भारतीय मानक

Indian Standard

IS/ISO/TS 18621-11 : 2022

ग्राफिक प्रौद्योगिकी — मुद्रित सामग्री के लिए छवि गुणवत्ता मूल्यांकन विधियाँ

भाग 11 कलर गैमट विश्लेषण

Graphic Technology — Image Quality Evaluation Methods for Printed Matter

Part 2 Colour Gamut Analysis

ICS 37.100.10

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NATIONAL FOREWORD

This Indian Standard (Part 2) which is identical to ISO/TS 18621-11 : 2022 ‘Graphic technology — Image quality evaluation methods for printed matter — Part 11: Colour gamut analysis’ issued by the International Organization for Standardization (ISO) was adopted by the Bureau of Indian Standards on the recommendation of the Graphic Art Technology Sectional Committee and approval of the Management and Systems Division Council.

The text of the International Standard has been approved as suitable for publication as an Indian Standard without deviations. Certain conventions are, however, not identical to those used in Indian Standards. Attention is particularly drawn to the following:

a) Wherever the words ‘International Standard’ appear referring to this standard, they should be read as `Indian Standard’; and

b) Wherever the words ‘International Standard’ appear, referring to this standard, they should be read as ‘Indian Standard’.

In this adopted standard, reference appears to an International Standard for which Indian Standard also exists. The corresponding Indian Standard, which is to be substituted in its place, is listed below along with its degree of equivalence for the editions indicated:

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
ISO 13655 Graphic technology — Spectral measurement and colorimetric computation for graphic arts images	IS/ISO 13655 : 2017 Graphic technology — Spectral measurement and colorimetric computation for graphic arts images	Identical

In this adopted standard, reference appears to an International Standard for which no Indian Standard exists. The Committee have reviewed the provisions of the following International Standards referred in this standard and has decided that they are acceptable for use in conjunction with this standard:

International Standard	*Title*
ISO 15076-1	Image technology colour management — Architecture, profile format and data structure — Part 1: Based on ICC.1:2010

Annexes A, B and C are for information and Annex D forms integral part of this standard.

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Introduction

The colour gamut that can be achieved by a reproduction system is an important attribute. It enables users to compare the colour reproduction capabilities of different printing systems and to determine whether one system can simulate all the colours available in another. This document describes procedures to define and compare colour gamuts.

Given a set of coordinates known to lie on the surface of a colour gamut, the volume of the gamut can be determined by segmenting the gamut into a series of tetrahedra, computing the volume of each tetrahedron and summing the results. For a reproduction process with three colour components, a colour will lie on the surface if it satisfies the condition that at least one component has a value of 0 or 1, where 1 represents the maximum amount of the colour component. However, printing processes usually have four or more colour components (e.g. Cyan, Magenta, Yellow and Black in four-colour process printing), and determining which coordinates lie on the gamut boundary cannot be done solely from the relative amounts of the colour components. For CMYK processes, in almost all cases, the Black colorant extends the gamut below the gamut vertex at each hue angle. This makes it possible to identify a set of coordinates which are expected to lie on the gamut surface from the relative colorant amounts and the coordinates of the two- and three-colour overprints. For processes with more than four colour components, some knowledge of the colorimetry of a sample of colours from the colour data encoding is needed in order to determine which colours lie on the boundary.

For these reasons, coordinates on the surface of the gamut of RGB and CMYK printing processes can be determined by printing a test chart with suitable colorant combinations, and measuring the colours; while for other printing processes, it is necessary to model the colorant-to-colorimetry relationship in order to identify colours on the gamut boundary. (RGB here refers to the input signal and supports the common situation where the printer driver accepts RGB instead of CMYK.)

Indian Standard

GRAPHIC TECHNOLOGY — IMAGE QUALITY EVALUATION METHODS FOR PRINTED MATTER

PART 11 COLOUR GAMUT ANALYSIS

IMPORTANT — The electronic file of this document contains colours which are considered to be useful for the correct understanding of the document. Users should therefore consider printing this document using a colour printer.

1 Scope

This document defines procedures to measure and compare the colour gamuts of RGB and CMYK printing processes.

It is not applicable to other printing processes.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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.

