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Graphic technology — Image quality evaluation methods for printed matter —

Part 21: Measurement of 1D distortions of macroscopic uniformity utilizing scanning spectrophotometers

Technologie graphique — Méthodes d'évaluation de la qualité d'image pour les imprimés —

Partie 21: Mesure des distorsions 1D d'uniformité macroscopique à l'aide de spectrophotomètres à balayage

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

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

This second edition cancels and replaces the first edition (ISO/TS 18621-21:2020), which has been technically revised.

The main changes are as follows:

— Formulae (1) to (6) have been corrected;

— the Bibliography has been updated.

A list of all parts in the ISO 18621 series can be found on the ISO website.

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 subject of image quality is broad and complex, due to its multidimensionality and the apparent characteristics of human vision. Many different methods can be available to provide a measure of a particular visual attribute in some particular viewing context and aimed at a particular printing technology. It is a challenge to have image quality evaluation methods that are independent of the marking technology, i.e. correlate with human perception to provide visual significance to measured differences across many printing technologies. The evaluation of perceived image quality is an active field of research.

The uniformity that can be achieved, or in fact the lack thereof, is an important factor in the evaluation of the overall print quality. Uniformity refers to the subjective impression of the homogeneity of the colour in extended areas up to the document size. Colour uniformity refers to all types of unintended but visible variations in colour, that may go in any direction in colour space and may have any spatial pattern. Spatial patterns include 1D, 2D, periodic, aperiodic, localized, large-scale and small-scale variations. They can be identified as streaks or streakiness, banding, gradients, mottle, moiré and others.

When evaluating perceived uniformity, the intended viewing distance should be taken into account. For practical application it is also common practice to distinguish 2 categories of uniformity that depend on the spatial frequency (or actually the angular frequency as seen by the eye):

— Microscopic uniformity such as graininess that is related to the imaging process and generally consists of a 2D random noise pattern. It is visually relevant for image objects as small as few square mm in size in case of normal reading distance (40 cm).

— Macroscopic uniformity involves distortions in the homogeneity that extend beyond few mm in one or both geometric dimensions. It is generally visible across the document page size with examples called banding, cording stripes or streaks.

This document focuses on the macroscopic uniformity that exhibits 1D type patterns that extend more or less across the printed area of a page. It uses well established colour measurement instruments as the basic measurement device, especially systems that can be combined with automated XY-tables for performing well-defined measurements in a complete 2D grid of measurement locations in an easy way. These systems generally have a minimum pitch in both dimensions of 6 mm. This method takes a much more rigorous approach than the 9-point sample method that is defined in ISO 12647-7 that is applicable to proofing systems.

The measurement method derives a single valued Macro-Uniformity-Score on a scale that ranges from 100 (“perfect uniformity”) to 0 (“extremely poor uniformity”). It is based on the evaluation of the average colour differences that occur in horizontal and vertical rows separately and adds them up to arrive at a single value. Then a formula is applied to compute the Macro-Uniformity-Score that is shown to correlate well with the perception of representative streaks or stripes of toner-based printing systems as well as inkjet based systems.

This document describes a methodology in such a way that other documents can apply it for specific use cases. Such documents will typically need to apply additional constraints on test pages and process control in order to ensure that the resulting Macro-Uniformity-Score can be compared between different printing devices, substrates and ink sets.

Graphic technology — Image quality evaluation methods for printed matter —

Part 21: Measurement of 1D distortions of macroscopic uniformity utilizing scanning spectrophotometers

1 Scope

This document defines a measurement method for the evaluation of distortions in the macroscopic uniformity of printed areas that are oriented in the horizontal and vertical direction, such as streaks and bands.

It provides requirements for the layout of the test form, the use of a colour measurement device taking measurements in a 2D sampling grid, and the formula to compute the Macro-Uniformity-Score.

This document does not cover any non-adjacent or non-horizontal nor vertical patterns. Due to the used spatial frequency, the Macro-Uniformity-Score does not measure high frequency (fine) patterns such as missing nozzles.

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 13655:2017, *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 terminology 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
banding
appearance of repeated 1-dimensional patterns within an area that should look homogeneous

Note 1 to entry: The related artefacts are called bands or stripes.

[SOURCE: ISO/TS 15311-1:2020, 3.1, modified — Definition has been made precise and a Note to entry has been added.]

