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# Photography — Photographic reflection prints —

## Part 1:
## Evaluation methods of image quality

*Photographie — Tirages photographiques par réflexion —*

*Partie 1: Méthodes d'évaluation de la qualité de l'image*

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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).

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For an explanation on 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 the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 42, *Photography*.

A list of all parts in the ISO 20791 series can be found on the ISO website.

# Introduction

Image quality of photographic prints is not based on any single feature but instead involves several factors. There are so-called "five major properties" for representing photographic image quality, and each one is essential: (1) density; (2) colour; (3) uniformity; (4) tone and (5) detail reproduction. Glossiness represents another important factor. It affects the observer's perception since it relates to the light specularly reflected from prints. Though the specularly reflected light contains no information from the printed image, it affects the observer's perception. Furthermore, sharpness of the shape of reflected light sources also affects the perception.

Several standards for image quality measurement have been documented by ISO/TC 42. Standards intended for analogue prints fail to properly address the effect of half tone dots, which required to produce inkjet and electrophotographic prints.

In recent years, the field of imaging science and technology has witnessed the investigation of measurement methods for digital prints. In addition, standards have been developed by ISO/IEC JTC 1/ SC 28 and ISO/TC 130. Some of these standards cannot be applied broadly to photographic prints because they focus on a specific technical or industrial field. However, the rest of these standards handle common aspects and can be applied to photographic prints with or without modifying the standard. This document provides information about the measurement methods for image quality that are applicable to photographic prints, including digital prints produced using a range of printing technologies.

ISO/TC 42 plans to develop test targets for image quality measurements on small size photographic prints. This document provides methods which can be applied for the measurements.

# Photography — Photographic reflection prints —

# Part 1:
# Evaluation methods of image quality

## 1 Scope

This document provides information and examples of measurement methods for evaluating the image quality of digital photographic reflection prints, including prints produced by ink jet, thermal dye transfer, electrophotography and silver halide (chromogenic) technologies. These measurement methods are intended especially to be applicable to small prints with a size of available picture area ranging from 35 mm × 45 mm to 360 mm × 450 mm, a popular and basic application of photographic print technology.

NOTE        The definition of "digital print" here is print made directly from digital data when there is no intermediate image carrier, or when the image carrier is refreshed for each impression, and thus each impression can be different in content if desired.

## 2 Normative references

There are no normative references in this document.

## 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 Terms

**3.1.1**
**reflectance factor**
ratio of the reflected flux as measured to the reflected flux under the same geometrical and spectral conditions for an ideal 100 % diffuse reflecting surface

[SOURCE: ISO/IEC 24790:2017, 3.30]

**3.1.2**
**spots per inch**
**spi**
spots per 25,4 mm

[SOURCE: ISO/IEC 24790:2017, 3.34]

**3.1.3**
**visual transfer function**
**VTF**
function used to represent human visual characteristics when dividing the system into parts and evaluating it as a superposition of transfer functions in the spatial frequency domain

**1**

**3.1.4**
**mura**
non-uniformity in the image that should be of uniform density or uniform colour

Note 1 to entry: Mura defects are larger than graininess or mottle, and it generally has ambiguous boundaries.

**3.1.5**
**addressability**
number of uniquely identifiable printable spot positions per unit distance

[SOURCE: ISO/IEC 29112:2018, 3.1.1]

**3.1.6**
**area modulation**
method of expressing gradation by changing the size or the frequency of dots

**3.1.7**
**density modulation**
method of expressing gradation by changing the density of pixels

**3.1.8**
**contrast transfer function**
**CTF**
ratio of the image contrast to the object contrast of a square-wave pattern as a function of spatial frequency

[SOURCE: ISO/TR 19319:2013, 2.2, modified — Notes 1 and 2 to entry were deleted.]

**3.1.9**
**modulation transfer function**
**MTF**
**spatial frequency response**
**SFR**
ratio, as a function of spatial frequency, of the measured modulation response in a print produced by a printing system, to the stimulus modulation presented to that printing system

[SOURCE: ISO/IEC 29112:2018, 3.1.16]

**3.1.10**
**line spread function**
**LSF**
normalized spatial signal distribution in the linearized output of an imaging system resulting from imaging a theoretical infinitely thin line

[SOURCE: ISO 12231:2012, 3.94, modified — Note 1 entry was deleted.]

**3.1.11**
**specular gloss**
gloss observed or measured at the specular angle

[SOURCE: ISO 8254-1:2009, 3.8]

**3.1.12**
**image clarity**
degree of sharpness of an image reflected by a specimen or transmitted through a specimen

[SOURCE: ISO 17221:2014, 3.1, modified — Note 1 to entry was deleted.]

## 3.2 Abbreviations

R          red

G          green

B          blue

V          visual

CIE        International Commission on Illumination

CIELAB     CIE 1976 (*L*a*b*) colour space

dpi        dots per inch

spi        spots per inch

cy/mm      cycle per millimetre

DOI        distinctness of image

# 4 Overview of the photographic print image quality

## 4.1 General

It is commonly understood that there are five major properties for representing the image quality of photographic prints, and each one is essential in representing the overall image quality. Each property can be further classified into several sub-properties. Table 1 presents these categorised properties and some related examples of measurements.

**Table 1 — Overview of properties and measurement methods**

| Property | Sub-property | Related measurement methods |
|---|---|---|
| (1) Density | a) Optical density | — Optical density R, G, B and V values for white, grey, black and each colour step |
| (2) Colour | a) Chromaticity | — Colorimetric value in colour space |
| | b) Colour gamut | — Coverage in colour space (area, volume) |
| (3) Uniformity | a) Micro uniformity | — Granularity and graininess (tens to hundreds of micrometres) |
| | b) Semi-micro uniformity | — Mottle (hundreds to thousands of micrometres) |
| | c) Macro uniformity | — Non-uniformity in print area, such as mura, banding and shading (thousands of micrometres to the whole printing area) |
| (4) Tone | a) Tone reproduction | — A characteristic of a printing system how colour or density is modulated by the change in the intensity of input image signal to the system. |
| | b) Capacity for tone reproduction | — Number of tonal steps |
| (5) Detail reproduction | a) Detail reproduction | — Contrast transfer function (CTF) property and several "spatial resolution" values |

The following aspects should be included when evaluating and measuring digital photographic print image quality, in comparison to that of traditional analogue photographic prints.

## 4.2   Density and colour

For density and colour measurement, additional colorants should be considered. In addition to cyan, magenta and yellow colorants, black colorant is typically used in many digital printing technologies. In some cases, more colorants, for example, orange or violet colorant, are used to improve density and colour reproduction. Of course, these additional colorants affect density and colorimetric value itself. Moreover, additional colorants can expand colour space because they enable vivid colour reproduction with less turbidity.

