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Graphic technology — Standard object colour spectra database for colour reproduction evaluation (SOCS)

Technologie graphique — Base de données de spectres de couleurs d'objets normalisée pour l'évaluation de la reproduction des couleurs (SOCS)

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Foreword

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

In exceptional circumstances, when a 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), it may decide by a simple majority vote of its participating members to publish a Technical Report. A Technical Report is entirely informative in nature and does not have to be reviewed until the data it provides are considered to be no longer valid or useful.

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ISO/TR 16066 was prepared by Technical Committee ISO/TC 130, *Graphic technology*.

The TC 130 Japanese National Committee prepared this database, and their efforts have made this Technical Report possible. The original form of this report was published as a technical report TR X 0012 by the Japanese Standards Association in Japanese in December 1998.

Introduction

The simplest way to evaluate the colour reproduction of colour image input devices is to input images of objects whose colours are exactly known and then to compare the pixel values to exact ones. For that purpose, input colour target standards have been already established in ISO 12641:1997, *Graphic technology — Prepress digital data exchange — Colour targets for input scanner calibration*. Evaluation becomes more complicated, however, when we consider metamers.

The perceived colours of a pair of objects are referred to as metamers if, under a particular illumination, they have the same tristimulus values even though they are spectrally different. The spectral pairs of such objects may be used to advantage in the assessment of differences among lighting conditions. If, for instance, a pair of spectra yield the same tristimulus values *X, Y, Z* under CIE illuminant D50, the difference between the two perceived colours of the pair of spectra as measured in the field under a different illumination is referred to as a metameric index, which can be used as a measure of the non-conformance of that illumination to D50.

While it may be sometimes preferable, e.g. for standards purposes, to use artificial pairs of perceived colours, i.e. those not coming from natural objects, natural metameric pairs have the advantage that one can assess the effect of non-standard lighting for a particular lighting condition. One may find, for instance, that a particular light source leads to unacceptably large deviations in skin tones, whereas the same source is quite acceptable for furniture colours.

Definitions with respect to metameric indices and the procedures for their evaluation are described in the following CIE publications:

CIE 15.2, *Colorimetry*, 2nd ed. (1986) (Contains Special Metamerism Index: Change in Illuminant)

CIE 51.2, *A method for assessing the quality of daylight simulators for colorimetry* (1999)

CIE 80, *Special metamerism index: Change in observer* (1989)

It can also be useful to consider metamers in the evaluation of such colour image input devices as colour scanners and digital cameras, which, though designed to capture images in a way similar to that of the human visual system (HVS), nonetheless deviate enough from HVS sensitivity so that colour reproduction of sensed colours in display devices or print outputs are significantly different from that desired, even when the illumination conditions of the original human observation of an object have been recreated for the observation of the output image.

To evaluate deviations due to variations in light sources and/or sensor sensitivities under actual conditions, it is useful to know the range of spectral differences in existing objects. Committee members have created an exhaustive collection of colours of existing objects, a database containing more than 50 000 items. This report details the extraction from the data of 365 colour samples and their classification into sets, of which there are two types, “typical sets” and “difference sets”. “Typical sets” refers to sets of typical spectral reflectances and transmittances of objects as classified into a number of different categories. “Difference sets” refers to sets of metamers whose tristimulus values are roughly typical but whose spectral values are significantly non-typical.

The entire original collection of more than 50 000 spectral data items is included, in electronic form, as part of this Technical Report in the data directory SourceData as described in Annex A.

Graphic technology — Standard object colour spectra database for colour reproduction evaluation (SOCS)

1 Scope

This Technical Report provides a database of typical and difference sets of existing object colour spectral data that are suitable for evaluating the colour reproduction of image input devices. It also includes the spectral reflectance and transmittance source data from which these data sets have been derived.

2 Standard object colour spectra

2.1 Object categories and sample selection

2.1.1 Categories and groups

The following categories and subcategories were first established:

(1) Photographic materials

  a. Transparencies

  b. Reflection prints

(2) Offset prints

(3) Computer colour prints

  a. Dye sublimation printer

  b. Electrostatic printer

  c. Ink-jet printer

(4) Paint (not for art)

(5) Paints (for art)

  a. Oil paints

  b. Water colours

(6) Textiles

  a. Synthetic dyes

  b. Plant dyes

(7) Flowers and leaves

(8) Outdoor scenes (Krinov data except for flowers and leaves)

(9) Human skin

a. Bare North Asian skin

b. Foundation-applied North Asian skin

c. Bare South Asian skin

d. Foundation-applied South Asian skin

e. Bare Caucasian skin

f. Bare Negroid skin

Spectral reflectance/transmittance data were then collected for more than 50 000 items falling into these categories/subcategories.

Categories (1) to (5) and subcategory (6)a are for artificial colours, while subcategory (6)b and categories (7) to (9) are for natural colours. Typical sets and difference sets were established from 365 samples in this database. A typical set is a set of representative spectral data of colour objects, while a difference set is a set of metamers whose colour under D65 illuminant is similar to typical set samples but differs significantly from them spectrally. Samples for the typical and difference sets were selected as shown in Table 1. The manner of selecting typical samples depended on whether colours were artificial or natural. In most artificial colour groups, all colours are synthesized by mixing three or four colorants, and distributed almost uniformly in their colour gamut. Colours in the paint (not for art) and paints (for art) categories, however, are synthesized by mixing more than four colorants, and these categories were dealt with in the same manner as with natural colours. Selection strategies are described in following subsections.

Table 1 — Numbers of selected typical/difference set colour samples

Group	Typical sets	Difference sets
Photo (transparency)	15	15
Photo (reflection print)	15	15
Offset prints	15	15
Dye sublimation printer	15	15
Electrostatic printer	15	15
Ink-jet printer	15	15
Textiles (synthetic dyes)	15	15
Flowers/grasses/leaves (includes Krinov's grasses and leaves)	25	25
Paint (not for art)	15	—
Oil paints	15	—
Water colours	15	—
Textiles (plant)	15	—
Non-grass/leaf Krinov	15	—
Bare North Asian skin	5	—
FD-applied North Asian skin	5	—
Bare South Asian skin	5	—
FD-applied South Asian skin	5	—
Bare Caucasian skin	5	—
Bare Negroid skin	5	—
Total	**365**	

NOTE 'Foundation' is a cosmetic used as a base for facial make-up. However, in this Technical Report, 'foundation applied skin' means skin that is not bare, but covered with foundation and/or face powder.

2.1.2 Typical set selection for artificial colour groups

There are seven artificial colour groups in Table 1: photographic transparency, photographic reflection prints, offset prints, dye sublimation printer, electrostatic printer, ink-jet printer, and textiles (synthetic dyes). Colour samples can be obtained for every hue in these groups.

Colorants can be expected to vary within any one group, as, for example, among the many products of different photographic prints material manufacturers. Spectral reflectance measurements were carried out for several representative products among them. Statistical analysis was carried out on the measurement data, and the product whose characteristics most closely approximated the statistical average for the products as a whole was determined to be a typical colour product. A mathematical explanation for this is found in Annex B. From a large number of colour samples for a typical product, fifteen samples were selected whose colours are nearest to pre-determined basic colours, which consist of three achromatic colours and twelve chromatic colours that are homogeneously distributed in twelve hues. Lightness and chromaticity of each chromatic colour was such that the colour gamut of each artificial colour group contained all the chromatic colours. Table 2 shows the achromatic colours (1-3) and the chromatic colours (4-15). The colour for each spectral data is calculated under D65 illuminant.

Table 2 — Basic colours for artificial colour groups

	*L**	*H**	*C**	*a**	*b**
1	20	—	0	0,0	0,0
2	50	—	0	0,0	0,0
3	80	—	0	0,0	0,0
4	40	0	30	30,0	0,0
5	45	30	35	30,3	17,5
6	50	60	37	18,5	32,0
7	60	90	45	0,0	45,0
8	60	120	30	−15,0	26,0
9	45	150	30	−26,0	15,0
10	45	180	23	−23,0	0,0
11	45	210	22	−19,1	−11,0
12	45	240	20	−10,0	−17,3
13	40	270	20	0,0	−20,0
14	35	300	27	13,5	−23,4
15	40	330	30	26,0	−15,0

2.1.3 Typical set selection for non-skin colour, natural colour groups

There are six natural colour groups in Table 1 for non-skin colours: flowers/grasses/leaves (including Krinov's grasses/leaves), paint (not for art), oil paints, watercolours, textiles (plant), and non-grass/leaf Krinov. Samples in natural colour groups are not distributed in whole hues, and typical samples cannot be selected on the basis of their colours. To select typical set samples for natural colour groups, an algorithm based on spectral distribution was developed. When principal component analysis was applied to all samples in a group, it became possible to express the data distribution in a low dimensional subspace. An equi-distanced lattice was set in the subspace, and a representative sample was selected from each lattice point. A mathematical explanation for this is found in Annex C. Twenty-five typical samples were selected from the 'flowers/grasses/leaves' group, while 15 typical samples were selected from each of the other groups.

2.1.4 Typical set selection for skin groups

There are six skin colour groups in Table 1: Bare North Asian skin, FD (foundation)-applied North Asian skin, Bare South Asian skin, FD-applied South Asian skin, Bare Caucasian skin, and Bare Negroid skin. Skin colours are not distributed over a wide range, and only five samples were selected from each group. These colours correspond to average and extreme colours over their distribution in CIELAB space. The mathematical explanation for this is found in Annex D.

2.1.5 Difference set selection

Difference set samples were selected for typical samples in the artificial colour groups and in the flowers/grasses/leaves group. Colour samples in difference sets have colours that, while similar to typical set sample colours under D65 illuminant, are significantly different spectrally. Samples whose colour was least different from a typical set were selected first. The most spectrally different colours among these were then selected to create the difference set. The mathematical explanation for this is found in Annex E.

2.2 Typical set samples and difference set samples

Typical set spectral data and difference set spectral data are stored in electronic form as files in the subdirectories designated ‘typical’ and ‘difference’ described in the directory TRDatabase that is part of this Technical Report. All spectral data are 31 dimensional, from 400 nm to 700 nm at 10 nm interval. The spectral data are presented as percent reflectance factor or percent transmittance factor. File names corresponding to the above groups are summarized in Table 3. The originally collected data can also be accessed from the data directory SourceData which is described in Annex A. Correspondence with original sample identification numbers (IDs) is summarized in Annex F.

The files ‘photo_t’, ‘photo_r’, ‘offset’, ‘print_ds’, ‘print_es’, ‘print_ij’, and ‘textiles_s’ in ‘typical’ directory include typical set samples from artificial colour groups, each sample with a number from 1 to 15 has a colour similar to its corresponding basic colour. The same holds for the difference set colours in the files ‘photo_t-d’, ‘photo_r-d’, ‘offset-d’, ‘print_ds-d’, ‘print_es-d’, ‘print_ij-d’, and ‘textiles_s-d’ in the ‘difference’ directory, since they are samples in artificial colour groups. For the other typical set samples and for the other difference set samples, which belong to natural colour groups, there is no such relation to basic colours. Nevertheless, the order of colour samples in ‘flowers_leaves’ file in the ‘typical’ directory corresponds to the order of colour samples in the ‘flowers_leaves-d’ file in the ‘difference’ directory. Such correspondences can be confirmed by comparing the L^*, a^* and b^* values of the samples in Annex F.