ISO 13655, *Graphic technology — Spectral measurement and colorimetric computation for graphic arts images*

ISO 15076-1, *Image technology colour management — Architecture, profile format and data structure — Part 1: Based on ICC.1:2010*

3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
colour gamut
range of colours that can be reproduced by an output device on a given medium, represented in a CIE-based colour space

Note 1 to entry: The CIE colour space for representation of colour gamuts is normally CIELAB.

3.2
gamut vertex
coordinate in a CIE-based colour space which represents a point on a *colour gamut* (3.1) surface and which is used in defining the surface of the gamut

3.3
gamut face
planar sub-division of the *colour gamut* (3.1) surface formed by three or more coplanar *gamut face edges* (3.4)

Note 1 to entry: The colour gamut of most output devices can be described in terms of a set of gamut faces that completely enclose all the colours that can be reproduced by the device, with no gaps or overlaps.

Note 2 to entry: In this document, gamut faces are defined as having three gamut vertices.

3.4
gamut face edge
line connecting two adjacent vertices of a *gamut face* (3.3)

Note 1 to entry: In a continuous gamut surface, each gamut face edge is shared by two gamut faces.

3.5
characterization model
mathematical model that converts between coordinates in a device colour encoding and a CIE-based colour space

3.6
device gamut
range of colours that corresponds to all possible combinations of colour channels of the device within the device data encoding, when printed on a substrate

3.7
usable gamut
subset of the *device gamut* (3.6) that corresponds to the set of combinations of colour channels of the device in practical use, when reproduced on an output medium

Note 1 to entry: The usable gamut of an output device is normally smaller than the device gamut owing to practical limitations in the combinations of colour channels. Most CMYK devices cannot produce a print in which all channels are set to the maximum. The usable gamut is applicable when the gamut to be determined is that of the system when used as part of a reproduction workflow, using an ICC profile to convert to output channels; while the device gamut is applicable when the gamut to be determined is that of the reproduction device independently of the profile and its colour separation method.

Note 2 to entry: In practice, some printers do not allow all possible combinations of ink to be printed, and an ink-limiting procedure is applied automatically in the printer. Where this is done, this "ink-limited" mode of printing still should be considered to be the "device gamut".

4 Describing a colour gamut

4.1 General

The colour gamut of a reproduction system is a volume in 3D colour space. It shall be mathematically described as a closed set of triangular faces on the surface of the gamut which completely encloses the gamut volume.

4.2 Requirements of a gamut boundary description

Each face should be defined by three colorimetric coordinates, and the set of faces shall be defined in such a way that it encloses the volume of the gamut without gaps or overlaps. The surface shall be encoded as an nx3 array of vertices (in which there are n vertices and each row represents the colour space coordinates of a gamut vertex) and an mx3 face array of indices into the vertices array (where there are m faces and each row of the array identifies the three row numbers in the vertex array which correspond to a gamut face). Each gamut vertex shall be described as a CIELAB L*, a*, b* value computed from spectral reflectance or tristimulus values according to ISO 13655, and when this is done it shall be stated which ISO 13655 measurement mode applies to the data. If the colour space used to describe the gamut vertices is not CIELAB computed according to ISO 13655, details of the colour space used (including the CIE colorimetric observer and illuminant) shall be reported as metadata associated with the gamut description. Where it is desired that the gamut description or comparison is media-relative, CIELAB L*, a*, b* coordinates shall be scaled as described in Annex D.

In order to satisfy the requirement to enclose the gamut volume without gaps or overlaps, the following conditions shall be met.

a) The three indices identifying each face shall identify vertices in clockwise order, when viewed from the exterior of the volume.

b) Each gamut face edge shall be common to two gamut faces.

CIELAB L*, a*, b* computed according to ISO 13655 should be used where it is important to be able to compare colour gamuts or where the gamut is derived from an ICC profile.

It is acknowledged that CIELAB is an approximately perceptually uniform colour space. The CIELAB space over-predicts perceived chroma at higher values of C^*_{ab} chroma, and hence at the gamut boundary, and this affects the gamut size.

Determining a set of faces that meet the conditions listed above from an arbitrary set of vertices is non-trivial. For this reason, this document provides a set of well-spaced coordinates in device space, and an associated triangulation. Full details of these data are given in Annex A.