## 4.3   Uniformity

Uniformity measurement includes micro, semi-micro and macro uniformity. Because some digital photographic prints contain a structure of microdots, the dots themselves can be perceived as a sort of micro structure. Displacement of dots or colour registration failure can cause misalignment of microstructure. Misalignment negatively impacts the micro or sub-micro uniformity. Such attributes should be a concern, especially for digital photographic prints.

NOTE       Dot size (or dot area), dot gain, dot placement accuracy, and colour bleed are important parameters for analyzing the image quality described in this document. Rosettes, moiré and reticulation streaking are also important parameters to consider when assessing the image quality of digital prints.

## 4.4   Tone

For tone measurement, the capacity for tone reproduction should be addressed in addition to tone curve. Depending on the original digital image file format, the image's capacity to differentiate pixel tone is limited; for example, 256 levels for 8-bit format, 1 024 levels for 10-bit format. It is important to measure the distinguishability of each of the available levels in the printed image.

## 4.5   Detail reproduction

Regarding detail reproduction, micro image structures directly affects how finely an image can be represented. However, there are many kinds of micro image structure now present in digital imaging across the variety of print technologies. For digital prints especially, one should be concerned with how the image is perceived by human eye. This is crucial when comparing the properties of prints produced with different printing technologies.

## 4.6   Glossiness

In addition to the five major properties above, reflective properties such as glossiness need to be addressed for all photographic prints but especially for digital photographic reflection prints. In traditional silver halide prints, colour images are generated inside the surface gelatin layer. However, in many types of digital print technologies, colorants are set on substrates, so that colorants themselves form some parts of the print surface. Thus, the intensity and uniformity of the light reflected from such prints will change depending on the illumination under which a print is observed.

## 4.7   Others

The above measurements address the quality of a given print, but the variation or repeatability of image quality among multiple prints is another important aspect. Colour variation affects not only identity in print duplication but also overall quality of a print series; for example, a photo book that includes various scenes in a specified sequence.

In this document, measurement methods for five major properties are described in the following clauses, from Clause 5 to Clause 9. In addition to the five major properties, glossiness measurement methods are described in Clause 10. Colour variation in printing will be described in another document of the ISO 20791 series (future ISO/TS 20791-2).

## 5   Density

Density can be measured according to ISO 5-3[7] and ISO 5-4[8]. With these methods, the red (R), green (G), blue (B) and Visual (V) density values can be assessed in a single measurement. A test chart for density measurements consists of several patches of sufficient size to be measured with an applied densitometer. A typical test chart is shown in Figure 1. It has grey, cyan, magenta, yellow, red, green and blue tone patches, with the numerical digital value at equal intervals. The maximum density of each colour and the density of $D_{min}$ patch in the test chart are especially important. The results of density measurements can also be used to evaluate the gamma attribute, as well as tone curve.
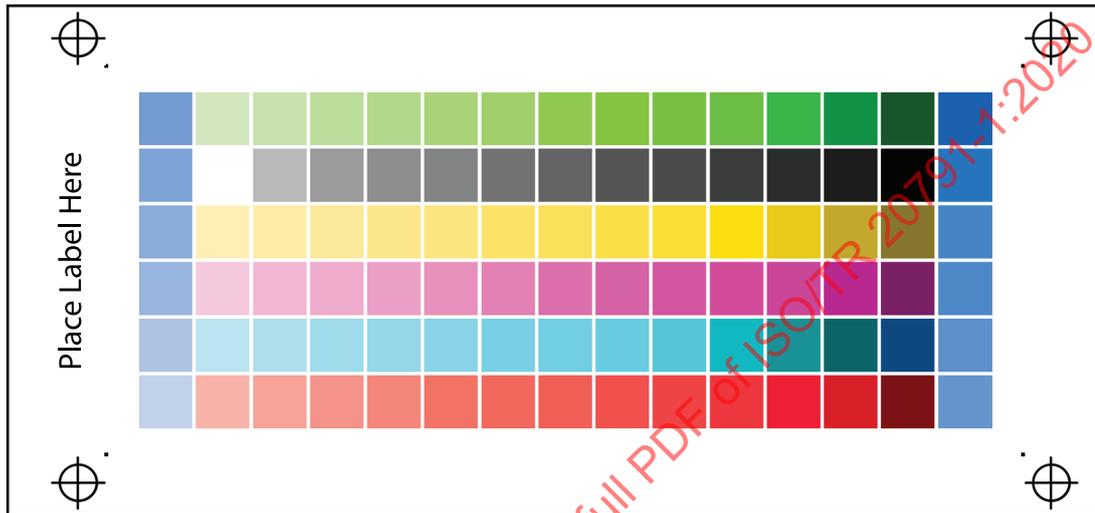


**Figure 1 — An example of a test chart for density and colour measurements (ISO 18944[9])**

## 6   Colour

Chromaticity can be measured according to ISO 11664-1[10], ISO 11664-4[11] and ISO 13655[12]. With these methods, colorimetric values $L*$, $a*$, and $b*$ in CIELAB 1976 colour space can be assessed in a single measurement and subsequent calculations. Conforming to ISO 13655, CIELAB values are computed using CIE illuminant D50 and the CIE 1931 standard colourimetric observer (often referred to as the 2° standard observer). Other illuminants can be used depending on circumstances and purpose of the measurement. A test chart for chromaticity measurements consists of several patches of sufficient size to be measured with an applied colorimeter. An example test chart is shown in Figure 1. Grey, cyan, magenta, yellow, red, green, blue and white patches are fundamental components of the test chart. Special colours can be added, for example, skin tones, leaf green and sky blue.