3.2
CIEDE2000
ΔE_{00}
colour difference as defined in ISO/CIE 11664-6 with the default weights for lightness, chroma and hue (1:1:1)

Note 1 to entry: The unit is 1.

3.3
streakiness
appearance of 1-dimensional isolated lines or random patterns within an area that should look homogeneous

Note 1 to entry: In case of a pattern that is clearly repeated, the distortion is mostly indicated as *banding* (3.1). The related artefact are called streaks.

3.4
test element
elemental part of a test pattern used to assess a particular aspect of a printing system

Note 1 to entry: In case of macroscopic uniformity, there is no distinction between the test element and the test pattern because of the fundamental large size of the element.

[SOURCE: ISO/IEC 29112:2018, 3.1.37, modified — A note to entry has been added.]

3.5
test page
arrangement in a printable page of *test elements* (3.4) or *test patterns* (3.6) designed to test one or more particular aspects of a printing system

Note 1 to entry: This is also known as test form.

[SOURCE: ISO/IEC 29112:2018, 3.1.38]

3.6
test pattern
specified arrangement of printable objects (test elements) designed to test a particular aspect of a printing system

Note 1 to entry: In case of macroscopic uniformity there is no distinction between the test element and the test pattern because of the fundamental large size of the element.

[SOURCE: ISO/IEC 29112:2018, 3.1.39, modified — A note to entry has been added.]

4 Requirements

4.1 Principles

The Macro-Uniformity-Score can be evaluated across a printed area with a minimum width or minimum height of 156 mm. This printed area shall originate from a digital input image or rectangular region that is defined by a uniformly tinted area. The colours rendered across the printed area shall be measured in a 2D grid of spot locations. The pitch for these measurement spots shall be maximal 6 mm in both dimensions. In the analysis adjacent CIEDE2000 colour differences[1] are determined between CIELAB colour values that are averaged along the vertical and horizontal projections separately.

4.2 Apparatus

4.2.1 General

The measurement device shall be in conformance with ISO 13655 and should have a measurement aperture (diameter) not smaller than 3 mm and not larger than 6 mm. The device should be capable of obtaining measurement values from a well-defined 2D sampling grid across the printed area. This may also be accomplished by using a hand-held device mounted in an appropriate XY-table.

4.2.2 Measurement condition

The sample backing shall be white and in conformance with ISO 13655:2017, Annex A. The measurement condition and sample backing material shall be reported.

4.3 Procedure

4.3.1 Test pattern

Each individual test pattern shall be composed as a uniformly tinted area in a given colour space, e.g. K-only, RGB, CMYK or a spot colour. There are no restrictions to the used colour nor the colour encoding, but the values provided in Annex A may prove useful in enabling Macro-Uniformity-Scores from different uses of this document to be compared. Documentation such as for Fogra M-score[2],[5] can provide guidelines on the selection of colours to test, and how to deal with the series of results from different colours.

The test page containing the test pattern should be in A4 format with at least 156 mm in any of 2 dimensions and preferably stored in PDF format. This corresponds to a matrix of 31 x 26 patches assuming a 6 mm sampling pitch. The patch matrix (n, m) needs to be used for the calculation, see 4.4. The dimensions used and the colour encoding shall be reported, see 4.5. A typical test pattern is depicted in Figure 1.

