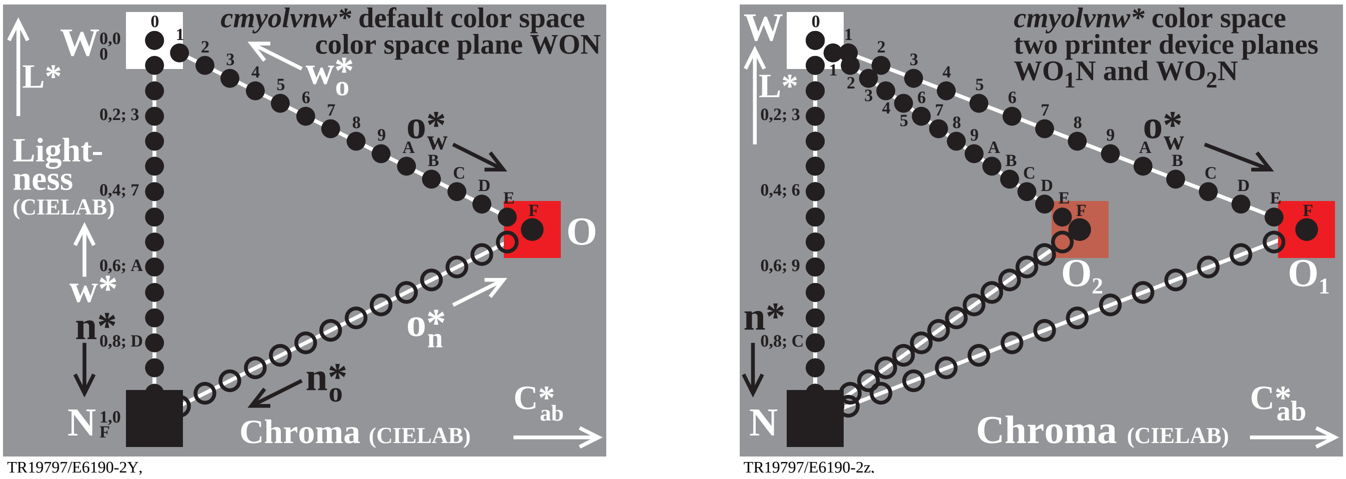

Figure 4: Equal spacing in relative CIELAB in hue planes WO_xN for different devices x.

Fig. 4 shows the 16 step colour series **equally spaced in relative CIELAB** in the hue plane WON (left) for the default device and in the hue planes WO_1N and WO_2N for two other different devices. The CIELAB chroma C^*_{ab} of the devices 1 and 2 is larger or smaller (right) compared to the default chroma (left) but the **relative spacing** in CIELAB is equal in all cases. The dark dots show the 16 step colour series which this Technical Report will produce on a printer. The coordinates used in this Technical Report are

n^* (relative blackness)

n^* changes from 0 to 1 (decimal) or from 0 to F (hexadecimal, 4bit) for the series White W to Black N (W–N).

o^*_w (relative orange redness of the whitish series w)

o^*_w changes from 0 to 1 (decimal) or from 0 to F (hexadecimal, 4bit) for the series White W to Orange red O (W–O). There are some other coordinates, e. g. relative whiteness w^* and relative orange redness of the blackish series o^*_n in Fig. 4 which have simple relationships to the above two relative coordinates and also to the CIELAB coordinates.

Remark 1: The method of this Technical Report is not designed to produce equal steps for the series O–N, O_1–N and O_2–N (hollow circles) but experimental and theoretical studies show that the spacing of this series is close to equal relative spacing if the method of this Technical Report is used.

Remark 2: For many applications the relative spacing of the whitish series W–O is more important compared to the blackish series O–N. For instance both for best differentiation of 16 colour steps and low toner consumption the series W–O is appropriate.

Remark 3: The ISO/IEC-test charts according to ISO/IEC 15775 include the 16 step default colour series W–O and W–N for the test of colour copiers.

It is within the **scope** of this Technical Report that the **relative spacing in CIELAB can be made the same** for all devices as shown in Fig. 4. Then the recognition of e.g. the 16 step series W–O, W–O_1 and W–O_2 is constant as long as the chroma of the colour O_2 is not too small. The colour difference of the default series W–O is about 120. For 16 steps this means that there is a colour difference in CIELAB of 8 (=120/15) between two adjacent colour steps. The perception threshold for the colour difference of colours side by side is about 1 CIELAB unit and for colours spacially separated about 3 in CIELAB units. For printers in the worst-case a reduction of the chroma of O_2 to 50% compared to the default chroma of O may be assumed. Even in this worst-case the colour difference (about 5 = 75/15 in CIELAB) is much above threshold for both adjacent and separated colour steps for the colour series between W–O_2.

The ISO/IEC-test charts 2 and 4 according to ISO/IEC 15775 include 8 colour series of 16 steps colours in Fig. B4 and D4. There are 128 standard colours which are shown in Fig. 5

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