In addition to colorimetric value itself, coverage in colour space is an important concern for digital photographic prints. Since $a*$-$b*$ chromaticity diagrams represent considerable information while remaining visually simple, they have been used widely in photography analysis. Examples of an $a*$-$b*$ chromaticity diagram are shown in Figure 2.
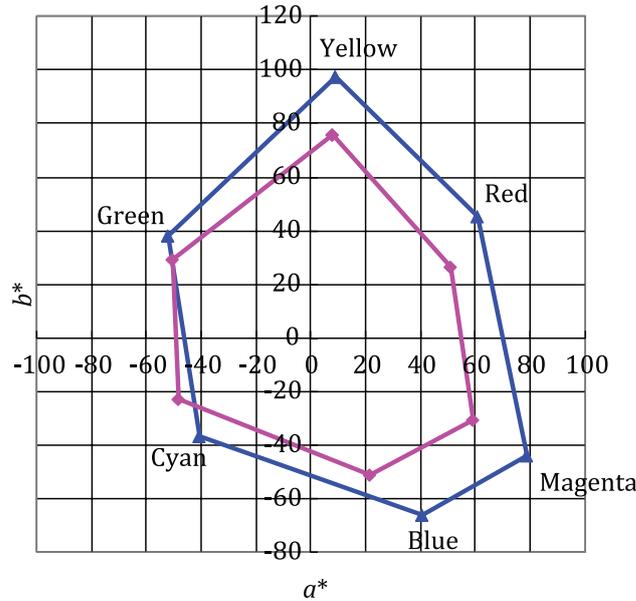
**Figure 2 — Examples of an *a\*-b\** chromaticity diagram**

Coverage in three-dimensional colour space is measured according to ISO/TS 18621-11[13]. Colour space coverage can thus be calculated as volume in CIELAB 1976 colour space. A sufficient number of patches is needed for the calculation of volume. An example test chart including 756 patches, as stipulated in ISO/TS 18621-11, is shown in Figure 3. If the print size is not large enough to contain the full test chart with suitable patch sizes, the test chart should be divided and printed across multiple prints



**Figure 3 — An example of a test chart for measurement of coverage in colour space**

For measuring volume in CIELAB 1976 colour space, ISO/TS 18621-11 provides a way to obtain measurement values; for example, the volume of a single gamut, or the volume of the interaction of two gamuts. A schematic image of coverage in colour space is shown in Figure 4. For evaluation of a photographic image, reporting the value of colour gamut area or colour gamut volume is not sufficient, because:

a)   the value does not indicate the dependence of luminance range, and

b)   the value does not indicate the hue direction which is sometimes more important than the value of the colour gamut.
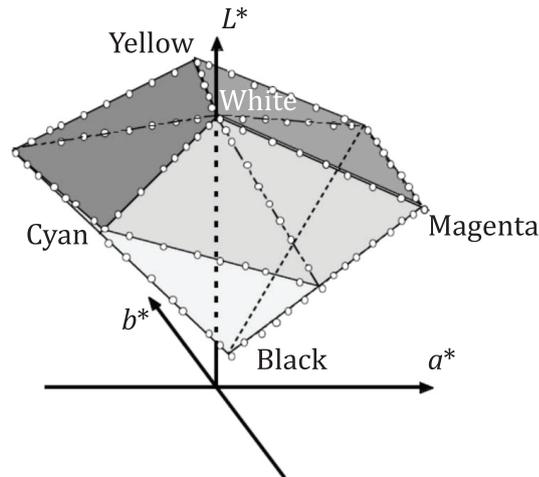
**Figure 4 — Schematic 3D image of coverage in colour space**

In those cases, a set of graphs of $a^*$-$b^*$ plane at a range of $L^*$ values is effective, providing a clear visual depiction of features of colour reproduction from shadow to highlight. Examples of such graph sets are shown in Figure 5. This type of graph is more preferable for quantitative and scientific representation of photographic image than a schematic 3D image such as Figure 4.



**a)** $L^*$=20     **b)** $L^*$=40     **c)** $L^*$=60     **d)** $L^*$=80
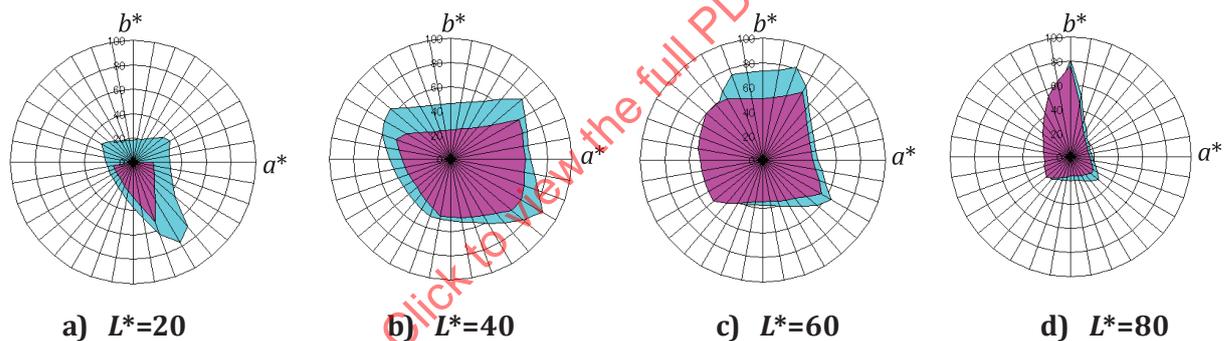
**Key**

■ system A

■ system B

**Figure 5 — Example graphs of area coverage in the $a^*$-$b^*$ plane at specific $L^*$ values**

# 7   Uniformity

## 7.1   General

For uniformity measurement, spatial dimensions are important. Uniformity is often sub-categorised at three levels: micro, semi-micro and macro uniformity. Variation of density, reflectance factor or colorimetric value is measured in each sub-category and calculated according to its specific size range.

— Micro uniformity: spatial fluctuation from tens to hundreds of micrometres.

— Semi-micro uniformity: spatial fluctuation from hundreds to thousands of micrometres.

— Macro uniformity: spatial fluctuation from thousands of micrometres to the whole printing area.

Both micro uniformity and semi-micro uniformity are sometimes called "noise" if the fluctuations are aperiodic. Macro uniformity is sometimes named according to its obvious visual feature such as "banding," "streak," "shading" and so on.

## 7.2   Micro uniformity

### 7.2.1   Granularity

Micro uniformity is sometimes measured with "granularity." ISO 10505[14] provides a photographic film measurement method called root mean square granularity. Density fluctuation is measured with a microdensitometer, and the root mean square value is calculated. A similar method can be applied to reflection analogue prints. However, this method is not appropriate for modern digital prints that have two-dimensional micro structures.

A simple way to measure two-dimensional granularity is the "graininess metric". Instead of a microdensitometer, this method uses a scanner with a minimum of 600 spi to obtain a two-dimensional density map as stipulated in ISO/IEC 13660[15], which has been withdrawn and replaced by ISO/IEC 24790[1] mentioned below. The two-dimensional density map is divided into small tiles, as shown in Figure 6. Granularity is then calculated as the root mean square deviation from the mean of density among tiles.