4.3 Device gamut and usable gamut

The device gamut can be determined either from the characterization model (usually represented by an ICC profile) or by direct measurement of colours that lie on the gamut boundary. To compute the usable gamut, an additional step is required in which the device coordinates are restricted to those available in the reproduction workflow. If an ICC profile is used to define the usable gamut, CIELAB gamut surface coordinates in the device gamut can be transformed to device coordinates and then back to CIELAB coordinates to obtain the usable gamut.

NOTE In some cases, the device or its driver can limit the range of colorant combinations, regardless of whether an ICC profile is used.

The procedure in 4.4 should be used for determining the gamut boundary vertex and face arrays. If a different procedure is used, it shall be stated when communicating the gamut boundary description which procedure was used to determine the gamut vertices, and whether the device gamut or usable gamut is described.

4.4 Procedures for describing a colour gamut

4.4.1 General

One of the following procedures should be used to describe the colour gamut of a reproduction system.

NOTE 1 In most cases, results obtained from these procedures, using the set of well-spaced coordinates in device space described in this document, give very similar results[2]. Certain factors affect the reproducibility of the gamut description, such as when the black in a toner-based printer results in a lower L* value than any of the other colorant combinations.

NOTE 2 An ICC profile is a convenient means of converting data between the device data encoding and the corresponding colorimetry, and it defines the colour gamut available in a workflow based on ICC profile conversions. Other methods of obtaining colorimetric values for coordinates on the gamut surface, such as direct measurement or a characterization model, is also used.

4.4.2 Procedure for describing the colour gamut of a reproduction system based on its ICC profile

The following procedure should be used to compute the faces and vertices of a gamut boundary description from an ICC profile for the reproduction system. The procedure is applicable to RGB and CMYK devices.

Where used, the ICC profile shall be created according to ISO 15076-1, from characterization data representing the printing process whose gamut is to be described. This method estimates the gamut of the device represented by the profile, and depending on the accuracy of the AToB1 tag and the BToA1 tag of the profile this estimate might or might not itself be accurate. The accuracy of AToB1 and BToA1 tags shall be reported.

To maintain accuracy, the precision of data used for both device coordinates and CIELAB coordinates shall be 16 bits or greater.

1) Generate an image whose pixels represent a set of device coordinates on the gamut boundary of the encoding. The image should be arranged so that the ratio of the relative colorant amounts varies in the horizontal direction, and the total colorant amount varies in the vertical direction. The white point and black point are repeated across the first and last rows in the coordinate array. Annex A gives details of images for this purpose for RGB and CMYK reproduction systems.

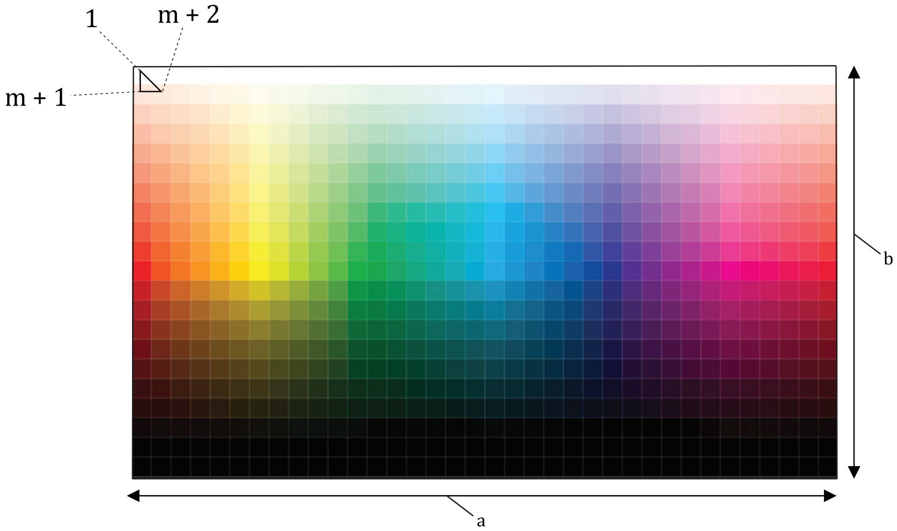
2) Convert the image in step 1) to CIELAB using an ICC profile for the reproduction medium, selecting the ICC-Absolute Colorimetric rendering intent.