Table 3 — File names that contain typical set samples and difference set samples for each group

Kind of set	Group	Directory\File name
Typical set	Photo (transparency)	typical\photo_t.txt
Typical set	Photo (reflection print)	typical\photo_r.txt
Typical set	Offset prints	typical\offset.txt
Typical set	Dye sublimation printer	typical\print_ds.txt
Typical set	Electrostatic printer	typical\print_es.txt
Typical set	Ink-jet printer	typical\print_ij.txt
Typical set	Textiles (synthetic dyes)	typical\textiles_s.txt
Typical set	Flowers/grasses/leaves (incl. Krinov's grasses and leaves)	typical\flowers_leaves.txt
Typical set	Paint (not for art)	typical\paint.txt
Typical set	Oil paints	typical\oil.txt
Typical set	Water colours	typical\water.txt
Typical set	Textiles (plant)	typical\textiles_p.txt
Typical set	Non-grass/leaf Krinov	typical\n_krinov.txt
Typical set	Bare North Asian skin	typical\n_asian_b.txt
Typical set	FD-applied North Asian skin	typical\n_asian_f.txt
Typical set	Bare South Asian skin	typical\s_asian_b.txt
Typical set	FD-applied South Asian skin	typical\s_asian_f.txt
Typical set	Bare Caucasian skin	typical\caucasian_b.txt
Typical set	Bare Negroid skin	typical\negroid_b.txt
Difference set	Photo (transparency)	difference\photo_t-d.txt
Difference set	Photo (reflection print)	difference\photo_r-d.txt
Difference set	Offset prints	difference\offset-d.txt
Difference set	Dye sublimation printer	difference\print_ds-d.txt
Difference set	Electrostatic printer	difference\print_es-d.txt
Difference set	Ink-jet printer	difference\print_ij-d.txt
Difference set	Textiles (synthetic dyes)	difference\textiles_s-d.txt
Difference set	Flowers/grasses/leaves (incl. Krinov's grasses and leaves)	difference\flowers_leaves-d.txt

3 Use of the colour spectra database

3.1 Use of typical sets

In this section examples of how the database may be used to evaluate the colour reproduction accuracy of a device are given. The usual colour reproduction evaluation scheme is as follows:

Object colour is calculated using colour matching functions $(\bar{x}, \bar{y}, \bar{z})$ where $\bar{x} = \left[\bar{x}(400), \bar{x}(410), ..., \bar{x}(700)\right]^t$, $\bar{y} = \left[\bar{y}(400), \bar{y}(410), ..., \bar{y}(700)\right]^t$, $\bar{z} = \left[\bar{z}(400), \bar{z}(410), ..., \bar{z}(700)\right]^t$ recommended by CIE 15.2. If the i-th object's spectral reflectance is $\beta_i = \left[\beta_i(400), \beta_i(410), ... , \beta_i(700)\right]^t$ and illumination intensity is $S = \left[S(400), S(410), ... , S(700)\right]^t$, the CIE-1931 XYZ values for the i-th object may be expressed as in equation (1):

$$\begin{cases} X_{0i} = k \sum_{\lambda=400}^{700} S(\lambda)\beta_i(\lambda)\bar{x}(\lambda) \\ Y_{0i} = k \sum_{\lambda=400}^{700} S(\lambda)\beta_i(\lambda)\bar{y}(\lambda) \\ Z_{0i} = k \sum_{\lambda=400}^{700} S(\lambda)\beta_i(\lambda)\bar{z}(\lambda) \end{cases} \quad (1)$$

where $k = \dfrac{100}{\sum_{\lambda=400}^{700} S(\lambda)\bar{y}(\lambda)}$

NOTE CIE 15.2 recommends that calculation shall be carried out from 380 nm to 780 nm at an interval of 5 nm. However, in the practical cases for which this data is used (with a data range of 400 nm to 700 nm at an interval of 10 nm) it is recommended that weighting functions such as those defined in ASTM E-308 be used.

Colour image input devices usually have sensors with three different spectral sensitivities. If actual sensor sensitivities are $(\bar{s}_r, \bar{s}_g, \bar{s}_b)$ $\bar{s}_r = \left[\bar{s}_r(400), \bar{s}_r(410), ..., \bar{s}_r(700)\right]^t$, $\bar{s}_g = \left[\bar{s}_g(400), \bar{s}_g(410), ..., \bar{s}_g(700)\right]^t$, $\bar{s}_b = \left[\bar{s}_b(400), \bar{s}_b(410), ..., \bar{s}_b(700)\right]^t$ output signals (R_i, G_i, B_i) for the i-th object may be expressed as in equation (2):

$$\begin{cases} R_i = \sum_{\lambda=400}^{700} S(\lambda)\beta_i(\lambda)\bar{s}_r(\lambda) \\ G_i = \sum_{\lambda=400}^{700} S(\lambda)\beta_i(\lambda)\bar{s}_g(\lambda) \\ B_i = \sum_{\lambda=400}^{700} S(\lambda)\beta_i(\lambda)\bar{s}_b(\lambda) \end{cases} \quad (2)$$

The (R_i, G_i, B_i) is converted to colour values in the CIE-1931 XYZ colour space. Equation (3) is often used for the conversion — though a higher order function may sometimes be desirable.

$$\begin{pmatrix} X_i \\ Y_i \\ Z_i \end{pmatrix} = \begin{pmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{22} & a_{23} \end{pmatrix} \begin{pmatrix} R_i \\ G_i \\ B_i \end{pmatrix} \quad (3)$$

Matrix elements $\{a_{ij}\}$ can be determined using the least square method, where the sum of squared colour differences for typical set colours are minimized in some colour space. The sum cannot be zero in practical cases. This residual colour difference is evaluated in a uniform colour space (e.g. CIELAB space). The conversion from the XYZ space to the CIELAB space is also described in CIE 15.2. Letting the converted values from (X_{0i}, Y_{0i}, Z_{0i}) and (X_i, Y_i, Z_i) be $(L^*{}_{0i}, a^*{}_{0i}, b^*{}_{0i})$ and $(L^*{}_i, a^*{}_i, b^*{}_i)$, respectively, the average colour difference for n typical set object colours may be expressed as in equation (4):

$$\Delta\bar{E}^*_{ab} = \frac{\sum_{i=1}^{n} \sqrt{\left(L^*_i - L^*_{0i}\right)^2 + \left(a^*_i - a^*_{0i}\right)^2 + \left(b^*_i - b^*_{0i}\right)^2}}{n} \quad (4)$$

The smaller the $\Delta\bar{E}^{*}_{ab}$, the better the colour reproduction. That is, in the event that sensor spectral sensitivities of colour image input devices can somehow be measured, it is possible to evaluate their colour reproducibility using actual object colours. It is also possible to estimate colour reproducibility using this database when designing the spectral sensitivities of image input devices.

Usually, a single image input apparatus does not need to input all the object colours in the world. Film scanners, for example, need only to scan colour films; it is not necessary for scanners to reproduce the colours of natural objects or scenery, and the colour reproduction of colour scanners only needs to be evaluated for colour films. That is why data here have been classified into object groups. For a scanner, therefore, only the typical set samples identified as “photo” in Table 3 (i.e. photo_t.txt and photo_r.txt) would be used for evaluation.

On the other hand, for evaluating digital cameras, human faces, flowers, leaves and outdoor objects always have high importance, and typical sets for these object groups would be used.

3.2 Use of difference sets

Difference sets contain samples whose appearance is similar to the appearance of typical sets samples under the standard illuminant D65, but whose spectral reflectance/transmittance is significantly different from that of typical set samples. That is, difference sets contain metamers. Let us first assume that β_j represents the spectral reflectance of a given difference set sample, a reflectance that corresponds to β_i, the spectral reflectance of a typical set sample. In this case, two sensor outputs will be calculated using two light sources S_1 and S_2. Four sets of R, G, and B values can then be obtained, as expressed in equations (5) through (8).

$$\begin{cases} R_{i1} = \sum_{\lambda=400}^{700} S_1(\lambda)\beta_i(\lambda)\bar{s}_r(\lambda) \\ G_{i1} = \sum_{\lambda=400}^{700} S_1(\lambda)\beta_i(\lambda)\bar{s}_g(\lambda) \\ B_{i1} = \sum_{\lambda=400}^{700} S_1(\lambda)\beta_i(\lambda)\bar{s}_b(\lambda) \end{cases} \tag{5}$$

$$\begin{cases} R_{i2} = \sum_{\lambda=400}^{700} S_2(\lambda)\beta_i(\lambda)\bar{s}_r(\lambda) \\ G_{i2} = \sum_{\lambda=400}^{700} S_2(\lambda)\beta_i(\lambda)\bar{s}_g(\lambda) \\ B_{i2} = \sum_{\lambda=400}^{700} S_2(\lambda)\beta_i(\lambda)\bar{s}_b(\lambda) \end{cases} \tag{6}$$

$$\begin{cases} R_{j1} = \sum_{\lambda=400}^{700} S_1(\lambda)\beta_j(\lambda)\bar{s}_r(\lambda) \\ G_{j1} = \sum_{\lambda=400}^{700} S_1(\lambda)\beta_j(\lambda)\bar{s}_g(\lambda) \\ B_{j1} = \sum_{\lambda=400}^{700} S_1(\lambda)\beta_j(\lambda)\bar{s}_b(\lambda) \end{cases} \tag{7}$$

$$\begin{cases} R_{j2} = \sum_{\lambda=400}^{700} S_2(\lambda)\beta_j(\lambda)\bar{s}_r(\lambda) \\ G_{j2} = \sum_{\lambda=400}^{700} S_2(\lambda)\beta_j(\lambda)\bar{s}_g(\lambda) \\ B_{j2} = \sum_{\lambda=400}^{700} S_2(\lambda)\beta_j(\lambda)\bar{s}_b(\lambda) \end{cases} \quad (8)$$

To compare colour differences, CIELAB values for these four colour values can be calculated as $\left(L^*_{i1}, a^*_{i1}, b^*_{i1}\right)$, $\left(L^*_{i2}, a^*_{i2}, b^*_{i2}\right)$, $\left(L^*_{j1}, a^*_{j1}, b^*_{j1}\right)$ and $\left(L^*_{j2}, a^*_{j2}, b^*_{j2}\right)$ through CIE-1931 XYZ values as described in 3.1. The colour difference between β_i and β_j under light source 1 will then be equal to ΔE^*_{ab1} in equation (9), and the colour difference between β_i and β_j under light source 2 will be equal to ΔE^*_{ab2} in equation (10). By comparing the differences with those for the human visual system, it becomes possible to evaluate a sensor's resemblance to human eyes.

$$\Delta E^*_{ab1} = \sqrt{\left(L^*_{i1} - L^*_{j1}\right)^2 + \left(a^*_{i1} - a^*_{j1}\right)^2 + \left(b^*_{i1} - b^*_{j1}\right)^2} \quad (9)$$

$$\Delta E^*_{ab2} = \sqrt{\left(L^*_{i2} - L^*_{j2}\right)^2 + \left(a^*_{i2} - a^*_{j2}\right)^2 + \left(b^*_{i2} - b^*_{j2}\right)^2} \quad (10)$$

4 Permissions

The primary intent of this Technical Report is to provide data in digital form for the use of individuals and organizations evaluating imaging systems. Therefore, the following is permitted:

a) The data files included as part of the Technical Report may be freely copied and used within the organization purchasing a copy of this Technical Report from ISO, or an authorized reseller of ISO documents. The data files (in either their original or any reformatted version) may not be distributed to any other individual or organization.

b) Where this database is used for research, development, or evaluation, any publication reporting such work shall identify this Technical Report as the source.

Annex A
(informative)

Spectral reflectance and transmittance source data

A.1 General

The spectral reflectance and transmittance source data collected as part of this project, and used to create the typical and difference set samples, are included as electronic attachments to this Technical Report. These data are classified into two groups, original data and interpolated data. The directory structure that contains these files is shown in Figure A.1.

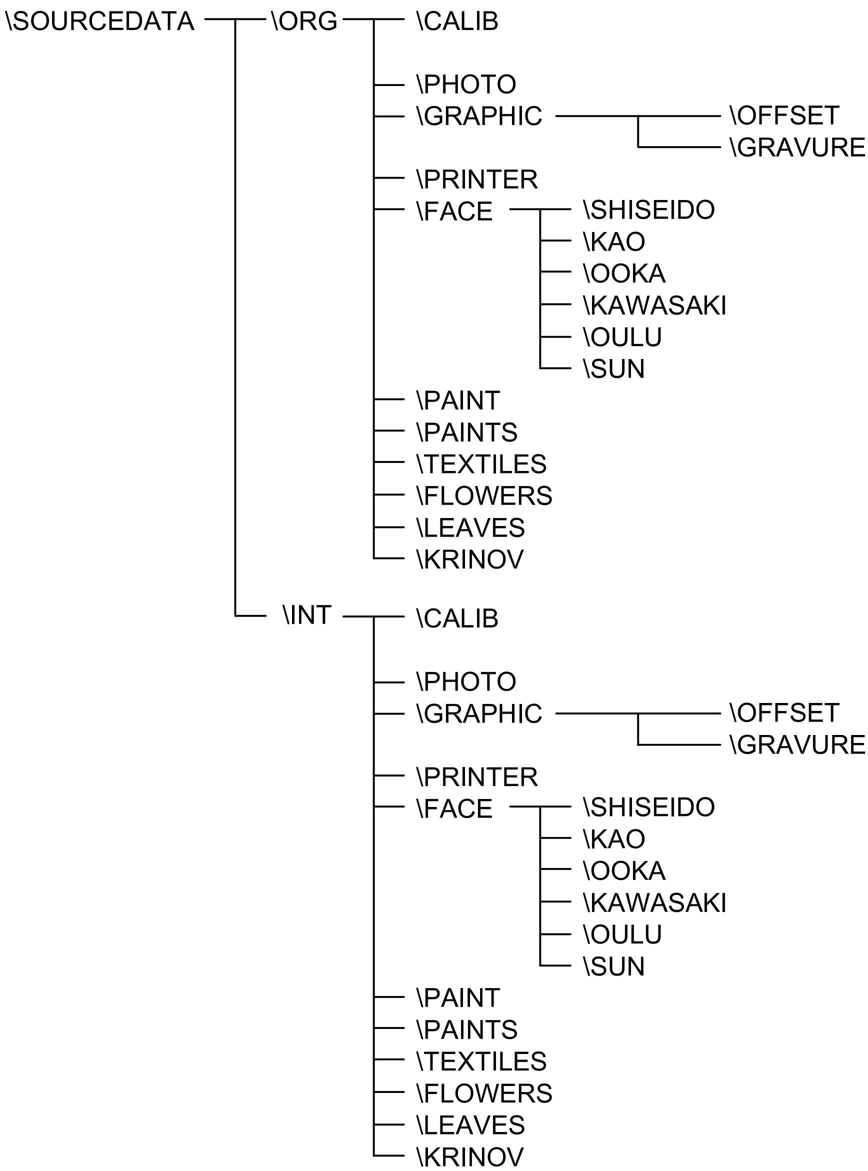

Figure A.1 — Directory structure of source data

A.1.1 \ORG files

ORG is an abbreviation of 'ORIGINAL DATA'. The \ORG directory includes original spectral reflectance and transmittance data measured by a spectral measurement apparatus. The data are classified in ten categories so that users can select data appropriate for their use, depending on the types of colour image input devices or the situations in which the data are used. The ten categories are shown below with names of directories where the data are stored.