NOTE      Within each tile of Figure 6, there are 900 evenly-spaced scanned pixels and the standard deviation of 900 density data is calculated. The size of each scanned pixel is 42 μm. It is a little bit larger than other referred methods but within the range of micro uniformity in this document (several tens to hundreds of micrometres).
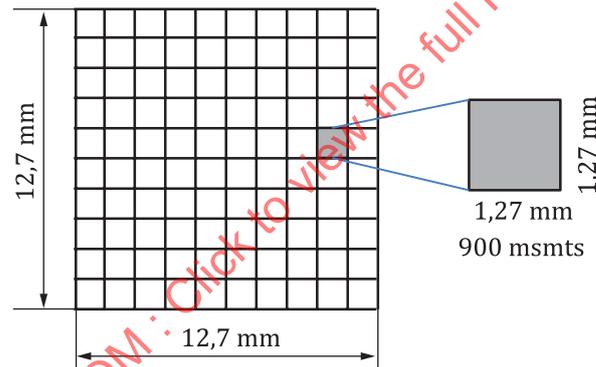


**Figure 6 — Schema for measuring "graininess metric"**

### 7.2.2   Graininess

In imaging science and technology fields, several methods have been proposed that take human visual perception into account[16][17][18]. Results of these methods are called "graininess" because they are a type of psychophysical property. Using these methods, the print image is scanned with a flat bed scanner. Two-dimensional digitised data from the scanned image are processed, and a graininess value is calculated. Power spectrum analysis and filtering using a visual transfer function are the essential components of the calculation. A schematic of this calculation process is shown in Figure 7. This process was originally proposed by R. P. Dooley and R. Shaw for perceptual noise measurements in electrophotography[16].
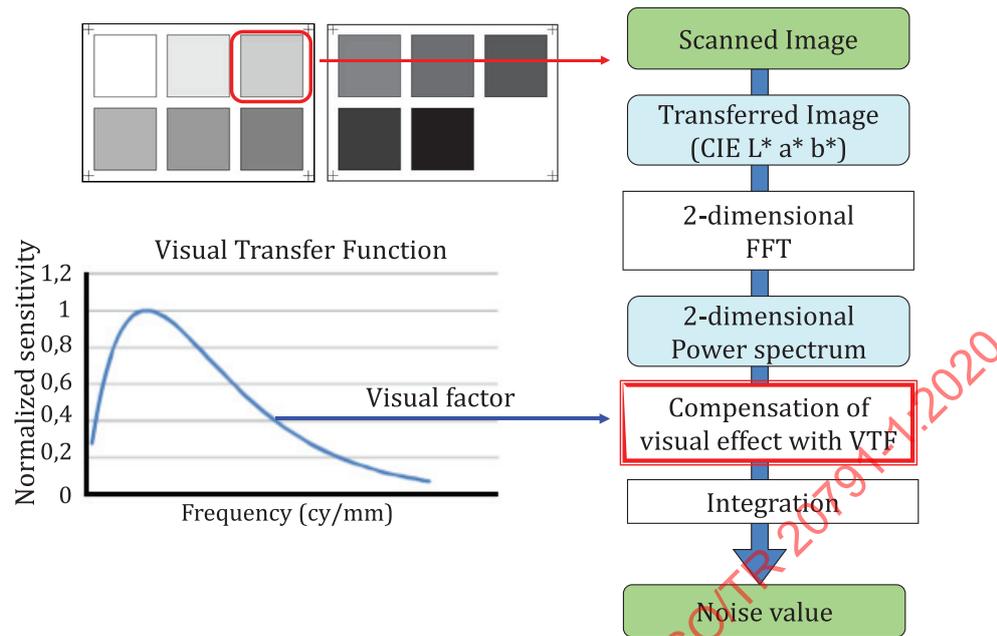
**Figure 7 — Schematic calculation process for granularity value**

The measurement of a modified "graininess metric" was proposed in ISO/IEC 24790[1]. In ISO/IEC 24790, graininess is defined as appearance of unintended microscopic, but visible aperiodic fluctuations of lightness. It is noted that microscopic means variations with spatial frequencies greater than about 0,4 cy/mm. In this modified method, the print image is scanned with a scanner with a minimum 1 200 spi. Power spectrum analysis and filtering are also used in this method. Wavelet transform is used, and frequency components higher than 1,48 cy/mm and lower than 0,37 cy/mm are removed. After inverse wavelet transform, the processed image is divided into small tiles as shown in Figure 8. This tiling functions as high-pass filtering in the following calculation process, which removes frequency components lower than 0,39 cy/mm. These processes have effects similar to the application of the visual transfer function above. Variance of the reflectance value inside each tile is calculated. Finally, the root of the average variance for all tiles becomes the value of the modified graininess metric.
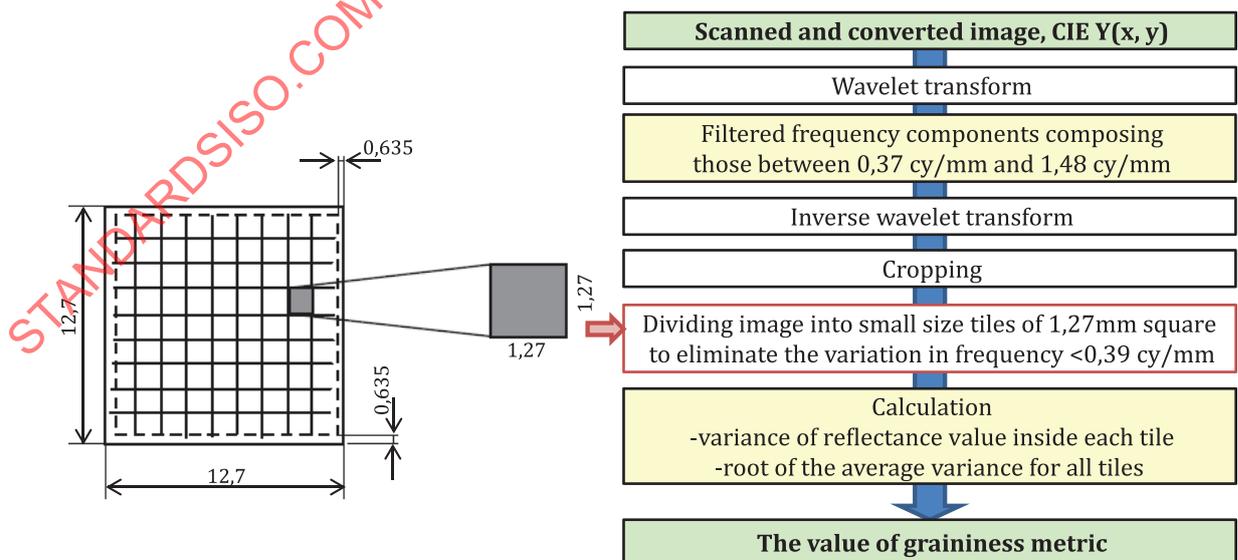


**Figure 8 — Measurement and calculation process for the modified "graininess metric" (ISO/IEC 24790)**

## 7.3 Semi-micro uniformity

Semi-micro uniformity is usually called "mottle". It relates to noise at frequencies lower than those of granularity and graininess. Methods similar to those used for measuring graininess can be used for measuring mottle. Mottle measurement differs from graininess measurement in the filtering. Noise components of lower spatial frequency, approximately from 0,1 to 1 cy/mm, are passed through the filtering process.