   The values calculated following step 2) are the gamut vertices of the device gamut for RGB and CMYK systems. These are also the usable gamut of an RGB reproduction system.

3) To obtain the usable gamut of a reproduction system, convert the CIELAB coordinates back to device coordinates and then back to PCS CIELAB coordinates, in both cases using the ICC-Absolute Colorimetric rendering intent. This step is necessary to ensure that only colorant values that are permitted by the colour separation model are represented in the gamut description.

4) The CIELAB coordinates for each patch from step 3) are read row-wise and arranged as an $m \times n \times 3$ array to form the vertex array where m is the number of columns in the test image and n is the number of rows.

5) To construct the face array for this data, start with the upper left device coordinate and move clockwise to the two coordinates in the next row, as shown in Figure 1. The first row of the faces list is therefore [1, m+2, m+1]. The next row in the faces list is [1, 2, m+2]. Continue to move through the device coordinates until the face list is fully populated with one row per face.



Key

a m pixels

b n pixels

Figure 1 — Triangulation of gamut target image

4.4.3 Procedure for describing the device gamut of a reproduction system based on its characterization model

The following procedure can be used to compute the faces and vertices of a gamut boundary description of a reproduction system using its characterization model.

1) From the device data in the test chart described in step 1) of 4.4.2, compute CIELAB values for each colour patch using the characterization model.

2) Follow steps 4) to 5) from 4.4.2 to obtain the face and vertex list.

4.4.4 Procedure for describing the device gamut of a reproduction system based on measurement of a printed gamut target

The following procedure can be used to derive the faces and vertices of a gamut boundary description of a reproduction system using computations based on direct measurement of printed specimens.

1) Print the test chart described in step 1) of 4.4.2 on the printer without colour management and measure the printed patches.

NOTE In order to determine the printer gamut independently on any ICC profile, colour management is not applied.

2) Follow steps 4) to 5) from 4.4.2 to obtain the face and vertex list.

4.4.5 Procedure for describing the device gamut of a reproduction system based on characterization data

The following procedure can be used to compute the faces and vertices of a gamut boundary description of a reproduction system from characterization data.

1) Select the characterization data set which represents the device, using a test chart such as that described in ISO 12642-1[1].

2) Use the alpha shapes method[3], [4], [5] to determine the set of connected faces which enclose the coordinates in step 1).

An alpha shapes radius of 40 is recommended. Since the radius depends on sampling size and distribution, other values may be optimal for a given data set. Alpha shapes may generate an error depending on the chosen radius.

NOTE The face list returned by the alpha shapes method will be different from that obtained by the procedure in 4.4.3 and 4.4.4, but the volume calculated from these data according to Clause 5 has been found to be in good agreement. See Reference [2] for more details.

5 Computing the volume of a colour reproduction gamut

5.1 General

The volume of colour reproduction gamuts shall be defined as follows.

5.2 Volume of a single gamut

5.2.1 Volume calculation

The gamut volume shall be calculated as shown below.

1) Define a point at the approximate centre of the gamut volume, whose CIELAB coordinates are the average of the coordinates of the white and black point of the gamut.

2) Add this point to the set of points defining each gamut face to form a set of tetrahedra spanning the gamut volume.

3) For each tetrahedron in turn, let the four vertices be p_1, p_2, and p_3 (corresponding to the planar face on the gamut boundary) and p_4 (the approximate gamut centroid), as shown in Figure 2. If each vertex p_1, etc is represented by its CIELAB L*, a* and b* coordinates, the (signed) volume of each tetrahedron should then be computed using the scalar triple product shown in Formula (1):