(1) Photographic materials (\PHOTO)

(2) Graphic prints (\GRAPHIC)

(3) Computer colour prints (\PRINTER)

(4) Paint (not for art) (\PAINT)

(5) Paints (for art) (\PAINTS)

(6) Textiles (\TEXTILES)

(7) Flowers (\FLOWERS)

(8) Leaves (\LEAVES)

(9) Human skin (\FACE)

(10) Krinov data (\KRINOV)

Sixteen spectral measurement devices were used to collect data in categories from (1) to (9). [Collection of data in category (10) is explained later.] These devices are reliable but do not output the same values, even if they measure the same object colours. To calibrate measured data, eight colour patches were produced and measured by the sixteen measurement devices under the same conditions as were in effect when they measured the object colours in categories from (1) to (9).

A detailed explanation file "README" for data in each category is included in each directory.

A.1.1.1 Photographic materials (\PHOTO)

Eight files are stored in the \PHOTO directory. They are shown in Table A.1. Transparent and reflection input targets standardized by ISO 12641:1997 were produced by four major vendors. Spectral transmittance or spectral reflectance for all colour patches in each target (288 colours) is recorded in each file.

Table A.1 — Files stored in \PHOTO directory

	Target	File name	No. of Colours
Transparency	Target-1	ph01_t.org	288
	Target-2	ph02_t.org	288
	Target-3	ph03_t.org	288
	Target-4	ph04_t.org	288
Reflection print	Target-1	ph01_r.org	288
	Target-2	ph02_r.org	288
	Target-3	ph03_r.org	288
	Target-4	ph04_r.org	288

A.1.1.2 Graphic prints (\GRAPHIC)

The \GRAPHIC directory is divided into two subdirectories, \OFFSET and \GRAVURE. The \OFFSET directory includes thirty files for colour patches printed by offset printing. They are summarised in Table A.2.

The colour patches are those standardized by C, M, Y and K ink quantities shown in ISO 12642:1996, *Graphic technology — Prepress digital data exchange — Input data for characterization of 4-colour process printing*, and as colour patch images in ISO 12640:1997, *Graphic technology — Prepress digital data exchange — CMYK standard colour image data (CMYK/SCID)*. The images were printed using ten kinds of ink and three kinds of paper. Spectral reflectances of all 928 colour patches in the images are stored in each file.

Table A.2 — Files stored in \OFFSET directory

Printing method	Ink	Paper	File name	No. of colours
Offset printing	Ink-1	Uncoated paper	of01_u.org	928
		Dull-coated paper	of01_d.org	928
		Gloss-coated paper	of01_g.org	928
	Ink-2	Uncoated paper	of02_u.org	928
		Dull-coated paper	of02_d.org	928
		Gloss-coated paper	of02_g.org	928
	Ink-3	Uncoated paper	of03_u.org	928
		Dull-coated paper	of03_d.org	928
		Gloss-coated paper	of03_g.org	928
	Ink-4	Uncoated paper	of04_u.org	928
		Dull-coated paper	of04_d.org	928
		Gloss-coated paper	of04_g.org	928
	Ink-5	Uncoated paper	of05_u.org	928
		Dull-coated paper	of05_d.org	928
		Gloss-coated paper	of05_g.org	928
	Ink-6	Uncoated paper	of06_u.org	928
		Dull-coated paper	of06_d.org	928
		Gloss-coated paper	of06_g.org	928
	Ink-7	Uncoated paper	of07_u.org	928
		Dull-coated paper	of07_d.org	928
		Gloss-coated paper	of07_g.org	928
	Ink-8	Uncoated paper	of08_u.org	928
		Dull-coated paper	of08_d.org	928
		Gloss-coated paper	of08_g.org	928
	Ink-9	Uncoated paper	of09_u.org	928
		Dull-coated paper	of09_d.org	928
		Gloss-coated paper	of09_g.org	928
	Ink-10	Uncoated paper	of10_u.org	928
		Dull-coated paper	of10_d.org	928
		Gloss-coated paper	of10_g.org	928

The \GRAVURE directory includes three files of colour patches printed by gravure printing. The files are shown in Table A.3. The colour patch images were printed using one type of paper under three different sets of conditions. The colour patch images were the same as those for the offset printing.

Table A.3 — Files stored in \GRAVURE directory

Printing method	Ink / Paper	Printing condition	File name	No. of colours
Gravure printing	Ink-1 / Gloss-coated paper	Standard	gr_s.org	928
		Minus	gr_m.org	928
		Plus	gr_p.org	928

A.1.1.3 Computer colour prints (\PRINTER)

The \PRINTER directory contains the 21 files shown in Table A.4. Three kinds of colour patch images were measured: 928-colour images, 512-colour images and 216-colour images. The 928-colour images, which are the same as those used for graphic prints colour patch measurement, were printed by printers whose C, M, Y and K components can be controlled from a computer program. The 512- and 216-colour images were employed for printers whose only computer-controllable components are R, G and B. For printers each of whose colour components was controlled in eight steps, 512 colours were printed and measured, while for printers each of whose colour components was controlled in six steps, 216 colours were printed and measured.

Table A.4 — Files stored in \PRINTER directory

Printing method	Printer ID	Files name	No. of colours
Dye sublimation	DS-1	pr_ds_1.org	512
	DS-2	pr_ds_2.org	928
	DS-3	pr_ds_3.org	512
	DS-4	pr_ds_4.org	512
	DS-5	pr_ds_5.org	216
Electrostatic	ES-1	pr_es_1.org	216
	ES-2	pr_es_2.org	216
	ES-3	pr_es_3.org	928
	ES-4	pr_es_4.org	216
Inkjet	IJ-1	pr_ij_1.org	216
	IJ-2	pr_ij_2.org	216
	IJ-3	pr_ij_3.org	216
	IJ-4	pr_ij_4.org	216
	IJ-5	pr_ij_5.org	216
	IJ-6	pr_ij_6.org	216
	IJ-7	pr_ij_7.org	216
Silver halide	SH-1	pr_sh_1.org	512
	SH-2	pr_sh_2.org	216
Other	OT-1	pr_ot_1.org	216
	OT-2	pr_ot_2.org	216
	OT-3	pr_ot_3.org	928

A.1.1.4 Paint (not for art) (\PAINT)

There is only one file in the \PAINT directory as shown in Table A.5. The file contains spectral reflectances of painted objects. The colours are used for exterior/interior objects, and are not for artistic painting.

Table A.5 — File stored in \PAINT directory

File name	Number of colours
paint.org	336

A.1.1.5 Paints (for art) (\PAINTS)

The \PAINTS directory contains the four files shown in Table A.6. Each file contains colour patch spectral reflectances of oil paints, old type oil paints, watercolours, or new type watercolours whose properties lie between those of water colours and oil paints. The old type oil paints are paints that were formerly used but are not any longer because they contain poisonous heavy metal ingredients. Watercolour patches were provided by Turner Colour Works Ltd., and oil paints patches were provided by Kusakabe Co. Ltd.

Table A.6 — Files stored in \PAINTS directory

Kind of paint	Files name	No. of colours
Water colour	pa_a.org	60
New type paints	pa_g.org	60
Oil paints	pa_o.org	91
Old type oil paints	pa_s.org	20

A.1.1.6 Textiles (\TEXTILES)

The \TEXTILES directory contains the six files shown in Table A.7. Colours on cotton, polyester, wool and silk clothes are produced by synthetic dyes, while others are produced by plant dyes. The data for silk cloth were provided by Consiglio Nazionale delle Ricerche, Italy, and the data for plant dyes were provided by Fuji Photo Film Co., Ltd.

Table A.7 — Data files for measured textiles

Type of objects	File names	No. of colours
Cotton cloth	cotton.org	714
Polyester cloth	poly.org	714
Wool cloth	wool.org	150
Silk cloth	silk.org	1000
Cotton cloth dyed with plant-dyes	plant_c.org	240
Silk yarn dyed with plant-dyes	plant_y.org	14

A.1.1.7 Flowers (\FLOWERS)

There is only one file in the \FLOWERS directory as shown in Table A.8. The data were provided by Japan Color Research Institute.

Table A.8 — File stored in \FLOWERS directory

File name	Number of colours
flower.org	148

A.1.1.8 Leaves (\LEAVES)

There is only one file in the \LEAVES directory, as shown in Table A.9. The data were provided by Japan Color Research Institute.

Table A.9 — File stored in \LEAVES directory

File name	Number of colours
leaf.org	92

A.1.1.9 Human skin (\FACE)

The \FACE directory is divided into six subdirectories: \SHISEIDO, \KAO, \OOKA, \KAWASAKI, \OULU and \SUN. Data file names were assigned according to the following rule: File names take the form of ‘ttgcppss’, where

tt represents the name of the data set,

g represents gender (f: female, m: male),

c represents skin condition (b: bare skin, f: foundation-applied skin),

pp represents position (ch: cheek, fh: forehead, nk: neck, zy: zygomatic region, am: arm, ha: hand), and

ss represents the measurement device used.

The \SHISEIDO directory stores spectral reflectance data collected by Shiseido Co., Ltd. and contains the 27 files shown in Table A.10. All data are for females and represent measured spectral reflectances for various skin positions and conditions. For any given locale, the order of individual subjects within each file is the same.

Table A.10 — Files stored in \SHISEIDO directory

Subject set (locale, nationality)	Skin condition	Position	File name	No. of colours
Bangkok	Foundation-applied skin	Cheek	baffchc1.org	62
	Bare skin	Forehead	bafbfhc1.org	62
	Bare skin	Cheek	bafbchc1.org	62
	Bare skin	Neck	bafbnkc1.org	62
Kualalumpur (Chinese family)	Foundation-applied skin	Cheek	kcffchc1.org	30
	Bare skin	Forehead	kcfbfhc1.org	30
	Bare skin	Cheek	kcfbchc1.org	30
	Bare skin	Neck	kcfbnkc1.org	30
Kualalumpur (India family)	Foundation-applied skin	Cheek	kiffchc1.org	30
	Bare skin	Forehead	kifbfhc1.org	30
	Bare skin	Cheek	kifbchc1.org	30
	Bare skin	Neck	kifbnkc1.org	30
Kualalumpur (Malay family)	Foundation-applied skin	Cheek	kmffchc1.org	30
	Bare skin	Forehead	kmfbfhc1.org	30
	Bare skin	Cheek	kmfbchc1.org	30
	Bare skin	Neck	kmfbnkc1.org	30
Taipei	Foundation-applied skin	Cheek	taffchc1.org	60
	Bare skin	Forehead	tafbfhc1.org	60
	Bare skin	Cheek	tafbchc1.org	60
	Bare skin	Neck	tafbnkc1.org	60
Tokyo-1	Bare skin	Neck	t1fbnkc1.org	976
	Bare skin	Cheek	t1fbchc1.org	976
	Bare skin	Zygomatic region	t1fbzyc1.org	976
Tokyo-2	Bare skin	Forehead	t2fbfhc1.org	123
	Bare skin	Cheek	t2fbchc1.org	123
	Foundation-applied skin	Forehead	t2fffhc1.org	123
	Foundation-applied skin	Cheek	t2ffchc1.org	123

The \KAO directory contains spectral reflectance data collected by the Kao Corporation. All data in this directory are for Japanese females and were collected in Tokyo. It contains the eight files shown in Table A.11. The order of individual subjects within each file is not the same.