Measurement of the "mottle metric" was also proposed in ISO/IEC 24790. In ISO/IEC 24790, mottle is defined as appearance of unintended, aperiodic macroscopic fluctuations of lightness. It is noted that macroscopic means variations with spatial frequencies less than about 0,4 cy/mm. In the filtering process, frequency components higher than 0,37 cy/mm and lower than 0,09 cy/mm are removed. As shown in Figure 9, the tile size is larger for "mottle" measurements than for "graininess metric" measurements; therefore frequency components lower than 0,20 cy/mm are removed in the calculation process. Variance of the reflectance value inside each tile is calculated. Finally, the root of the average of the variance of all tiles is used as the value of the mottle metric.
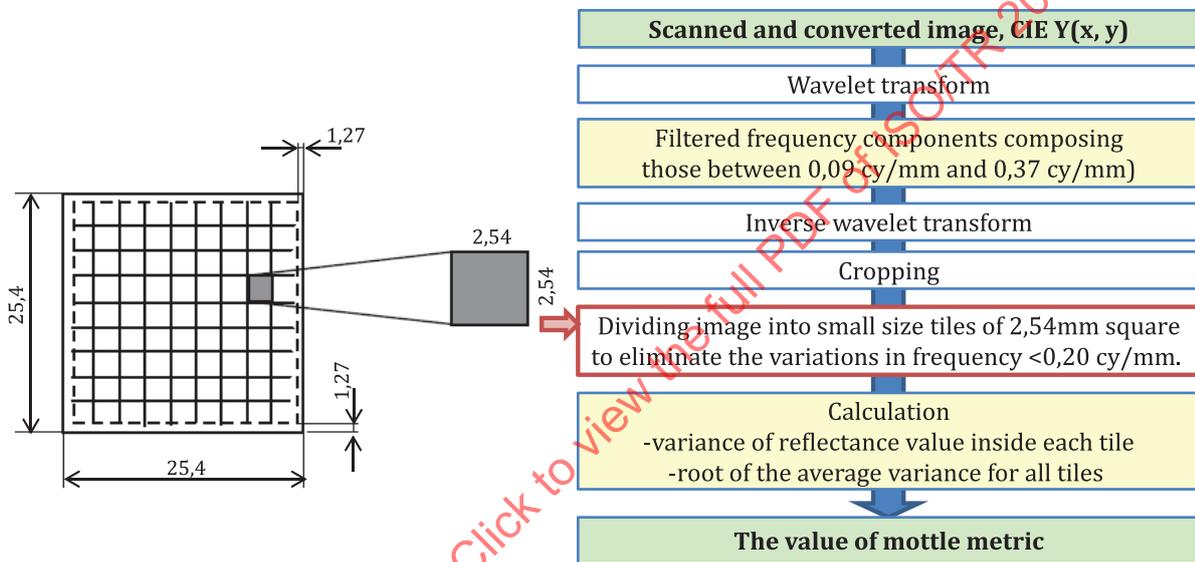


**Figure 9 — Measurement and calculation process for the "mottle metric" (ISO/IEC 24790)**

## 7.4 Macro uniformity

Macro uniformity refers to fluctuation in larger portions of the print image, up to the whole print area. In measuring macro uniformity, a plain image print is scanned with a flat bed scanner. The scanned image is divided into multiple tiles whose size is set at between 1 mm and 20 mm. Density or colourimetric value of every tile is calculated and analysed. Various measures of macro uniformity are listed below.

— Standard deviation of the value of all tiles.

— Difference between maximum and minimum values across all tiles.

— 95th percentile value of the pairwise differences between all possible pairs of values across all tiles.
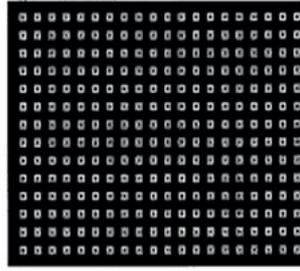
**Figure 10 — An example of measuring points for macro uniformity**

Measurement of macro uniformity is proposed with the draft document of ISO/TS 18621-21[19]. In this measurement method, a test pattern including the plain grey image shown in Figure 11 is printed. The scanned image is divided into multiple square tiles of side length 6 mm. CIEDE2000 colour difference $\Delta E_{00}$ is calculated between neighbouring averaged tiles in each row and column. The "macro uniform score" value, which is a number in the range zero to one hundred, is calculated from all the row and column data, according to Formula (1).

$$Macro\ Uniformity\ Score = 100 \times \left[ \frac{1}{2^{\left(\frac{2 \times \Delta E_{total}}{15}\right)}} \right]$$