$$V = -\frac{\vec{a} \cdot \left(\vec{b} \times \vec{c} \right)}{6} \quad (1)$$

where

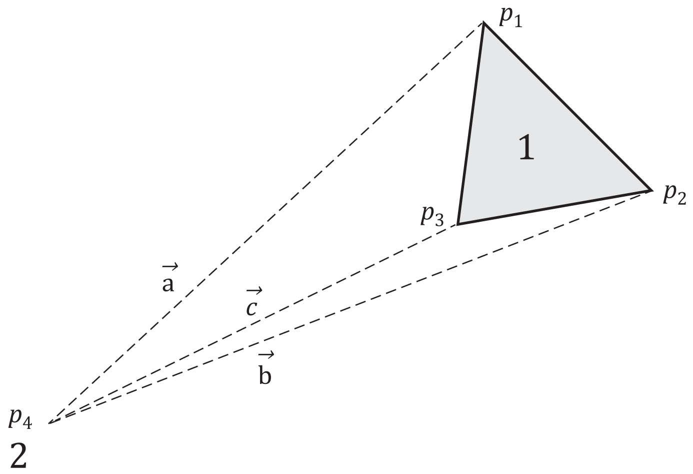
$\vec{a} = p_1 - p_4$

$\vec{b} = p_2 - p_4$

$\vec{c} = p_3 - p_4$

The '·' and ' × ' symbols denote dot product and cross product, respectively.

4) Sum the volumes of all the tetrahedra to obtain the total gamut volume.



Key

1 gamut face p_1, p_2, p_3 viewed from outside

2 fixed point p_4 at approximate gamut centre

Figure 2 — Tetrahedron formed from single gamut face defined by vertices $p_{1\text{-}3}$ and fixed point p_4

NOTE 1 The sign of the scalar triple product in Formula (1) depends on the winding order of the planar face, and in the clock-wise order defined, as shown in Figure 2, it is negative.

NOTE 2 If the scalar triple product is positive for a given tetrahedron, this might indicate a "fold" in the colour gamut. See Annex C for more details.

The volume shall be reported as the number of "cubic CIELAB units", i.e. the number of hexahedra with sides of 1,0 in the dimensions of CIELAB L*, a* and b*.

5.2.2 Verifying the volume calculation

If the conditions in 4.2 are met, the procedure in 5.2.1 will result in an accurate estimate of the gamut volume. An additional check can be performed by computing the solid angle of each tetrahedron and summing them. If the faces of the gamut surface correctly enclose the volume, the resulting value will be equal to the solid angle of a sphere, i.e. 4π steradians.

NOTE A method of calculating the solid angle of a tetrahedron is given in Reference [6].

For guidance, the gamut volumes calculated from a set of reference profiles is provided in Annex B. This can be used to verify the correctness of the procedure used.

In practice it can be difficult to satisfy the conditions in 4.2 for every face in a gamut. It is recommended that the total solid angle is reported with the estimated volume. The volume associated with the number of incorrectly-oriented faces should also be calculated and reported.

When the target image method is used to calculate the gamut surface the gamut volume shall be reported as:

Gamut volume = 123456 (32)

where the figure in parentheses indicates the maximum error in the calculation. If this value is greater than 1 % of the total volume, an alternative method for calculation of the gamut surface should be used. See Annex C for details.

Differences in the CMM used to perform the profile transforms describe above, especially in the LUT interpolation methods used, can give rise to small differences in volume estimates. Differences in the finite precision of computation are also a potential source of differences in volume estimates, although in practice these differences are generally negligible.

5.3 Volume of the intersection of two gamuts

5.3.1 General

One of the two following procedure should be used to compute the intersection of two colour gamuts, and the resulting volume.

5.3.1.1 Triangulated intersection

1) Determine all the coordinates at which the gamut face edges of the faces in the first gamut intersect the faces of the surface of the second gamut.

2) Determine all the coordinates where the gamut face edges of the faces in the second gamut intersect the faces of the surface of the first gamut.

3) Determine the vertices of the first gamut which lie inside the second gamut.

4) Determine the vertices of the second gamut which lie inside the first gamut.

5) Determine the set of triangular faces that connect the edge-face intersections and the vertices found in steps 1) to 4), using the alpha shapes method[4], [5]. For the alpha shapes method, a radius of 40 is recommended.

6) Compute the volume of the resulting set of tetrahedra using Formula (1).

NOTE If one gamut encloses the other, either step 1) or step 2) yields no coordinates, and the volume of the intersection gamut is given by the volume of the smaller of the two gamuts.

5.3.1.2 Voxel-based intersection

1) Define a grid of CIELAB coordinates at a resolution of 1 in the dimensions of L*, a* and b*.