Table A.11 — Files stored in \KAO directory

Subject set (place, nationality)	Skin condition	Position	File name	No. of colours
Tokyo (Japanese)	Bare skin	Forehead	tofbfhc2.org	271
	Foundation-applied skin	Forehead	tofffhc2.org	266
	Bare skin	Zygomatic region	tofbzyc2.org	461
	Foundation-applied skin	Zygomatic region	toffzyc2.org	325
	Bare skin	Cheek	tofbchc2.org	460
	Foundation-applied skin	Cheek	toffchc2.org	325
	Bare skin	Arm	tofbamc2.org	37
	Bare skin	Neck	tofbnkc2.org	313

The data in the \SHISEIDO and \KAO directories were all obtained with contact-type spectral measuring devices. In contrast, the data in the \OOKA and \KAWASAKI directories were obtained with both contact-type and remote-type measuring devices. Most subjects were males and a small portion of them were non-Japanese. Table A.12 shows the composition by sex and nationality. Measured positions were forehead, zygomatic region, and cheek. The data in \OOKA are stored in the 27 files shown in Table A.13 and organized with respect to sex, skin condition, position, and measuring device, as in \SHISEIDO and \KAO. The same is true for the data in \KAWASAKI (27 files; Table A.14).

Table A.12 — Composition of subjects in \OOKA and \KAWASAKI

	OOKA		KAWASAKI		
	Male	**Female**	**Male**	**Female**	**Total**
Japan	43	7	66	14	130
China	3	3	1	0	7
Korea	1	0	0	0	1
Taiwan	0	0	1	0	1
Singapore	1	0	0	0	1
Egypt	2	0	0	0	2
Bangladeshi	1	0	0	0	1
Turkey	1	0	0	0	1
France	1	0	0	0	1
Canada	0	0	1	0	1
Finland	0	0	1	0	1
Total	**53**	**10**	**70**	**14**	**147**

Table A.13 — Files stored in \OOKA directory

Subject set (sex / skin condition)	Position	Type of measurement device	Files name	No. of colours
Male / Bare skin	Forehead	Contact-1	oombfhc1.org	53
	Zygomatic region	Contact-1	oombzyc1.org	53
	Cheek	Contact-1	oombchc1.org	53
	Forehead	Contact-2	oombfhc2.org	53
	Zygomatic region	Contact-2	oombzyc2.org	53
	Cheek	Contact-2	oombchc2.org	53
	Forehead	Remote	oombfhr.org	53
	Zygomatic region	Remote	oombzyr.org	53
	Cheek	Remote	oombchr.org	53
Female / Bare skin	Forehead	Contact-1	oofbfhc1.org	5
	Zygomatic region	Contact-1	oofbzyc1.org	5
	Cheek	Contact-1	oofbchc1.org	5
	Forehead	Contact-2	oofbfhc2.org	5
	Zygomatic region	Contact-2	oofbzyc2.org	5
	Cheek	Contact-2	oofbchc2.org	5
	Forehead	Remote	oofbfhr.org	5
	Zygomatic region	Remote	oofbzyr.org	5
	Cheek	Remote	oofbchr.org	5
Female / Foundation-applied skin	Forehead	Contact-1	oofffhc1.org	5
	Zygomatic region	Contact-1	ooffzyc1.org	5
	Cheek	Contact-1	ooffchc1.org	5
	Forehead	Contact-2	oofffhc2.org	5
	Zygomatic region	Contact-2	ooffzyc2.org	5
	Cheek	Contact-2	ooffchc2.org	5
	Forehead	Remote	oofffhr.org	5
	Zygomatic region	Remote	ooffzyr.org	5
	Cheek	Remote	ooffchr.org	5

Table A.14 — Files stored in \KAWASAKI directory

Subject set (sex / skin condition)	Position	Type of measurement device	Files name	No. of colours
Male / Bare skin	Forehead	Contact-1	kambfhc1.org	70
	Zygomatic region	Contact-1	kambzyc1.org	70
	Cheek	Contact-1	kambchc1.org	70
	Forehead	Contact-2	kambfhc2.org	70
	Zygomatic region	Contact-2	kambzyc2.org	70
	Cheek	Contact-2	kambchc2.org	70
	Forehead	Remote	kambfhr.org	70
	Zygomatic region	Remote	kambzyr.org	70
	Cheek	Remote	kambchr.org	70
Female / Bare skin	Forehead	Contact-1	kafbfhc1.org	2
	Zygomatic region	Contact-1	kafbzyc1.org	2
	Cheek	Contact-1	kafbchc1.org	2
	Forehead	Contact-2	kafbfhc2.org	2
	Zygomatic region	Contact-2	kafbzyc2.org	2
	Cheek	Contact-2	kafbchc2.org	2
	Forehead	Remote	kafbfhr.org	2
	Zygomatic region	Remote	kafbzyr.org	2
	Cheek	Remote	kafbchr.org	2
Female / Foundation-applied skin	Forehead	Contact-1	kafffhc1.org	12
	Zygomatic region	Contact-1	kaffzyc1.org	12
	Cheek	Contact-1	kaffchc1.org	12
	Forehead	Contact-2	kafffhc2.org	12
	Zygomatic region	Contact-2	kaffzyc2.org	12
	Cheek	Contact-2	kaffchc2.org	12
	Forehead	Remote	kafffhr.org	12
	Zygomatic region	Remote	kaffzyr.org	12
	Cheek	Remote	kaffchr.org	12

Data collected by Oulu University, Finland, and by Sun Chemical Corporation, and containing a significant amount of non-Asian data, have also been added to the database. These data were obtained with contact-type devices and stored in \OULU and \SUN directories, respectively (see Tables A.15 and A.16).

Table A.15 — Files stored in \OULU directory

Subject set (place/race/sex)	Skin condition	Position	File name	No. of colours
Oulu/Caucasian/Male	Bare skin	--	ocmbxxc3.org	234
Oulu/Caucasian/Female	Bare skin	--	ocfbxxc3.org	66
Oulu/Caucasian/Female	Foundation applied skin	--	ocffxxc3.org	3
Oulu/Negroid/Male	Bare skin	--	onmbxxc3.org	24
Oulu/Asian/Male	Bare skin	--	oambxxc3.org	9
Oulu/Asian/Female	Bare skin	--	oafbxxc3.org	21

Table A.16 — Files stored in \SUN directory

Subject set (Place/Race/Sex)	Skin condition	Position	File name	No. of colours
Carlstadt/Negroid/Male	Bare skin	Forehead	cnmbfhc4.org	5
		Zygomatic region	cnmbzyc4.org	5
		Neck	cnmbnkc4.org	5
		Hand	cnmbhac4.org	5
Carlstadt/Negroid/Female	Bare skin	Forehead	cnfbfhc4.org	9
		Zygomatic region	cnfbzyc4.org	9
		Neck	cnfbnkc4.org	9
		Hand	cnfbhac4.org	9
Carlstadt/Caucasian/Male	Bare skin	Forehead	ccmbfhc4.org	15
		Zygomatic region	ccmbzyc4.org	15
		Neck	ccmbnkc4.org	15
		Hand	ccmbhac4.org	15
Carlstadt/Caucasian/Female	Bare skin	Forehead	ccfbfhc4.org	3
		Zygomatic region	ccfbzyc4.org	3
		Neck	ccfbnkc4.org	5
		Hand	ccfbhac4.org	5
Carlstadt/Caucasian/Female	Foundation applied skin	Forehead	ccfffhc4.org	2
		Zygomatic region	ccffzyc4.org	2
Carlstadt/Others/Male	Bare skin	Forehead	combfhc4.org	6
		Zygomatic region	combzyc4.org	6
		Neck	combnkc4.org	6
		Hand	combhac4.org	6
Carlstadt/Others/Female	Bare skin	Forehead	cofbfhc4.org	1
		Zygomatic region	cofbzyc4.org	1
		Neck	cofbnkc4.org	1
		Hand	cofbhac4.org	1

A.1.1.10 Krinov data (\KRINOV)

Data in the \KRINOV directory were originally published in the paper “Spectrol, naye otrazhatel’naya sposobnost’ pirodnykh obrazovanii” by E.L.Krinov (Izadeltel’stvo Akad. Nauk, USSR, 1947). The English version was published in the report “Spectral Reflectance Properties of Natural Formations” TT-439 (1953), National Research Council of Canada, Ottawa. The translation was made by G. Belkov. The data include spectral reflectances of many outdoor scenes. The spectral reflectance data were converted to electronic data. Eight files are included in the \KRINOV directory (Table A.17), according to the classifications in the original report.

Table A.17 — Files stored in \KRINOV directory

Classification	Files name	No. of colours
Forests and shrubs	krinov1.org	49
Grass	krinov2.org	119
Mosses and lichens	krinov3.org	7
Field and garden crops	krinov4.org	54
Bare areas and soils	krinov5.org	89
Roads	krinov6.org	14
Water surfaces and snow	krinov7.org	22
Buildings and building materials	krinov8.org	16

A.1.1.11 Calibration data (\CALIB)

Sixteen spectral measurement devices were used in this project. Spectral reflectance data for eight calibration colour patches are contained in the \CALIB directory. These data were measured by a standard spectral measurement device ‘00’, and by the sixteen spectral measurement devices ‘01’ - ‘16’. Measurement conditions were the same as those under which data collection was carried out. Table A.18 shows the seventeen files in this directory.

Table A.18 — Files stored in \CALIB directory

Measurement device ID	Type of measurement device	File name	No. of colours
0	Chamber	cp00.org	8
1	Contact	cp01.org	8
2	Contact	cp02.org	8
3	Contact	cp03.org	8
4	Contact	cp04.org	8
5	Contact	cp05.org	8
6	Remote	cp06.org	8
7	Remote	cp07.org	8
8	Remote	cp08.org	8
9	Remote	cp09.org	8
10	Chamber	cp10.org	8
11	Chamber	cp11.org	8
12	Contact	cp12.org	8
13	Contact	cp13.org	8
14	Chamber	cp14.org	8
15	Contact	cp15.org	8
16	Contact	cp16.org	8

A.1.2 \INT files

INT is an abbreviation for 'INTERPOLATED DATA'. The \INT directory includes normalized and interpolated spectral reflectance and transmittance data.

Normalization and interpolation processing were applied to original data in \ORG directory. Normalization was executed so that data magnitude measured by devices '1' to '16' should be approximated to that by the standard device '0', using calibration data (CP00 ~ CP16) in the \ORG\CALIB directory. Interpolation was executed so that all data should be sampled in the wavelength range from 400 nm to 700 nm at 10 nm intervals.

The amount of data stored in the \INT directory is exactly the same as that stored in the \ORG directory, including directory names, except for Krinov data. The only difference is that the extension of each file is '.int' instead of '.org'. None of the subdirectories in \INT have an explanation document file (READMExx). The \INT directory contains an explanation document file (README10) that explains the normalisation and interpolation algorithms applied here.

There were eight samples in Krinov data to which satisfactory interpolation could not be applied. They are not included in the .int files. Table A.19 shows SAMPLE_IDs of the removed data.

Table A.19 — Removed data from the files in \INT\KRINOV directory

Files name	SAMPLE_IDs not included
krinov1.int	#20, #27
krinov2.int	—
krinov3.int	—
krinov4.int	—
krinov5.int	—
krinov6.int	—
krinov7.int	#336, #342, #350, #351, #352, #353
krinov8.int	—

A.2 Data format

The data format recommended in Annex C of ISO 12641:1997 *Graphic technology — Prepress digital data exchange — Colour targets for input scanner calibration*, and Annex B of ISO 12642:1996 *Graphic technology — Prepress digital data exchange — Input data for characterization of 4-colour process printing targets* is adopted for data description. However, variation in keyword definition and data ordering is allowed, even if this format is adopted. Though necessary keyword addition is allowed, the following simple format is used in this database:

- Required keywords shall be used.
- Spectral data of one colour shall exist between BEGIN_DATA and END_DATA, and each line shall include only wavelength (in ascending order) and a reflectance or transmittance value.
- Though one file can contain a lot of spectral data, all necessary information describing spectral data shall be described in each data header, considering users who select arbitrary data sets from the file.
- Considering that multiple spectral data are allowed to be stored in a data file, keyword SAMPLE_ID and SAMPLE_LOC shall be necessarily used to discriminate between similar spectral data.

For example, for measuring many colour patches in the order (1,1), (2,1), (3,1), (4,1), ... (Figure A.2), SAMPLE_IDs are assigned as 1, 2, 3, 4, ... , and SAMPLE_LOCs are assigned as 0101, 0201, 0301, 0401, …. SAMPLE_ID normally (with some exceptions) shows the data order in a data file. SAMPLE_LOC basically shows the allocation of colour patches.

Spectral data described by the standard data format are shown in the following examples.

Example 1: Spectral percent reflectance factor data for graphic prints

Colour patches defined in ISO 12642:1996 were printed on dull-coated paper, using ink-01. This example shows a file where the colour of each patch was measured and stored. A keyword 'SAMPLE_LOC' was added. In this case, spectral reflectances were measured in the wavelength region from 400 nm to 700 nm at 10 nm intervals.