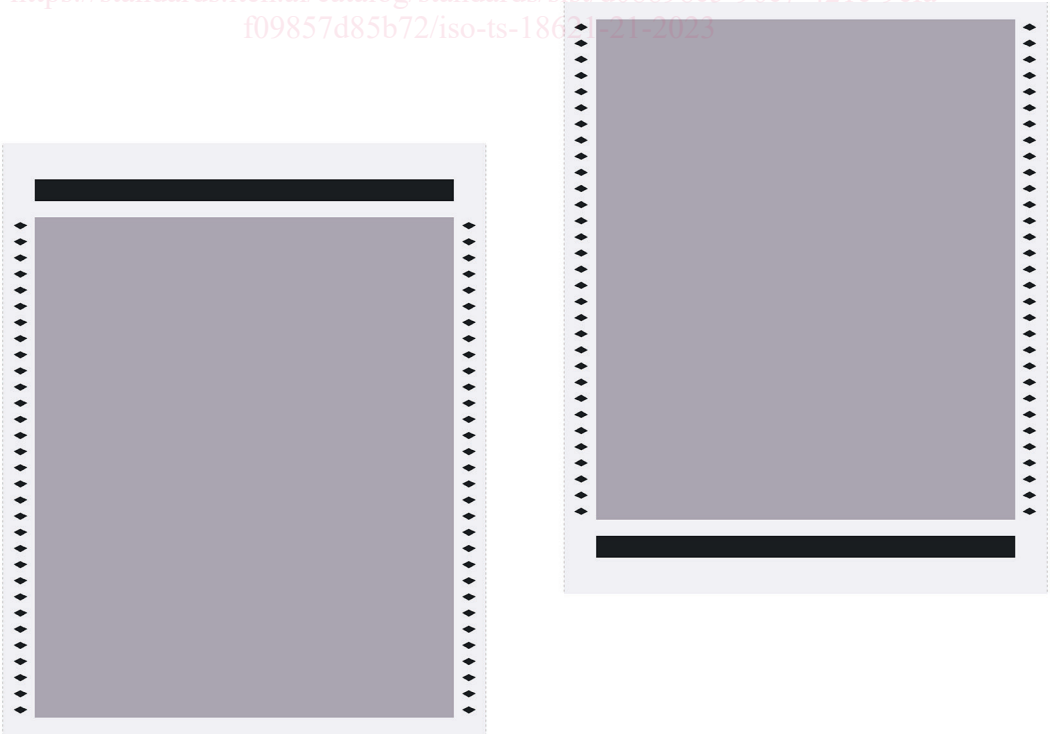

Figure 1 — Example of a test form with markers to enable automated scanning measurements

4.3.2 Printing and measuring

Print the digital test form, defined in 4.3.1, in a printing workflow that is appropriate for the print system, taking into account the corresponding output intent profile.

Measure the CIELAB values at all measurement grid locations (806 L*,a*,b*-triplets in case of a grid with 31 x 26 patches) in accordance with ISO 13655, preferably by using M1 method. The colour measurements in the patches around the perimeter should be within the printed area. If this cannot be ensured these colour patches can be omitted in the next processing. This shall be reported.

If there is a reason to omit the measurements of patches around the perimeter (measurements in the 1st row, the last row, the 1st column and the last column) from measurement data because of possibility of measurement error, store and proceed with the remaining CIELAB values (696 L*,a*,b*-triplets in case of the recommended layout) in ISO 28178 compliant format.

4.4 Evaluation

a) Average all CIELAB measurements across all patches along both dimensions *j* and *i*, as shown in Formulae (1) and (2):

$$Lab_{r,j} = \frac{1}{m}\sum_{i=1}^{m} Lab_{j,i} \tag{1}$$

$$Lab_{c,i} = \frac{1}{n}\sum_{j=1}^{n} Lab_{j,i} \tag{2}$$

where *i* and *j* are the running variables going from 1 to *m* and 1 to *n*, respectively, and *Lab* refers to the triplet of CIELAB values commonly denoted as (L*, a*, b*).

b) Compute the CIEDE2000 colour difference ΔE_{00} between neighbouring averaged patches in each row and between neighbouring averaged patches in each column using Formulae (3) and (4). For the A4 format with n = 29 rows (r) and m = 24 (c) columns there will be 28 colour differences for each row and 23 colour difference values for each column.

$$\Delta E_{r,j} = \Delta E_{00}\left(Lab_{r,j},\ \ Lab_{r,j+1}\right) \tag{3}$$

$$\Delta E_{c,i} = \Delta E_{00}\left(Lab_{c,i},\ \ Lab_{c,i+1}\right) \tag{4}$$

c) Average colour differences for rows (r) and columns (c) and to get the total colour difference ΔE_t normalize them. See Formulae (5) to (7).

$$\Delta E_r = \frac{\sum_{j=1}^{n-1}\Delta E_{r,j}}{n-1} \tag{5}$$

$$\Delta E_c = \frac{\sum_{i=1}^{m-1}\Delta E_{c,i}}{m-1} \tag{6}$$

$$\Delta E_t = \frac{\Delta E_r + \Delta E_c}{2} \tag{7}$$

d) Compute the Macro-Uniformity-Score as using Formula (8):