2) For each coordinate, determine whether it lies inside or outside the two gamuts using the procedure in 5.3.2.

3) Sum the number of coordinates which are inside both gamuts. This is the volume in cubic CIELAB units.

NOTE This procedure results in small errors where the voxel lies partially in and out of a gamut, but such errors tend to cancel each other out.

5.3.2 Determining if a coordinate is inside or outside a gamut

One method of determining whether a coordinate lies within a closed triangulated surface is to subtend a line from the coordinate to the approximate gamut centroid and find the intersections with the surface triangles that lie on this line. In a convex polyhedron an in-gamut coordinate has zero such intersections; if the gamut is not convex, an in-gamut coordinate may have zero or an even number of intersections. Thus, if the number of intersections is odd the coordinate lies outside the gamut.

NOTE A method of calculating the intersection between a line segment and a triangle is given in Reference [7] and a Matlab implementation is available in Reference [8].

6 Comparing colour gamuts

6.1 General

Two colour reproduction gamuts, defined as in 5.2 shall be compared as shown below, where the volume of the two gamuts, computed as in 5.3, is V_1 and V_2, and the intersection of the two volumes is V_i.

NOTE 1 The methods listed here were described in Deshpande, Green and Pointer, 2012[9] and 2015[10]. Relevant metrics are also described in CIE 168:2005[11].

NOTE 2 Sources of uncertainty in the gamut description include measurement noise, printer variability, and potential errors in the triangulation. These uncertainties can affect the accuracy and precision of the gamut metric values computed as described in this clause.

The methods for calculating a gamut boundary described in this document shall not be used to determine whether a colour is in or out of gamut.

The methods for calculating a gamut boundary described in this document shall not be used to determine the gamut boundary of a discrete set of colours.

6.2 GCI

The Gamut Comparison Index (GCI) is a goodness-of fit measure of the two gamuts, computed by:

$$I_{GC} = (V_i^2)/(V_1 V_2)$$

A GCI of 1,0 indicates a perfect match in volume and intersection, while a GCI of 0 indicates the two gamuts have no intersection.

6.3 Gamut coverage

The proportion of reproduction gamut 1 covered by reproduction gamut 2 is:

$$V_i/V_1$$

6.4 Out-of-gamut volume proportion

The proportion of gamut 1 that lies outside gamut 2 is given by:

$$(V_1 - V_i)/V_1$$

7 Encoding and communicating a colour gamut description

7.1.1 When communicating a colour gamut description, the following information shall be given:

a) device type and name;

b) substrate type and name;

c) colorant space (e.g. CMYK, RGB);

d) colour space (e.g. CIELAB, spectral reflectance, etc.);

e) a list of vertices;

f) a list of faces in the colour space;

g) the ISO 13655 measurement condition used in making the measurements.

7.1.2 In addition, the following information should also be given.

a) a list of device coordinates corresponding to the vertices;

b) viewing conditions;

c) device model, profile and characterization data;

d) colour separation method (black generation, TAC), ink sequence and halftoning method;

e) CIELAB values of the primary colorants. (If included, these values shall match those of the corresponding vertices in the gamut description) ;

f) the alpha shape radius used in any alpha shape calculation, if different from 40.

Where the procedures and test chart described in 4.3 have been used, a compact form of communicating the gamut description may be used. The compact form shall give the information in 7.1.1 a) and b) [and optionally in 7.1.2 a) to d)], and the statement “Defined according to ISO/TS 18621-11.”

Annex A
(informative)