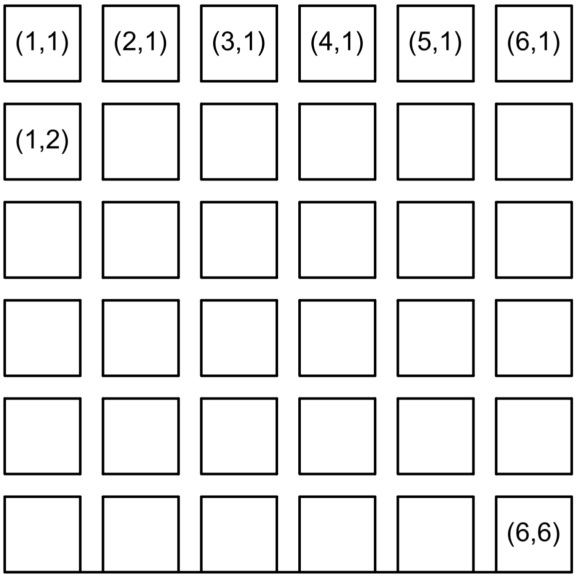

Figure A.2 — Relationship between SAMPLE_LOC and colour patches location

```
SPECTRUM            # This is a standard identifier which is newly defined instead of ISO 12641 etc.
ORIGINATOR "TOYO TECHNO RESEARCH CO., LTD."     # File creator
DESCRIPTOR "reflectance of 4-color offset printing"     # File content
CREATED         "September 9,1997"          # File creation date
INSTRUMENTATION     "02:0/45:Black backing material"         # Measurement device and condition
MEASUREMENT_SOURCE    "Tungsten lamp"      # Illumination used for measurement
PRINT_CONDITIONS     "ink01:dull-coated paper"
NUMBER_OF_FIELDS   2
KEYWORD    "SAMPLE_LOC"      # A keyword which indicates positions of colour patches
BEGIN_DATA_FORMAT
SPECTRAL_NM     SPECTRAL_PCT
END_DATA_FORMAT
#
SAMPLE_ID   "1"        # Colour patch ID number
SAMPLE_LOC       "0A01"     # Colour patch location on paper
NUMBER_OF_SETS      31
BEGIN_DATA
400  2.393000E+001
410  3.179000E+001
...
...
700  3.410000E+000
END_DATA
#
```

```
SPECTRUM
ORIGINATOR "TOYO TECHNO RESEARCH CO., LTD."
DESCRIPTOR "reflectance of 4-color offset printing"
CREATED     "September 9,1997"
INSTRUMENTATION     "02:0/45:Black backing material"
MEASUREMENT_SOURCE     "Tungsten lamp"
PRINT_CONDITIONS     "ink01:dull-coated paper"
NUMBER_OF_FIELDS   2
KEYWORD     "SAMPLE_LOC" # Patch location in printing form
BEGIN_DATA_FORMAT
SPECTRAL_NM     SPECTRAL_PCT
END_DATA_FORMAT
#
SAMPLE_ID   "2"
SAMPLE_LOC       "0A02"
NUMBER_OF_SETS       31
BEGIN_DATA
400  1.375000E+001
410  1.421000E+001
...
...
700  8.131000E+001
END_DATA
#
...
...
SPECTRUM
...
...
END_DATA
#
(End of file)
```

Example 2: Spectral percent transmittance factor data for transparent input target

This second example shows a file where the colour of each patch in a transparent input target defined in ISO 12641:1997 was measured and stored. A keyword ‘SAMPLE_LOC’ was added in this case also. Spectral transmittances were measured in the wavelength region from 380 nm to 780 nm at 5 nm intervals.

```
SPECTRUM          # This is a standard identifier which is newly defined instead of ISO 12641 etc.
ORIGINATOR "FUJI PHOTO FILM LTD."      # File creator
DESCRIPTOR "IS12641,Transmittance"    # File content
MATERIAL     "Transparency"         # Input target material
MANUFACTURER "M4"                   # Input target manufacturer
CREATED             "February 5,1998"           # File creation date
PROD_DATE  "January ,1998"         # Date when the target was produced
INSTRUMENTATION     "10:0/d"          # Measurement device and condition
KEYWORD     "SAMPLE_LOC"             # A keyword which indicates positions of colour
NUMBER_OF_FIELDS   2
BEGIN_DATA_FORMAT
SPECTRAL_NM     SPECTRAL_PCT
END_DATA_FORMAT
#
SAMPLE_ID   "1"          # Colour patch ID number
SAMPLE_LOC       "01A"          # Colour patch location on the target
NUMBER_OF_SETS       81
BEGIN_DATA
380  5.000000E-002
385  6.000000E-002
390  1.400000E-001
...
...
775  4.397000E+001
780  4.747000E+001
END_DATA
#
```

```
SPECTRUM
ORIGINATOR "FUJI PHOTO FILM LTD."
DESCRIPTOR "ISO 12641,Transmittance"
MATERIAL     "Transparency"
MANUFACTURER "M4"
CREATED       "February 5,1998"
#
PROD_DATE  "January ,1998"
INSTRUMENTATION     "10:0/d"
KEYWORD     "SAMPLE_LOC"
NUMBER_OF_FIELDS   2
BEGIN_DATA_FORMAT
SPECTRAL_NM      SPECTRAL_PCT
END_DATA_FORMAT
#
SAMPLE_ID    "2"
SAMPLE_LOC        "01B"
NUMBER_OF_SETS       81
BEGIN_DATA
380  3.000000E-002
385  7.000000E-002
390  1.600000E-001
...
...
780  5.057000E+001
END_DATA
#
...
...
SPECTRUM
...
...
...
END_DATA
(End of file)
```

A.3 Data manipulation tools

A.3.1 General

Two programs are provided to assist the user in using the source data provided as part of this annex. They are a data conversion program and a data selection program. Both programs can be found in the directory "SourceData/Programs".

A.3.2 File conversion program (std2dsp.exe)

A.3.2.1 Computing environment

The computing environment that this program was prepared for was Windows 95 using VC++ (Ver.4.2).

A.3.2.2 Program function

This program converts data files saved in the standard data format, defined for this database, to tab delimited text files which can be input to typical spread sheet programs.

A.3.2.3 Command syntax

The command must be executed at a DOS prompt. Its syntax is:

std2dsp inputfile outputfile

where:

inputfile is the name (including extension) of a data file stored in this database outputfile is name to be assigned to the output file created.

If the program and input file are not in the current directory, path names must be included. Unless otherwise specified, the output file will be stored in the current directory.

A.3.3 Data selection program (stdsel.exe)

A.3.3.1 Computing environment

The computing environment that this program was prepared for was Windows 95 using VC++ (Ver.4.2).

A.3.3.2 Program function

This program examines the headers in data files (saved in the standard data format defined for this database) containing multiple data sets, and selects spectral data sets which satisfy specified conditions. The operations which may be performed are to either get or delete the selected data sets.

A.3.3.3 Command syntax

The command must be executed at a DOS prompt. Its syntax is:

stdsel conditionfile inputfile outputfile

where:

conditionfile is the name (including extension) of a text file containing the selection criteria

inputfile is the name (including extension) of a data file stored in this database

outputfile is name to be assigned to the output file created.

If the program and input file are not in the current directory, path names must be included. Unless otherwise specified, the output file will be stored in the current directory.

A.3.3.4 Condition file structure

A.3.3.4.1 Basis pattern 1, Single assignment

The condition file is a series of text lines that consist of the "operation", the "keyword", and the "selection criteria". Operators are GET and DEL.

Examples:

GET MANUFACTURER Company
— Data sets with 'Company' under the keyword 'MANUFACTURER' in data headers are selected.

DEL MANUFACTURER Company
— Data sets with 'Company' under the keyword 'MANUFACTURER' in data headers are deleted.

GET MANUFACTURER Company
GET MANUFACTURER ABC
— Data sets with 'Company' and 'ABC' under the keyword 'MANUFACTURER' in data headers are selected.

GET MANUFACTURER Company
DEL MANUFACTURER ABC
— Data sets with 'Company' under the keyword 'MANUFACTURER' in data headers are selected and those with 'ABC' under the same keyword are deleted.

A.3.3.4.2 Basic pattern 2, region assignment

The condition file is a series of text lines that consist of the "operation", a FROM "keyword", and "selection criteria" pair and a TO "keyword", and "selection criteria" pair. Operators are GETFROM or DELFROM.

Examples

GETFROM AAA CompanyA TO AAA CompanyB
— Data sets, within the input file selected, between a data set with 'CompanyA' under the keyword 'AAA' to a data set with 'CompanyB' under the same keyword are selected.

DELFROM AAA CompanyA TO AAA CompanyB
— Data sets, within the input file selected, between a data set with 'CompanyA' under the keyword 'AAA' to a data set with 'CompanyB' under the same keyword are deleted.

A.3.3.4.3 Basic pattern 3, order assignment

The condition file is a series of text lines that consist of the "operation", a FROM "number" and a TO "number". Operators are GETFROMN or DELFROMN.

Examples

GETFROMN 3 TO 16
— Data sets, within the input file selected, from the 3rd data set to the 16th data set are selected.

DELFROMN 3 TO 16
— Data sets, within the input file selected, from the 3rd data set to the 16th data set are deleted.

A.4 Acknowledgments

A.4.1 Organizations who contributed to the database construction

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A.4.2 Sponsors of the project

The project was sponsored by the New Energy and Industrial Technology Development Organization (NEDO) and the Japanese Standards Association (JSA).

Annex B
(normative)

Typical set selection method for artificial colour groups

Data files used for typical set sample selection for artificial colour groups are summarized in Table B.1. For non-graphic-print categories, all relevant files were deemed to contain candidates for colour selection. For the graphic print category, however, offset print/gloss-coated paper files were deemed to contain a wide enough colour gamut for their colours to represent the graphic prints category as a whole, and only these files were used for the selection.

Table B.1 — Data files used for data selection

Group	Data files
Photo (transparency)	ph01_t.int, ph02_t.int, ph03_t.int, ph04_t.int ph02_t.org ph03_t.org ph04_t.org
Photo (reflection print)	ph01_r.int, ph02_r.int, ph03_r.int, ph04_r.int
Offset prints	of01_g.int, of02_g.int, of03_g.int, of04_g.int, of05_g.int, of06_g.int, of07_g.int, of08_g.int, of09_g.int, of10_g.int
Dye sublimation printer	pr_ds_1.int, pr_ds_2.int, pr_ds_3.int, pr_ds_4.int, pr_ds_5.int
Electrostatic printer	pr_es_1.int, pr_es_2.int, pr_es_3.int, pr_es_4.int
Ink-jet printer	pr_ij_1.int, pr_ij_2.int, pr_ij_3.int, pr_ij_4.int, pr_ij_5.int, pr_ij_6.int, pr_ij_7.int
Textiles (synthetic dyes)	cotton.int, poly.int, wool.int, silk.int

In a typical set sample selection, for each category, a single typical colour product is first determined as follows:

Assume that there are K products in the category, and that files contain spectral reflectance data for M colour patches from each product.

Tristimulus values (X, Y, Z) under D65 illuminant are first estimated for all colour patches. A set of tristimulus values (X_i, Y_i, Z_i,) for the i-th sample may be expressed as:

$$X_i = 100 \times \frac{\sum_\lambda \beta_\lambda H_\lambda \bar{x}_\lambda}{\sum_\lambda H_\lambda \bar{y}_\lambda}$$

$$Y_i = 100 \times \frac{\sum_\lambda \beta_\lambda H_\lambda \bar{y}_\lambda}{\sum_\lambda H_\lambda \bar{y}_\lambda} \qquad \text{(B.1)}$$

$$Z_i = 100 \times \frac{\sum_\lambda \beta_\lambda H_\lambda \bar{z}_\lambda}{\sum_\lambda H_\lambda \bar{y}_\lambda}$$

where $\bar{x}_\lambda, \bar{y}_\lambda, \bar{z}_\lambda$ are colour matching functions, β_λ is the spectral reflectance of the sample, and H_λ is the spectral intensity of D65 illuminant.

