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Image quality evaluation methods for printed matter —

Part 11: Colour gamut analysis

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Foreword

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This document was prepared by Technical Committee ISO/TC 130, *Graphic technology*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

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. 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.

Image quality evaluation methods for printed matter —

Part 11: **Colour gamut analysis**

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

ISO 12642-1, *Graphic technology — Input data for characterization of four-colour process printing — Part 1: Initial data set*

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

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 http://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 surface and which is used in defining the surface of the gamut

3.3
gamut face
planar sub-division of the colour gamut surface formed by three or more coplanar gamut face edges

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

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

Note 1 to entry: Ink space is an alternative term for device gamut.

3.7
usable gamut
subset of the device gamut 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 shall 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.

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

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

CIELAB L*, a*, b* computed according to ISO 13655 is recommended 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 not perceptually uniform, and that this affects the gamut size. Determining a set of faces that meet these conditions 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 is recommended 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 shall 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[1]. 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 can 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 may or may 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 × n × 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.

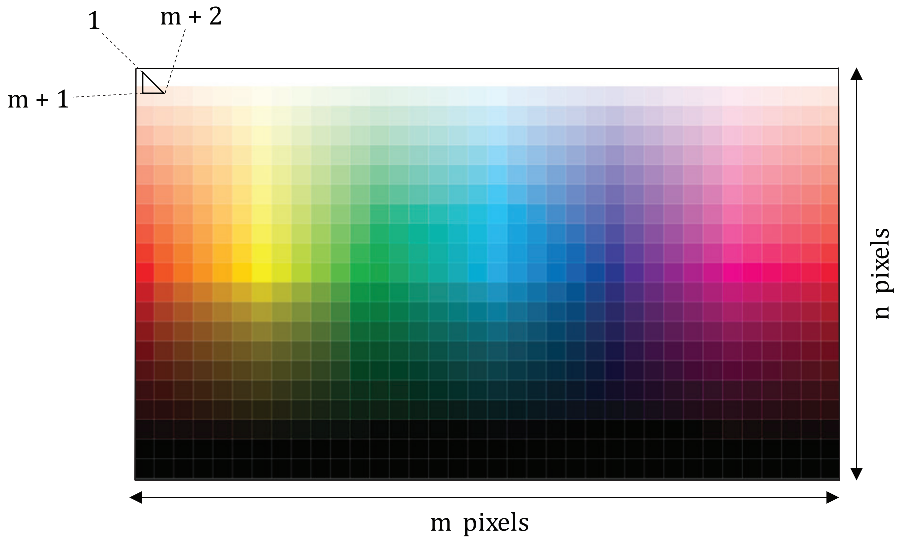

Figure 1 — Triangulation of gamut target image

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 4.4.2 1) 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.

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

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 can 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. below has been found to be in good agreement. See Reference [1] 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.