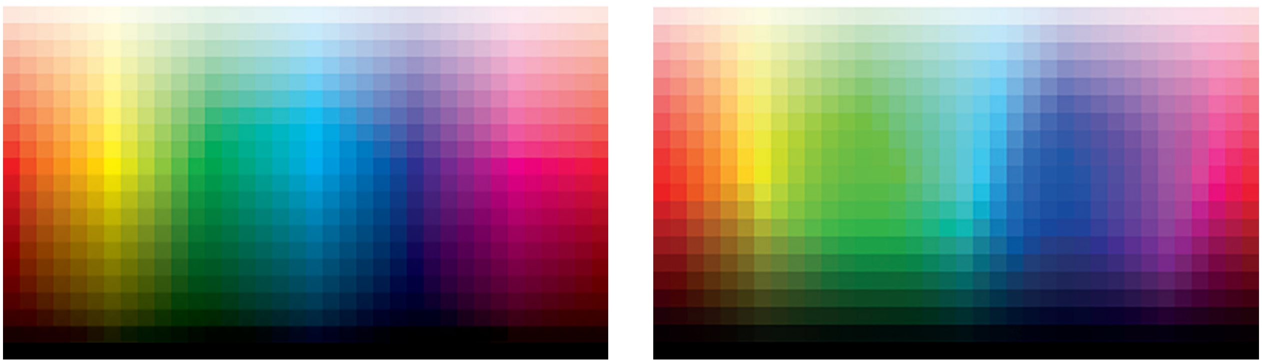
Images for use in determining the gamut boundary of RGB and CMYK printing processes

A.1 Overview

The gamut boundary images described in this annex have been extensively tested using the procedures in 4 and 5 above and found to give consistent results[2]. The CMYK coordinates of the images, together with the associated face arrays, are described below.

A.2 Gamut boundary image

A test image for defining colour gamut boundaries is described in Green and Revie, 2018[2], based on Green, 2001[12]. Two images, one in 16-bit CMYK encoding and the other in 16-bit RGB encoding, are provided, with patches arranged as described in 4.4.2 1) above. The RGB image has 36 uniform steps in colorant combination ratios and 21 uniform steps in colorant amounts. The CMYK image has 36 uniform steps in colorant combination ratios and 22 uniform steps in colorant amounts. The images are shown in Figure A.1. Electronic versions of the images in Figure A.1, together with CMYK and RGB data files, are available at https://standards.iso.org/iso/ts/18621/-11/ed-2/en.



a) CMYK

b) RGB

Figure A.1 — Gamut boundary images CMYK and RGB

A.3 Gamut boundary image triangulation

Face arrays for the test images described in A.2 are provided as electronic files to this document, and are available at https://standards.iso.org/iso/ts/18621/-11/ed-2/en. Each row of the data files contains one face, and the three values in each row represent the indices of the corresponding vertices. To form the vertex array, the CIELAB coordinates found as described in 4.4.2 2) from the images described in A.2, shall be read row-wise so that the left-most pixel in row 1 is assigned to be vertex 1, the left-most but one pixel in row 1 is assigned to be vertex 2, and so on until all the pixels have been assigned to a vertex number.

Annex B
(informative)

Gamut volumes for a set of reference profiles

Table B.1 gives gamut volumes for a set of reference profiles available from the ICC Profile Registry[13]. These volumes were computed at double precision, following the steps described in 5.2.1. The volumes given in Table B.1 can be used to verify the procedure used to calculate a gamut volume. Results should differ from the values given in Table B.1 by no more than 0,5 % for device gamuts and 1 % for usable gamuts.

Additional resources for analysing colour gamuts are available on the ICC web site[14].

Table B.1 — Gamut volumes for a selection of reference profiles

Profile	Device gamut volume	Usable gamut volume
CGATS21_CRPC1.icc	84275	77878
CGATS21_CRPC2.icc	151455	143587
CGATS21_CRPC3.icc	165774	157811
CGATS21_CRPC4.icc	253751	244966
CGATS21_CRPC5.icc	331539	320457
CGATS21_CRPC6.icc	389137	377047
CGATS21_CRPC7.icc	525902	512469
SC_paper_eci.icc	261876	227491

Annex C
(informative)