These obtained tristimulus values are then used to estimate individual spectral reflectances for their corresponding colour patches. This estimated spectral reflectance $\hat{\beta}_{ik}$ may be calculated as:

$$\hat{\beta}_{ik} = \begin{bmatrix} \hat{\beta}_{ik1} \\ \hat{\beta}_{ik2} \\ \\ \hat{\beta}_{ikM} \end{bmatrix} = S_k^- \cdot \begin{bmatrix} X_i \\ Y_i \\ Z_i \end{bmatrix} \tag{B.2}$$

The matrix S_k^- is obtained by equation (B.3), using the least squares method.

$$S_k^- = \begin{bmatrix} c_{11} c_{12} c_{13} \\ c_{21} c_{22} c_{23} \\ \\ c_{M1} c_{M2} c_{M3} \end{bmatrix} = K_{\beta R} \, K_{RR}^{-1} \tag{B.3}$$

where $K_{RR} = \dfrac{1}{N} \begin{bmatrix} X_1 Y_1 Z_1 \\ X_2 Y_2 Z_2 \\ \\ X_N Y_N Z_N \end{bmatrix}^t \bullet \begin{bmatrix} X_1 Y_1 Z_1 \\ X_2 Y_2 Z_2 \\ \\ X_N Y_N Z_N \end{bmatrix}$ and $K_{\beta R} = \dfrac{1}{N} \begin{bmatrix} \beta_{11} \beta_{12} & \beta_{1M} \\ \beta_{21} \beta_{22} & \beta_{2M} \\ \\ \beta_{N1} \beta_{N2} & \beta_{NM} \end{bmatrix}^t \bullet \begin{bmatrix} X_1 Y_1 Z_1 \\ X_2 Y_2 Z_2 \\ \\ X_N Y_N Z_N \end{bmatrix}$

This computation is executed for all the colour samples of each product.

Using the k-th matrix, each spectral reflectance may be estimated as $\hat{\beta}_{ik} = \begin{bmatrix} \hat{\beta}_{ik1} \\ \hat{\beta}_{ik2} \\ \\ \hat{\beta}_{ikM} \end{bmatrix}$, and the sum of squared estimation error E_k may be computed as:

$$E_k = \sum_{i=1}^{N} E_{ik} = \sum_{i=1}^{N} \left\{ \sum_{m=1}^{M} \left(\hat{\beta}_{ikm} - \beta_{ikm} \right)^2 \right\} \tag{B.4}$$

If E_k is the minimum among the sums for K products, the k-th product is deemed to be typical.

Annex C
(normative)

Typical set selection method for non-skin colour, natural colour groups

Data files used for typical set sample selection in non-skin colours, natural colour groups are summarized in Table C.1. Within these groups, a number of colours have been deemed inappropriate for selection and removed as candidates, as shown in parentheses in Table C.1. They include metallic colours, snow colours exhibiting more than 100 % reflectance in Krinov samples, and colours generated with fluorescent colorants.

Table C.1 — Data files used for data selection, with removed SAMPLE_IDs noted

Group	Data files (removed SAMPLE_IDs)
Flowers/Leaves	flower, leaf, krinov1 ~ krinov4 (except #20, #27)
Paint (not for art)	paint
Oil paints	pa_o (except #39), pa_s
Water colours	pa_a (except#58, #59, #60), pa_g
Textiles (plant)	plant_c, plant_y
Non-grass/leaf Krinov	krinov5 ~ krinov8 (except #336, #339, #340, #341, #342, #350, #351, #352, #353)

Principal component analysis in 31-dimensional space is applied to data samples in each group. The largest three components are used to determine data distribution in a three-dimensional subspace. A cubic lattice is defined in the space. The data sample that is nearest to each cube centre is selected as a typical set sample. A lattice constant is determined so that a given number of cubes will have at least one sample. Figure C.1 illustrates a simple two-dimensional example. The filled-in circles in Figure C.1 represent data points selected as typical set samples.

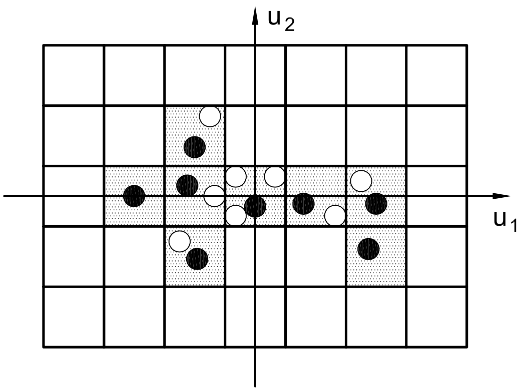

Figure C.1 — Typical set selection for natural colours

The selection procedure is as follows:

For data samples i = 1~N, a mean vector and a covariance matrix are computed for spectral reflectance data $\beta_i = \begin{pmatrix} \beta_{i1} \\ \beta_{i2} \\ \vdots \\ \beta_{iM} \end{pmatrix}$ as equations (C.1) and (C.2), respectively.

$$\bar{\beta} = \begin{pmatrix} \bar{\beta}_1 \\ \bar{\beta}_2 \\ \vdots \\ \bar{\beta}_M \end{pmatrix} = \begin{pmatrix} \sum_{i=1}^{N} \beta_{i1} \\ \sum_{i=1}^{N} \beta_{i2} \\ \vdots \\ \sum_{i=1}^{N} \beta_{iM} \end{pmatrix} \quad \text{(C.1)}$$

$$V_{\beta\beta} = \begin{pmatrix} \frac{\sum_{i=1}^{N}\left(\beta_{i1}-\bar{\beta}_1\right)^2}{N} & \frac{\sum_{i=1}^{N}\left(\beta_{i1}-\bar{\beta}_1\right)\left(\beta_{i2}-\bar{\beta}_2\right)}{N} & \cdots & \frac{\sum_{i=1}^{N}\left(\beta_{i1}-\bar{\beta}_1\right)\left(\beta_{iM}-\bar{\beta}_M\right)}{N} \\ \frac{\sum_{i=1}^{N}\left(\beta_{i2}-\bar{\beta}_2\right)\left(\beta_{i1}-\bar{\beta}_1\right)}{N} & \frac{\sum_{i=1}^{N}\left(\beta_{i2}-\bar{\beta}_2\right)^2}{N} & \cdots & \frac{\sum_{i=1}^{N}\left(\beta_{i2}-\bar{\beta}_2\right)\left(\beta_{iM}-\bar{\beta}_M\right)}{N} \\ \vdots & \vdots & \ddots & \vdots \\ \frac{\sum_{i=1}^{N}\left(\beta_{iM}-\bar{\beta}_M\right)\left(\beta_{i1}-\bar{\beta}_1\right)}{N} & \frac{\sum_{i=1}^{N}\left(\beta_{iM}-\bar{\beta}_M\right)\left(\beta_{i2}-\bar{\beta}_2\right)}{N} & \cdots & \frac{\sum_{i=1}^{N}\left(\beta_{iM}-\bar{\beta}_M\right)^2}{N} \end{pmatrix} \quad \text{(C.2)}$$

Diagonalizing the covariance matrix $V_{\beta\beta}$, principal components (u_1, u_2, …) are obtained with Eigenvalues $\sigma_1^2,\ \sigma_2^2,\ \ldots$.

$$O^{-1} V_{\beta\beta} O = \begin{pmatrix} \sigma_1^2 & 0 & \cdots & 0 \\ 0 & \sigma_2^2 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & \sigma_M^2 \end{pmatrix}. \quad \text{and} \quad O = \left(u_1 \ \ u_2 \ \ \cdots \ \ u_M\right) \quad \text{(C.3)}$$

Assuming that Eigenvalues are ordered in decreasing magnitude, u_1, u_2 and u_3 may be used to span the subspace from which the typical samples are selected. Each colour sample coordinate is converted to a new coordinate γ_i as

$$\begin{pmatrix} \left(\beta_i \cdot u_1\right) \\ \left(\beta_i \cdot u_2\right) \\ \left(\beta_i \cdot u_3\right) \end{pmatrix}$$

The operation described above for determining a data distribution in 3-dimensional space is then applied to these vectors.

Annex D
(normative)

Typical set selection method for skin groups

Data files used for typical set sample selection in skin groups are summarized in Table D.1.

Table D.1 — Data files used for data selection

Group	Data files
North-Asian (bare skin)	kcfbchc1, kcfbfhc1, kcfbnkc1, tafbchc1, tafbfhc1, tafbnkc1, tofbamc2, tofbchc2, tofbfhc2, tofbnkc2, tofbzyc2
North-Asian (foundation-applied skin)	kcffchc1, taffchc1, toffchc2, ttoffhc2, toffzyc2
South-Asian (bare skin)	bafbchc1, bafbfhc1, bafbnkc1, kifbchc1, kifbfhc1, kifbnkc1, kmfbchc1, kmfbfhc1, kmfbnkc1
South-Asian (foundation-applied skin)	kiffchc1, kmffchc1, baffchc1
Caucasian (bare skin)	ocfbxxc3, ocmbxxc3, ccfbfhc4, ccfbhac4, ccfbnkc4, ccfbzyc4, ccmbfhc4, ccmbhac4, ccmbnkc4, ccmbzyc4
Negroid (bare skin)	onmbxxc4, cnfbfhc4, cnfbhac4, cnfbnkc4, cnfbzyc4, cnmbfhc4, cnmbhac4, cnmbnkc4, cnmbzyc4

Five colour samples are selected from all data samples in each group: one mean, and four extreme colours in CIELAB space under D65 illuminant. The selection procedure is as follows:

a) L*, a* and b* values under D65 illuminant for all data samples are calculated.

b) (L*, a*, b*) values are used to calculate a mean and a covariance matrix. Let the mean be the first target colour C_0, principal components be λ_1, λ_2 and λ_3, and Eigenvalues be σ_1^2, σ_2^2 and σ_3^2, respectively. The direction of the first principal component is set so that L* component is positive, the direction of the second principal component is set so that b* component is positive, and the direction of the third principal component is set so that a* component is positive.

c) Other four target colours C_1, C_2, C_3 and C_4 are determined on the basis of Eqs.(D.1)~(D.4) below:

$$C_1 = 2\sigma_1 \cdot \lambda_1 + C_0 \tag{D.1}$$

$$C_2 = -2\sigma_1 \cdot \lambda_1 + C_0 \tag{D.2}$$

$$C_3 = -(2\sigma_2 \cdot \lambda_2 - 2\sigma_3 \cdot \lambda_3) + \sigma_1 \cdot \lambda_1 + C_0 \tag{D.3}$$

$$C_4 = (2\sigma_2 \cdot \lambda_2 - 2\sigma_3 \cdot \lambda_3) - \sigma_1 \cdot \lambda_1 + C_0 \tag{D.4}$$

d) Colour samples whose colour differences ΔE_{ab} from target colours are minimum are selected as typical set samples. Typical set samples are ordered from the sample with the highest reflectance. The corresponding order for the target colours is C_1, C_3, C_0, C_4, and C_2.

Annex E
(normative)

Difference set selection method

The procedure for selecting difference set samples is as follows:

a) For each typical set sample β_{typical}, a colour difference ΔE_{ab} (under D65 illuminant) with respect to each colour sample β is calculated, and samples that satisfy equation (E.1) below are extracted.

$$\Delta E_{ab}\left(\beta_{\text{typical}}, \beta\right) \leqslant 5 \tag{E.1}$$

b) Among these extracted samples, the sample that corresponds to the maximum Euclidean distance $\left\|\beta_{\text{typical}} - \beta\right\|$ in 31-dimensional space from the typical sample is selected as a difference set sample.

c) If there is no sample that satisfies equation (E.1), the sample that corresponds to the minimum colour difference ΔE_{ab} is selected as a difference set sample.

Annex F
(informative)

Correspondence between typical/difference samples and original collected data samples

The selection methods described in Annexes B through E were used to select typical set samples and difference set samples from the collected samples described in Annex A. In Annex F, the correspondence between the selected data and samples in the original database is summarized. Tables F.1 through F.19 show the correspondence for typical set samples, and tables F.20 through F.27 show those for difference set samples. In addition to the correspondence information, Tables F.1 through F.19 contain L*, a* and b* values for every typical set sample. Using Tables F.1 through F.7, it is also possible to calculate colour differences between basic colours and typical set colours. Tables F.20 through F.27 contain colour differences ΔE_{ab} from corresponding typical set colours, as well as L*, a*, b* values. The L*, a* and b* values in these tables are calculated with D65 CIE illuminant.