(1)
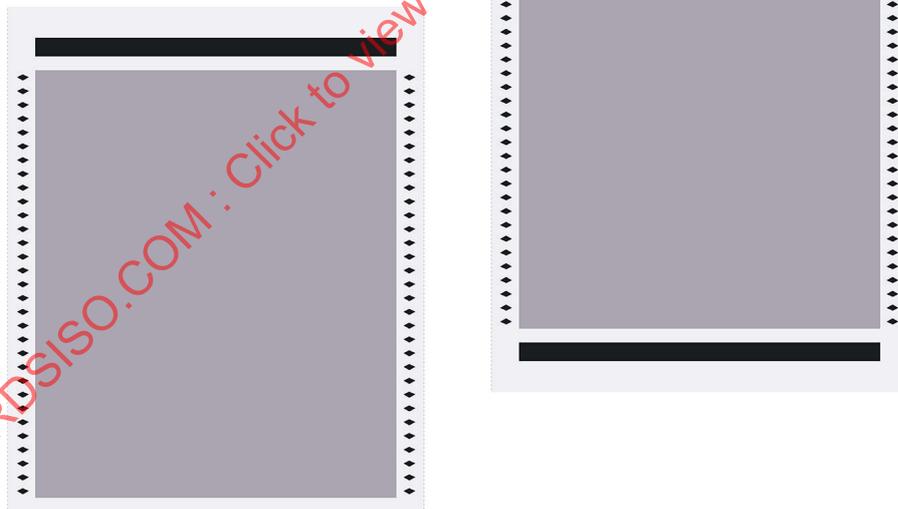


**Figure 11 — Test chart for macro uniformity score (ISO/TS 18621-21)**

Banding is the appearance of one dimensional bands within a plain image. It is one case in which macro uniformity is perceived as being poor. ISO/IEC 24790[1] provides the measurement method of banding. Components of periodic banding or line-shaped defects are extracted through power spectrum analysis within the process of this measurement. One dimensional L* profile is calculated from the scanned image and any high frequency component larger than 0,5 cy/mm is removed by the filtering process between Fourier and inverse Fourier transform. The local extrema are extracted from the filtered profile and the value of the banding metric is calculated from pooled summation of the local extrema. See ISO/IEC 24790:2017, 5.2.9, for details of calculation process.
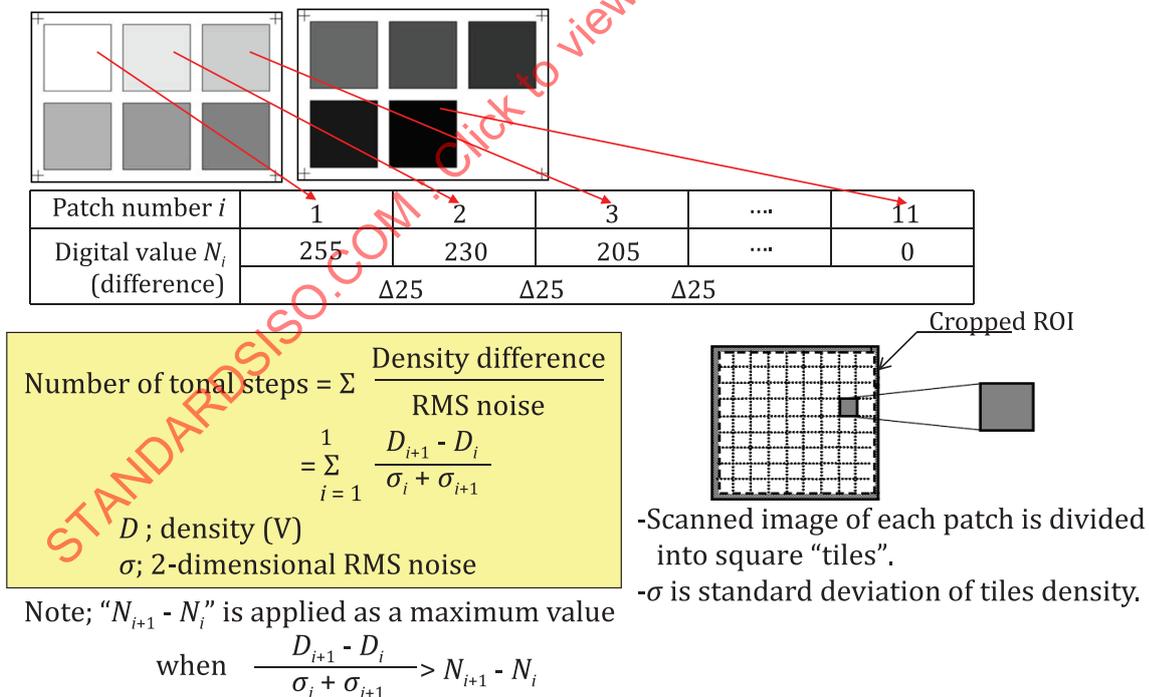
# 8 Tone

## 8.1 Tone reproduction

Tone reproduction is a characteristic of a printing system describing how colour and/or density is modulated by the change in the intensity of the input image signal to the system in order to best reproduce the image according to a viewer's subjective preference. Tone reproduction is designed to represent a preferable image quality for each printer with respect to its characteristics, such as reproducible dynamic range in tone and colour, noise level and halftone process.

The tone curve is one of the basic parameters of tone reproduction. It is a curve that describes the relationship between the input signals and the output density of prints using the methods stated in Clause 5.

## 8.2 Capacity for tone reproduction

As mentioned above, the capacity for tone reproduction is an important property for digital photographic prints because an original digital image consists of pixels, which have a limited digital level. As the value of the noise level increases, it becomes more difficult to distinguish the difference between patches of similar grey levels.

To address this concern, a number of tonal steps[20][21] can be measured with a calculation process shown in Figure 12. The density difference between two patches is divided by the noise measurement value, and the results are summed from the patch of minimum density to the patch of maximum density. Results of micro or semi-micro uniformity described in 7.2 and 7.3 can be applied as the noise measurement value. Care should be taken to apply the same property [e.g., density ($D$), reflectance factor ($Y$) or luminance factor ($L^*$)] for both values: the denominator value (difference of property) and the numerator value (noise).



Number of tonal steps $= \Sigma \dfrac{\text{Density difference}}{\text{RMS noise}}$

$$= \sum_{i=1}^{1} \frac{D_{i+1} - D_i}{\sigma_i + \sigma_{i+1}}$$

$D$ ; density (V)
$\sigma$; 2-dimensional RMS noise

Note; "$N_{i+1} - N_i$" is applied as a maximum value

when $\dfrac{D_{i+1} - D_i}{\sigma_i + \sigma_{i+1}} > N_{i+1} - N_i$

-Scanned image of each patch is divided into square "tiles".
-$\sigma$ is standard deviation of tiles density.

**Figure 12 — Schematic calculation process for a number of tonal steps**

Number of tonal steps is affected by both dynamic range and noise. When two prints with similar dynamic range are compared, the degree of noise has a strong impact on results of number of tonal steps. One opinion worth noting is that number of tonal steps is a type of noise expression because prints that are compared are often found to have a similar dynamic range.

## 9   Detail reproduction

### 9.1   General

Detail reproduction is a characteristic that shows how finely an image is reproduced on prints and how sharply the edge of an image element is reproduced. It is measured as a tonal difference between adjacent image elements. Therefore, it relates to the dynamic range in density or colorimetric measurements and above-mentioned tone curve. Larger tonal differences between finer image elements result in higher levels of detail reproduction.

One important aspect of detail reproduction is spatial resolution. The term "dpi" as printer addressability usually does not correspond to the quality of detail reproduction in the printed image, because other parameters (input image data, media, colorants, screening and so on) also affect the detail reproduction of prints.

NOTE      As indicated above, sometimes the term "dots per inch (dpi)" of printers is expressed as a property of prints, which can cause misunderstanding.

In addition, the term dpi has different meanings in various technologies. Even though the term "dpi" is useful for comparing the ability of detail reproduction among similar systems, extreme differences arise especially between area modulation technology and density modulation technology. While tone and colours are represented with multiple dots in area modulation technology, they can be represented with a single dot in density modulation technology.

So the term "dpi" is not appropriate for comparing prints quality, particularly when generated by different technologies.