Errors in triangulation

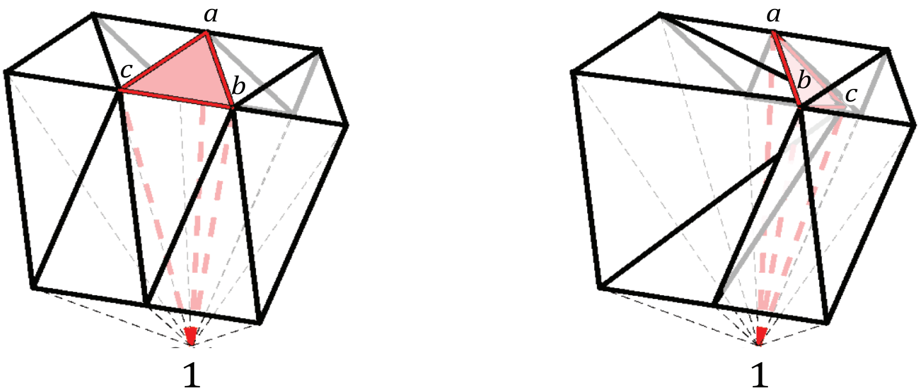
C.1 General

It can be difficult to satisfy the conditions in 4.2 for every face in a gamut. For the gamut boundary target described in Annex A, the winding order of the vertices in a face may be altered during the transformation between colour spaces. Where this happens, an overlap occurs between faces. When visualized, this results in an apparent fold in the surface.

This annex describes the problem of such folds in the surface of the gamut. When they occur, they are introduced during the colour conversion step and can be due either to limitations in the profile building algorithm or errors in the measurement data from which the profile is constructed. They are more likely when vertices are closely spaced.

Figure C.1 shows a part of a gamut surface with no fold (on the left) and a similar part of a gamut surface with a fold. In this case, the surface triangle (*abc*) shown in red has been "folded" under other triangles on the surface.

NOTE This problem does not occur when the alpha shapes method is used to construct the gamut surface as a different triangulation is used in that case.



Key

1 origin

Figure C.1 — Part of a gamut surface showing a an incorrectly oriented ("folded") face

These folded surface triangles usually arise where device values change in the opposite direction to the associated colour values. This behaviour is generally undesirable, but in most cases, their impact is small and might not be noticeable in rendered images.

C.2 Identification and impact

As noted in 4.1, the indices of faces of the device gamut defined by the RGB and CMYK target images are encoded in a clockwise manner when viewed from outside the gamut (counter clockwise when viewed from the centre). When viewed from a point in the interior of the gamut the rotation order of folded surfaces triangle is reversed relative to the rotation order of the other surface triangles.

Where this effect occurs, the solid angle formed by the tetrahedra (see 5.2.2) is not 4π steradians.

The faces which have been folded can be identified by noting the sign of the scalar triple product used in the volume calculation in 5.2.1 ($a \cdot b \times c$) is reversed relative to the other surface triangles. The volume of these tetrahedra is counted up to three times in the calculation in 5.2.1 and so the maximum error in the gamut volume calculation is given as three times the total volume of these tetrahedra.

NOTE The actual error is almost always less than this maximum value which occurs when surfaces are coplanar.

Annex D
(normative)

Media-relative colour gamuts

In Clauses 4 to 7, measurements are relative to a perfect reflecting diffuser. In some situations, it is desirable to obtain a gamut boundary description that is relative to the media white point, where the CIE colorimetry has been scaled so that the media white has CIELAB values [100, 0, 0]. This may be done to discount differences in white point between two reproduction media, for example to compare a print gamut with a display gamut.

Media-relative colorimetry shall be obtained by either applying the Media-relative colorimetric rendering intent in place of the ICC-Absolute colorimetric intent in the procedures described in Clause 4, or by scaling CIE colorimetry by Formula (D.1) (see ISO 15076-1).

$$Y_r = \frac{Y_{D50}}{Y_{MW}} Y_a \qquad X_r = \frac{X_{D50}}{X_{MW}} X_a \qquad Z_r = \frac{Z_{D50}}{Z_{MW}} Z_a \tag{D.1}$$

where

X_r, Y_r and Z_r	are the media-relative XYZ values;
X_{D50}, Y_{D50} and Z_{D50}	are the colorimetry of the D50 illuminant;
X_{MW}, Y_{MW} and Z_{MW}	are the measured XYZ values of the media white point;
X_a, Y_a and Z_a	are the measured XYZ values of the stimulus relative to a perfect diffuse reflector, adapted to D50.

Media-relative scaling changes the magnitude of the colorimetric coordinates and hence the size of the colour gamut. To avoid ambiguity, if gamut coordinates are the result of media-relative scaling it shall always be reported, and media-relative gamuts shall not be compared with other gamut boundary descriptions in which media-relative scaling has not been applied.

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