Table F.1 — Correspondence of typical set samples in ‘photo_t’ to original sample IDs

	file	Sample ID	L*	a*	b*
1	ph02_t.int	281	20,6	−0,5	2,1
2	ph02_t.int	273	50,7	−0,5	1,9
3	ph02_t.int	157	80,4	0,2	−0,0
4	ph02_t.int	132	51,6	31,8	−7,0
5	ph02_t.int	199	48,9	32,6	21,2
6	ph02_t.int	251	51,7	14,4	25,3
7	ph02_t.int	135	68,6	7,6	42,1
8	ph02_t.int	53	58,9	−13,1	21,0
9	ph02_t.int	54	42,5	−17,7	8,7
10	ph02_t.int	67	42,6	−28,4	−4,4
11	ph02_t.int	156	50,2	−29,5	−28,7
12	ph02_t.int	68	36,8	−13,7	−18,2
13	ph02_t.int	69	41,6	5,5	−21,0
14	ph02_t.int	70	31,3	17,4	−21,9
15	ph02_t.int	119	51,0	22,4	−11,9

Table F.2 — Correspondence of typical set samples in ‘photo_r’ to original sample IDs

	file	Sample ID	L*	a*	b*
1	ph03_r.int	282	21,3	−0,4	1,8
2	ph03_r.int	186	49,0	−1,5	3,6
3	ph03_r.int	268	78,0	−1,2	3,0
4	ph03_r.int	72	37,2	28,9	−2,6
5	ph03_r.int	61	37,6	26,2	9,9
6	ph03_r.int	243	48,9	27,2	31,4
7	ph03_r.int	247	64,9	1,7	40,5
8	ph03_r.int	125	67,8	−18,2	26,5
9	ph03_r.int	66	34,1	−27,0	11,2
10	ph03_r.int	67	37,6	−23,4	−1,0
11	ph03_r.int	68	38,0	−13,6	−12,9
12	ph03_r.int	80	37,5	−18,8	−21,7
13	ph03_r.int	81	41,7	4,4	−23,1
14	ph03_r.int	82	36,5	17,2	−24,1
15	ph03_r.int	71	41,5	21,6	−12,0

Table F.3 — Correspondence of typical set samples in ‘offset’ to original sample IDs

	file	Sample ID	L*	a*	b*
1	of04_g.int	833	23,2	−0,2	3,2
2	of04_g.int	68	49,5	0,1	−1,3
3	of04_g.int	399	80,3	−0,0	−1,4
4	of04_g.int	643	44,4	30,2	2,7
5	of04_g.int	668	44,3	29,0	11,5
6	of04_g.int	692	52,6	10,0	33,1
7	of04_g.int	691	59,5	−0,0	36,7
8	of04_g.int	562	58,7	−17,1	27,1
9	of04_g.int	705	44,9	−28,9	12,9
10	of04_g.int	805	37,1	−18,6	−4,3
11	of04_g.int	533	47,6	−17,6	−8,4
12	of04_g.int	656	43,5	−11,2	−15,9
13	of04_g.int	632	40,7	−0,7	−24,6
14	of04_g.int	499	33,8	12,3	−21,1
15	of04_g.int	457	41,8	24,1	−15,6

Table F.4 — Correspondence of typical set samples in 'print_ds' to original sample IDs

	file	Sample ID	L*	a*	b*
1	pr_ds_2.int	882	19,4	0,8	1,5
2	pr_ds_2.int	528	51,7	−0,2	−3,2
3	pr_ds_2.int	74	77,9	−3,0	−1,8
4	pr_ds_2.int	673	37,3	32,5	0,9
5	pr_ds_2.int	349	37,6	24,0	18,7
6	pr_ds_2.int	552	58,5	13,3	46,6
7	pr_ds_2.int	558	55,7	5,6	41,9
8	pr_ds_2.int	665	59,1	−11,7	17,8
9	pr_ds_2.int	825	40,5	−20,3	19,9
10	pr_ds_2.int	800	38,6	−15,4	2,9
11	pr_ds_2.int	154	46,0	−14,2	−13,7
12	pr_ds_2.int	534	43,9	−11,5	−11,6
13	pr_ds_2.int	632	35,6	−6,2	−28,1
14	pr_ds_2.int	535	27,3	11,5	−28,9
15	pr_ds_2.int	653	35,4	28,2	−13,6

Table F.5 — Correspondence of typical set samples in 'print_es' to original sample IDs

	file	Sample ID	L*	a*	b*
1	pr_es_3.int	66	19,5	0,9	2,0
2	pr_es_3.int	615	48,7	0,5	1,3
3	pr_es_3.int	76	80,0	0,2	−0,3
4	pr_es_3.int	94	40,6	29,8	2,0
5	pr_es_3.int	96	39,0	26,3	19,3
6	pr_es_3.int	546	47,9	16,9	34,3
7	pr_es_3.int	545	56,8	0,6	43,1
8	pr_es_3.int	513	64,3	−13,7	22,8
9	pr_es_3.int	563	42,0	−24,2	22,2
10	pr_es_3.int	527	43,1	−19,1	0,6
11	pr_es_3.int	490	49,7	−15,8	−10,4
12	pr_es_3.int	455	45,8	−8,0	−17,1
13	pr_es_3.int	456	37,7	3,3	−19,1
14	pr_es_3.int	421	28,7	23,0	−23,6
15	pr_es_3.int	415	35,2	32,8	−16,0

Table F.6 — Correspondence of typical set samples in 'print_ij' to original sample IDs

	file	Sample ID	L*	a*	b*
1	pr_ij_4.int	37	15,7	8,7	0,3
2	pr_ij_4.int	87	40,4	−2,2	−5,8
3	pr_ij_4.int	173	77,5	−0,2	−7,5
4	pr_ij_4.int	117	39,4	32,7	−0,4
5	pr_ij_4.int	116	38,7	29,3	14,5
6	pr_ij_4.int	121	46,2	13,0	37,7
7	pr_ij_4.int	164	66,3	7,4	41,8
8	pr_ij_4.int	128	58,5	−10,1	32,9
9	pr_ij_4.int	92	49,5	−31,0	20,0
10	pr_ij_4.int	93	50,5	−27,3	2,7
11	pr_ij_4.int	51	33,7	−16,6	−13,3
12	pr_ij_4.int	94	51,6	−16,7	−18,3
13	pr_ij_4.int	88	39,8	6,6	−24,8
14	pr_ij_4.int	82	31,7	22,9	−27,5
15	pr_ij_4.int	124	48,2	22,4	−13,1

Table F.7 — Correspondence of typical set samples in 'textiles_s' to original sample IDs

	file	Sample ID	L*	a*	b*
1	cotton.int	705	21,8	−0,1	−1,8
2	cotton.int	702	52,2	0,1	−1,3
3	cotton.int	698	79,7	−0,4	0,6
4	cotton.int	684	47,3	36,4	0,8
5	cotton.int	53	47,0	33,6	15,5
6	cotton.int	150	51,0	18,7	40,4
7	cotton.int	214	65,0	0,3	44,0
8	cotton.int	263	58,2	−10,8	26,7
9	cotton.int	316	36,5	−32,0	15,3
10	cotton.int	395	44,1	−19,1	−2,6
11	cotton.int	444	43,3	−16,8	−11,7
12	cotton.int	481	41,0	−9,0	−15,6
13	cotton.int	529	43,1	1,5	−25,1
14	cotton.int	584	32,6	15,9	−20,7
15	cotton.int	626	43,4	27,1	−13,2

Table F.8 — Correspondence of typical set samples in 'flowers_leaves' to original sample IDs

	file	Sample ID	L*	a*	b*
1	krinov1.int	47	15,0	−1,0	3,1
2	flower.int	130	23,2	48,3	−19,8
3	flower.int	115	30,5	35,2	−50,9
4	krinov2.int	105	48,9	−6,5	37,4
5	flower.int	121	43,9	20,2	−33,2
6	leaf.int	59	61,1	−18,4	40,5
7	flower.int	21	54,5	53,9	48,3
8	flower.int	125	39,7	56,9	−16,8
9	flower.int	13	39,5	32,7	−33,2
10	flower.int	109	74,2	2,9	75,0
11	flower.int	48	59,8	20,7	8,6
12	flower.int	136	56,0	5,2	−33,1
13	flower.int	34	81,4	−11,8	72,1
14	krinov4.int	206	67,8	−6,6	33,0
15	flower.int	23	58,5	54,2	22,5
16	flower.int	11	77,8	18,2	76,5
17	flower.int	30	75,9	14,1	26,6
18	flower.int	16	74,3	21,2	−8,1
19	flower.int	46	82,9	4,3	61,3
20	flower.int	145	81,1	−4,5	25,7
21	flower.int	105	84,5	−1,3	5,1
22	flower.int	132	80,7	21,9	5,0
23	flower.int	65	89,5	−2,6	71,8
24	flower.int	27	93,5	−5,5	21,9
25	flower.int	123	89,8	6,1	1,1

Table F.9 — Correspondence of typical set samples in 'paint' to original sample IDs

	file	Sample ID	L*	a*	b*
1	paint.int	63	51,7	41,5	66,8
2	paint.int	78	39,3	8,6	12,9
3	paint.int	324	37,5	54,4	−19,1
4	paint.int	268	49,6	−32,7	−23,5
5	paint.int	180	81,0	−8,7	78,9
6	paint.int	88	69,4	24,7	90,2
7	paint.int	333	49,2	62,3	12,7
8	paint.int	205	72,1	−34,4	73,4
9	paint.int	115	70,1	2,4	10,4
10	paint.int	274	71,6	−20,7	−18,0
11	paint.int	169	84,8	−3,2	90,6
12	paint.int	22	81,3	25,4	13,4
13	paint.int	161	86,9	−1,1	9,4
14	paint.int	272	81,2	−14,1	−10,9
15	paint.int	1	95,3	−0,4	1,6

Table F.10 — Correspondence of typical set samples in 'oil' to original sample IDs

	file	Sample ID	L*	a*	b*
1	pa_o.int	51	4,3	18,4	−26,5
2	pa_o.int	81	55,1	−64,6	14,8
3	pa_o.int	65	31,2	62,1	41,3
4	pa_s.int	4	69,9	−15,4	79,3
5	pa_o.int	48	55,4	1,4	20,1
6	pa_s.int	1	35,2	48,8	−41,8
7	pa_o.int	73	61,0	−37,7	−15,7
8	pa_o.int	34	55,4	−1,6	−43,1
9	pa_o.int	82	54,2	64,2	74,6
10	pa_o.int	52	37,4	69,1	57,3
11	pa_o.int	62	73,6	15,0	45,5
12	pa_o.int	11	78,2	−2,5	3,6
13	pa_o.int	4	90,7	−14,5	88,5
14	pa_o.int	74	81,2	19,2	54,6
15	pa_o.int	89	94,7	−2,9	13,4

Table F.11 — Correspondence of typical set samples in 'water' to original sample IDs

	file	Sample ID	L*	a*	b*
1	pa_g.int	41	4,0	23,3	–32,0
2	pa_a.int	31	40,0	–16,4	–37,7
3	pa_g.int	10	38,3	61,4	51,2
4	pa_a.int	23	77,7	–30,7	74,7
5	pa_g.int	50	56,8	15,8	49,0
6	pa_a.int	37	26,1	55,1	–43,4
7	pa_a.int	24	70,4	–62,4	58,8
8	pa_a.int	50	67,0	–42,0	–9,1
9	pa_a.int	35	57,5	11,3	–46,3
10	pa_g.int	19	62,7	55,9	90,4
11	pa_a.int	46	71,4	16,8	32,1
12	pa_g.int	46	84,5	0,3	17,6
13	pa_a.int	5	93,1	–16,2	89,9
14	pa_a.int	14	80,6	29,2	35,4
15	pa_g.int	2	96,2	–0,6	1,5

Table F.12 — Correspondence of typical set samples in 'textiles_p' to original sample IDs

	file	Sample ID	L*	a*	b*
1	plant_c.int	95	19,9	0,4	4,3
2	plant_c.int	65	33,6	37,5	–5,2
3	plant_c.int	177	40,6	13,3	14,1
4	plant_c.int	191	59,8	30,4	57,4
5	plant_c.int	62	46,8	52,3	–1,0
6	plant_c.int	123	62,6	10,3	22,9
7	plant_c.int	76	55,5	31,9	–10,5
8	plant_c.int	115	64,1	–5,0	–6,7
9	plant_c.int	185	73,7	20,1	61,5
10	plant_c.int	187	84,1	–4,3	56,4
11	plant_c.int	49	75,3	10,2	20,5
12	plant_c.int	111	79,0	–3,4	2,7
13	plant_c.int	181	87,7	–9,1	48,5
14	plant_c.int	229	87,5	–4,8	32,7
15	plant_c.int	25	87,1	0,7	11,7

Table F.13 — Correspondence of typical set samples in 'n_krinov' to original sample IDs

	file	Sample ID	L*	a*	b*
1	krinov5.int	304	15,7	0,5	2,0
2	krinov5.int	296	39,8	4,2	6,2
3	krinov8.int	356	53,6	16,8	23,3
4	krinov5.int	231	54,4	1,7	10,4
5	krinov5.int	251	65,0	3,4	18,6
6	krinov6.int	330	63,0	2,4	10,1
7	krinov7.int	338	74,6	1,9	0,3
8	krinov5.int	236	77,5	2,6	22,4
9	krinov7.int	347	80,8	0,2	4,4
10	krinov7.int	343	80,6	0,2	−7,0
11	krinov5.int	234	85,2	0,0	12,7
12	krinov7.int	348	87,3	−0,9	8,9
13	krinov7.int	354	89,4	0,1	1,3
14	krinov7.int	337	90,5	−0,9	−3,3
15	krinov7.int	345	89,7	−8,4	−3,0