The measurement methods using patterns of fine lines are described in 9.2. And measurement method with contrast resolution test target is described in 9.3.
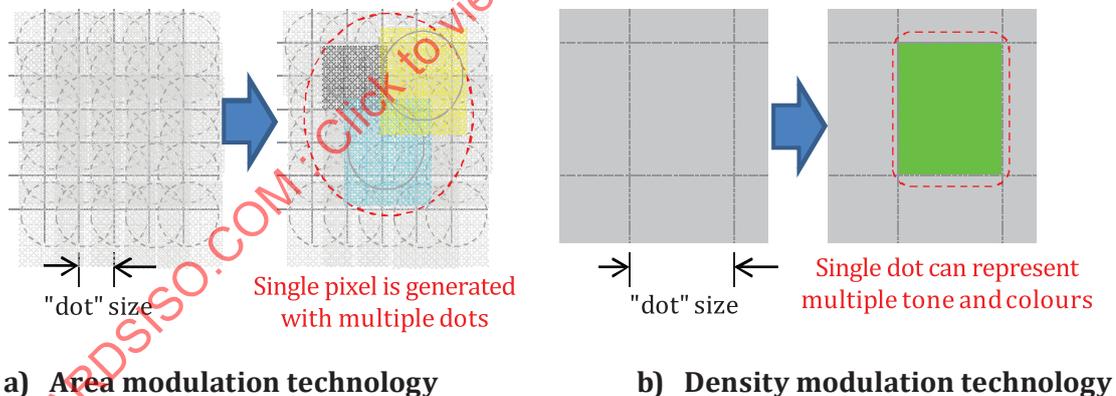


"dot" size    Single pixel is generated with multiple dots

"dot" size    Single dot can represent multiple tone and colours

**a)  Area modulation technology**          **b)  Density modulation technology**

**Figure 13 — Schematic of differences between a) and b)**

### 9.2   Resolution measured with patterns of fine lines

Detail reproduction can be evaluated by means of patterns of fine lines; a typical pattern is shown in Figure 14. CTF metrology is applied in this measurement. Densities of both lines and blank spaces are measured with micro densitometers or scanners. The CTF value is then calculated with Formula (2). This formula is a density-based measurement. An analogous measurement that uses similar formula, but is based on optical reflectance, is also popular in the field of graphic technology.

$$CTF = \frac{d_{\text{lines}} - d_{\text{blanks}}}{d_{\text{lines}} + d_{\text{blanks}}}$$

(2)
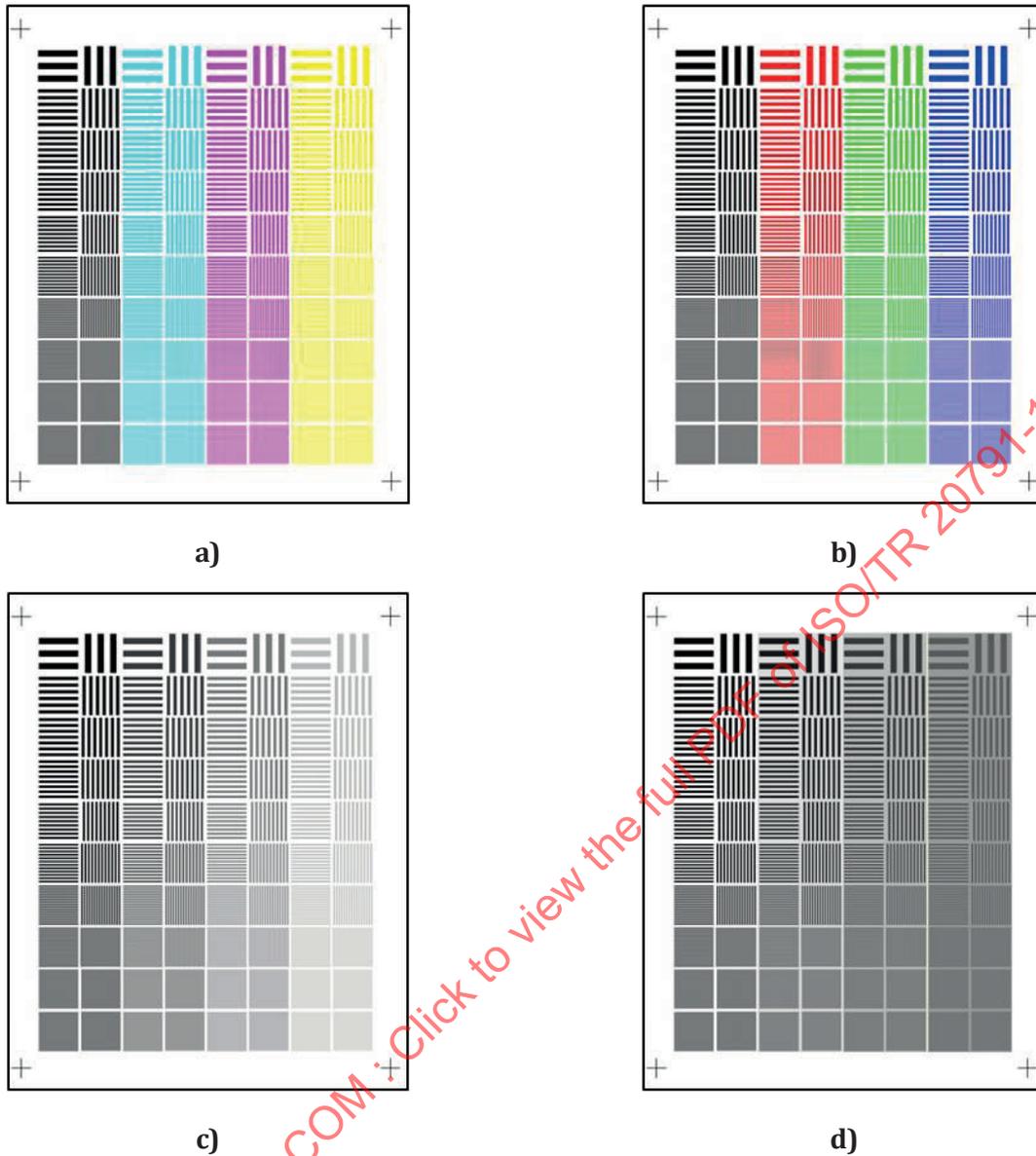
**Figure 14 — Typical patterns for evaluation of detail reproduction**

The method of "printer modulation transfer function (MTF) estimation from 1-D repeating patterns" is proposed in ISO/IEC 29112[2]. Printed test patterns shown in Figure 15 are captured with a scanner. Fourier analysis of a repeating one-dimensional square-wave pattern provides an estimation of a printer MTF characteristic. The document defines that the spatial frequency at 50 % modulation provides an estimation of the perceived sharpness of repeated detail, and that the spatial frequency at 10 % modulation provides an estimation of the limiting resolution of repeated detail.