Table F.14 — Correspondence of typical set samples in 'n_asian_b' to original sample IDs

	file	Sample ID	L*	a*	b*
1	tofbchc2.int	112	71,5	7,4	16,6
2	tafbchc1.int	41	69,6	12,7	14,4
3	tofbfhc2.int	377	64,9	9,9	18,7
4	tofbnkc2.int	84	60,3	8,9	21,6
5	tofbfhc2.int	253	57,8	12,9	21,3

Table F.15 — Correspondence of typical set samples in 'n_asian_f' to original sample IDs

	file	Sample ID	L*	a*	b*
1	toffchc2.int	299	71,3	9,0	18,1
2	toffchc2.int	267	69,0	11,6	15,4
3	toffzyc2.int	121	64,8	10,7	18,5
4	tofffhc2.int	222	61,6	9,1	20,5
5	toffzyc2.int	3	58,4	13,1	18,9

Table F.16 — Correspondence of typical set samples in 's_asian_b' to original sample IDs

	file	Sample ID	L*	a*	b*
1	bafbnkc1.int	41	67,9	8,9	21,3
2	bafbchc1.int	24	64,4	12,9	18,4
3	kmfbfhc1.int	4	56,7	11,9	20,7
4	kifbchc1.int	27	50,7	10,9	22,6
5	kifbchc1.int	9	44,0	12,8	19,0

Table F.17 — Correspondence of typical set samples in 's_asian_f' to original sample IDs

	file	Sample ID	L*	a*	b*
1	kmffchc1.int	29	70,6	8,2	17,2
2	baffchc1.int	26	64,0	13,4	17,6
3	baffchc1.int	53	59,2	12,0	20,7
4	kiffchc1.int	7	54,4	11,5	22,4
5	kiffchc1.int	18	47,8	12,2	19,5

Table F.18 — Correspondence of typical set samples in 'caucasian_b' to original sample IDs

	file	Sample ID	L*	a*	b*
1	ocfbxxc3.int	25	71,4	9,2	15,5
2	ocmbxxc3.int	177	67,7	14,9	15,3
3	ocmbxxc3.int	206	63,8	12,9	16,0
4	ocmbxxc3.int	104	58,3	10,2	16,5
5	ccmbzyc4.int	4	56,5	16,7	15,4

Table F.19 — Correspondence of typical set samples in 'negroid_b' to original sample IDs

	file	Sample ID	L*	a*	b*
1	cnfbfhc4.int	1	52,3	12,1	22,5
2	onmbxxc3.int	12	50,7	10,7	19,2
3	onmbxxc3.int	16	41,6	11,3	16,6
4	cnfbhac4.int	5	35,3	12,1	14,2
5	cnmbhac4.int	5	31,4	9,2	9,1

Table F.20 — Correspondence of difference set samples in 'photo_t-d' to original sample IDs

	file	Sample ID	L*	a*	b*	ΔE_{ab}
1	ph02_t.int	280	24,4	0,9	2,6	4,0
2	ph03_t.int	186	46,4	−0,8	3,2	4,5
3	ph03_t.int	266	77,8	−0,7	3,0	4,1
4	ph03_t.int	144	52,9	32,3	−2,6	4,7
5	ph04_t.int	199	49,5	33,3	25,1	4,1
6	ph02_t.int	239	50,1	13,7	22,8	3,0
7	ph01_t.int	135	70,7	11,6	46,4	6,2
8	ph01_t.int	53	61,2	−11,0	21,5	3,2
9	ph04_t.int	54	46,0	−18,3	11,4	4,5
10	ph03_t.int	67	43,4	−25,3	−2,8	3,6
11	ph03_t.int	156	54,1	−32,5	−32,7	6,4
12	ph01_t.int	68	38,3	−13,0	−19,8	2,4
13	ph01_t.int	69	44,3	4,9	−21,9	2,9
14	ph04_t.int	71	28,7	20,7	−23,0	4,4
15	ph03_t.int	119	52,7	18,6	−10,2	4,4

Table F.21 — Correspondence of difference set samples in 'photo_r-d' to original sample IDs

	file	Sample ID	L*	a*	b*	ΔE_{ab}
1	ph04_r.int	281	24,3	1,2	−0,8	4,3
2	ph03_r.int	274	53,6	−1,9	3,0	4,7
3	ph03_r.int	267	82,8	−2,2	3,5	4,9
4	ph01_r.int	72	38,6	31,6	−3,1	3,1
5	ph02_r.int	61	40,1	26,5	6,6	4,2
6	ph03_r.int	232	39,2	23,8	29,2	10,5
7	ph04_r.int	64	57,9	0,3	40,5	7,1
8	ph04_r.int	137	68,2	−16,5	30,1	4,0
9	ph04_r.int	66	33,1	−30,1	9,2	3,9
10	ph02_r.int	67	40,0	−23,7	−2,0	2,7
11	ph04_r.int	56	37,7	−9,9	−10,8	4,3
12	ph02_r.int	80	38,6	−20,7	−23,6	2,9
13	ph02_r.int	81	43,0	1,6	−25,1	3,7
14	ph01_r.int	82	37,2	19,2	−27,8	4,4
15	ph01_r.int	71	43,1	24,3	−13,9	3,6

Table F.22 — Correspondence of difference set samples in 'offset-d' to original sample IDs

	file	Sample ID	L*	a*	b*	ΔE_{ab}
1	of06_g.int	25	20,6	0,1	−0,4	4,4
2	of02_g.int	528	50,7	2,0	2,3	4,3
3	of10_g.int	157	84,5	−0,5	−1,1	4,2
4	of03_g.int	481	48,6	32,2	1,6	4,7
5	of04_g.int	517	48,9	29,5	9,4	5,0
6	of06_g.int	558	54,6	6,6	30,2	4,9
7	of06_g.int	557	61,3	−4,1	35,5	4,6
8	of01_g.int	700	54,3	−19,4	26,5	5,0
9	of09_g.int	568	49,2	−27,1	13,3	4,7
10	of10_g.int	805	39,2	−17,8	−4,7	2,2
11	of10_g.int	681	44,0	−15,2	−7,0	4,5
12	of09_g.int	780	39,3	−12,0	−13,9	4,7
13	of04_g.int	462	43,8	−1,6	−25,8	3,5
14	of01_g.int	283	38,6	12,4	−22,3	5,0
15	of07_g.int	628	37,7	21,7	−16,6	4,8

Table F.23 — Correspondence of difference set samples in 'print_ds-d' to original sample IDs

	file	Sample ID	L*	a*	b*	ΔE_{ab}
1	pr_ds_4.int	74	17,9	−2,6	0,6	3,8
2	pr_ds_3.int	293	53,1	−0,4	−0,1	3,3
3	pr_ds_5.int	173	77,2	−1,9	−3,1	1,8
4	pr_ds_2.int	668	39,0	35,6	3,1	4,1
5	pr_ds_2.int	565	36,1	22,4	18,8	2,2
6	pr_ds_3.int	419	60,7	13,1	50,3	4,4
7	pr_ds_4.int	354	58,4	9,6	41,1	4,9
8	pr_ds_2.int	670	56,5	−14,6	13,9	5,5
9	pr_ds_4.int	155	42,9	−19,4	18,3	3,1
10	pr_ds_3.int	155	36,4	−12,3	5,5	4,6
11	pr_ds_2.int	133	43,9	−11,5	−11,6	4,0
12	pr_ds_2.int	154	46,0	−14,2	−13,7	4,0
13	pr_ds_1.int	157	34,2	−2,8	−28,1	3,6
14	pr_ds_4.int	21	28,6	8,5	−29,5	3,3
15	pr_ds_3.int	277	37,4	29,8	−16,3	3,7

Table F.24 — Correspondence of difference set samples in 'print_es-d' to original sample IDs

	file	Sample ID	L*	a*	b*	ΔE_{ab}
1	pr_es_3.int	147	23,2	−0,5	0,1	4,4
2	pr_es_4.int	130	53,1	−0,9	−0,1	4,9
3	pr_es_3.int	75	75,2	0,2	0,0	4,8
4	pr_es_3.int	307	39,7	29,9	3,1	1,4
5	pr_es_3.int	343	39,0	26,9	24,1	4,8
6	pr_es_2.int	158	50,3	15,4	31,0	4,3
7	pr_es_2.int	164	58,5	1,8	47,4	4,7
8	pr_es_1.int	135	60,7	−14,3	20,9	4,2
9	pr_es_3.int	562	46,1	−29,7	24,6	7,2
10	pr_es_3.int	172	40,9	−20,1	3,7	3,9
11	pr_es_3.int	453	52,6	−17,5	−13,6	4,6
12	pr_es_2.int	88	47,7	−5,5	−14,8	3,9
13	pr_es_3.int	171	34,2	1,9	−16,5	4,6
14	pr_es_3.int	457	29,6	21,9	−19,0	4,9
15	pr_es_3.int	451	34,0	31,5	−12,1	4,3

Table F.25 — Correspondence of difference set samples in 'print_ij-d' to original sample IDs

	file	Sample ID	L*	a*	b*	ΔE_{ab}
1	pr_ij_2.int	37	22,3	4,2	1,6	8,1
2	pr_ij_1.int	51	37,6	−5,4	−6,7	4,4
3	pr_ij_3.int	173	75,8	2,2	−9,1	3,3
4	pr_ij_5.int	117	39,5	33,8	0,5	1,4
5	pr_ij_7.int	73	36,3	27,7	16,2	3,3
6	pr_ij_5.int	121	45,7	14,7	39,0	2,2
7	pr_ij_2.int	164	65,1	6,5	44,6	3,3
8	pr_ij_5.int	134	63,1	−12,6	31,5	5,4
9	pr_ij_5.int	62	51,0	−35,5	17,6	5,3
10	pr_ij_5.int	63	51,4	−33,4	2,1	6,2
11	pr_ij_3.int	8	30,5	−16,6	−14,3	3,4
12	pr_ij_7.int	52	57,6	−15,0	−18,0	6,2
13	pr_ij_3.int	45	41,8	8,0	−22,2	3,6
14	pr_ij_1.int	40	26,3	23,4	−32,1	7,0
15	pr_ij_5.int	124	49,8	19,2	−6,6	7,4

Table F.26 — Correspondence of difference set samples in ‘textiles_s-d’ to original sample IDs

	file	Sample ID	L*	a*	b*	ΔE_{ab}
1	silk.int	583	17,6	−1,4	0,4	5,0
2	wool.int	128	53,8	1,8	−1,2	2,3
3	wool.int	121	79,9	2,8	0,6	3,3
4	silk.int	209	46,6	37,1	5,1	4,4
5	poly.int	52	43,6	31,9	12,5	4,8
6	poly.int	150	50,3	19,1	36,5	3,9
7	silk.int	439	63,4	2,8	46,1	3,6
8	poly.int	249	57,7	−6,9	28,0	4,1
9	poly.int	316	42,1	−33,5	16,5	5,9
10	cotton.int	380	46,7	−16,9	−0,8	3,9
11	poly.int	408	39,9	−19,3	−9,4	4,7
12	silk.int	634	42,3	−7,4	−12,9	3,4
13	silk.int	719	41,3	−2,6	−25,6	4,4
14	silk.int	812	29,2	17,5	−18,0	4,6
15	silk.int	121	44,1	23,7	−13,7	3,5

Table F.27 — Correspondence of difference set samples in ‘flowers_leaves-d’ to original sample IDs

	file	Sample ID	L*	a*	b*	ΔE_{ab}
1	krinov1.int	25	20,8	–3,5	4,9	6,5
2	flower.int	126	24,6	51,4	–10,1	10,2
3	flower.int	6	34,9	38,4	–41,5	10,9
4	leaf.int	10	53,7	–6,9	38,1	4,9
5	flower.int	89	42,7	18,0	–31,9	2,8
6	leaf.int	27	58,8	–12,8	38,3	6,4
7	flower.int	2	53,3	47,7	36,6	13,3
8	flower.int	128	30,8	49,8	–26,6	15,1
9	flower.int	129	37,2	34,2	–31,2	3,3
10	flower.int	74	76,2	5,1	74,1	3,1
11	flower.int	68	56,2	22,6	14,2	7,0
12	flower.int	90	52,7	12,1	–25,6	10,6
13	flower.int	63	89,6	–6,4	66,9	11,1
14	leaf.int	2	65,3	–9,3	37,0	5,4
15	flower.int	147	50,5	66,3	19,5	14,8
16	flower.int	25	75,4	22,0	81,6	6,8
17	flower.int	35	69,4	13,9	18,5	10,3
18	flower.int	29	76,0	21,1	–6,5	2,4
19	flower.int	71	78,6	5,1	66,4	6,7
20	flower.int	27	93,5	–5,5	21,9	13,0
21	flower.int	104	89,0	–1,1	5,2	4,5
22	flower.int	133	78,3	24,9	4,5	3,9
23	flower.int	54	87,7	–2,5	69,2	3,2
24	flower.int	148	92,8	–1,3	11,8	10,9
25	flower.int	104	89,0	–1,1	5,2	8,2

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