NOTE     ISO/IEC 29112 includes not only square wave spatial frequency response (SFR) but a variety of methods to evaluate resolution of a printer with some correlation with subjective resolution of printed images as described in ISO/IEC 29112:2018, Annex F. Included are the native addressability, the effective addressability, the edge blurriness, the edge raggedness, the slanted-edge SFR and the square-wave SFR. The document is intended to be used for monochrome prints by electro-photography.

**Figure 15 — Test patterns for "printer MTF estimation" in ISO/IEC 29112, (left) 0° orientation and (right) 90° orientation**

## 9.3 Resolution measured with contrast-resolution test target

Resolution evaluation needs to reflect how the human visual system perceives the image. For this purpose, a test chart called "the contrast-resolution test target" has been developed. It is shown in Figure 16. A resolution score has been proposed using this test chart[22] The chart consists of one hundred patches with concentric circles, with ten levels each for spatial resolution and contrast. Resolution score is judged by the visibility of concentric circles; the number of distinguishable patches is reported. It is mainly used in graphic prints, but it can be applied to photographic prints as well.
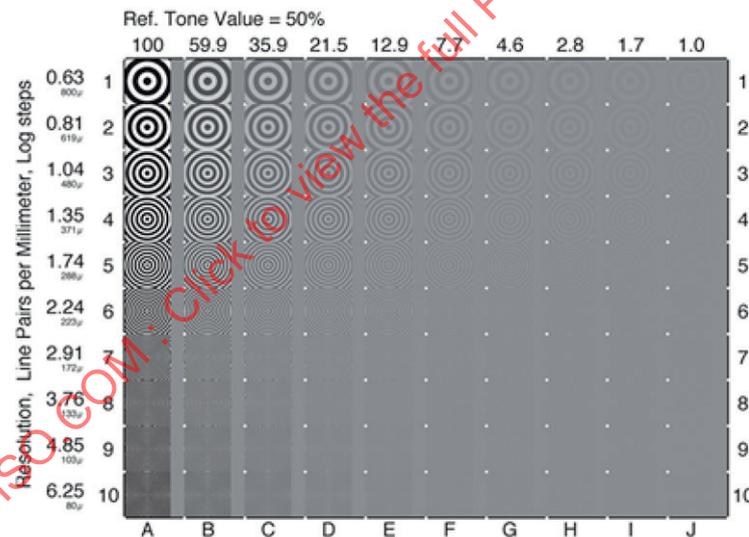


**Figure 16 — Contrast-resolution test target**

Objective measurement of the contrast-resolution test target has been proposed in ISO/TS 18621-31[23]. This method uses a flat bed scanner. The scanned image is compared with a reference image in terms of key visual aspects. Resolution score is calculated as the summation of correlation factors over the one hundred patches.
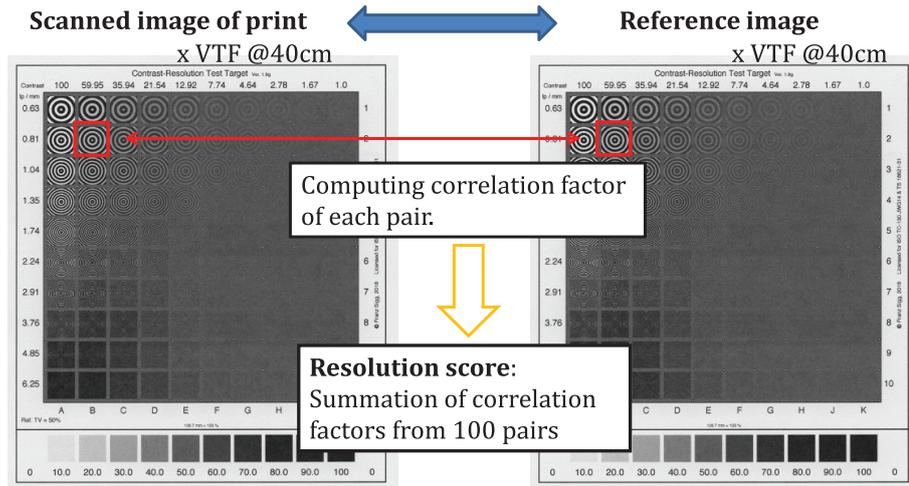
**Figure 17 — Schematic calculation process for resolution score using flat bed scanner**

# 10 Glossiness

## 10.1 General

In addition to the five major properties mentioned in Clauses 5 to 9, reflective properties such as glossiness are significant for photographic prints. Ambient light is reflected off the surface of prints both specularly and diffusely. Even in cases where specularly reflected light carries no information about the print image, it can affect the observer's perception. Such perceptions have led to the establishment of glossiness preferences.

Several types of surface finishing are typically available; for example, glossy, matte and silk. In addition to surface finishing, other glossiness differences may arise due to the imaging layer surface structure generated by different print technologies. For example, in traditional silver halide prints, colour images are generated inside the surface gelatin layer, whereas in many modern digital print technologies, colorants are set on substrates and form parts of the print surface.

"Specular gloss" is the glossiness sub-property most often measured; it simply represents the intensity of the specularly reflected light[5][24]. This sub-property is widely used for various surfaces of materials and samples to characterise them as "high gloss" or "low gloss." However, in some cases of photographic print evaluation, observers perceive a "glossy" surface even for the "low gloss" samples. Some researchers have pointed out that the sharpness of the reflected light affects the human perception of gloss. They recommend measuring additional properties relating to the sharpness of reflected light, such as "Distinctness of Image" (DOI) or "Image clarity"[25]. It is also mentioned that the combination of DOI and "Specular gloss" is correlated well to the human perception[26].

NOTE        In addition to the above characteristics, the spectrum of the reflected light can be changed according to observation angle. This phenomenon is sometimes called bronzing which used to be observed on some older types of digital prints where pigments are applied on glossy papers. It can be measured with goniometric spectrocolorimetry[27][28].

## 10.2 Specular gloss

Measurement of specular gloss is stipulated in ISO documents ISO 8254-1[5] and ISO 2813[24]. These stipulations are referenced in ISO/TS 15311-1[29] and can also be applied to photographic prints. In the measurement of specular gloss (Figure 18), the incident angle is selected from among 20°, 60°, 75° and 85°. Smaller angles (20°) are typically appropriate for distinguishing differences among high gloss samples, while larger angles (75° or 85°) are appropriate for distinguishing differences among low gloss samples. For comparing many kinds of photographic prints at one time, 60 degrees is the most widely used.