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Photography — Archiving systems — Imaging systems quality analysis —

Part 1: Reflective originals

Photographie — Systèmes d'archivage — Analyse de la qualité des systèmes d'image —

Partie 1: Documents réfléchissants

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Foreword

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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).

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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 42, *Photography*.

This first edition of ISO 19264-1 cancels and replaces the first edition of ISO/TS 19264-1, which has been technically revised.

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

Electronic imaging systems, such as scanners and cameras, can be used for digitizing physical records, e.g. documents, pictures, maps. The resulting digital images can be more or less accurate in terms of how well they reproduce the original record's tones, colours, details, etc. These and other characteristics of a digital image can be assessed by imaging systems' quality analysis. In general, the achievable accuracy of digital reproductions depends on the nature of the original record and the digitization, especially the performance of the imaging system and the applied system settings.

In some organizations, e.g. within the archiving and cultural heritage field, where considerable resources are put into digitization projects, it is key to ensure that the required imaging systems' quality is met and that it is consistent. To this end, imaging systems' quality analysis can assist those developing or acquiring imaging systems with the assessment and verification of system performance, such as the specified resolution and dynamic range of a scanner, and the comparative performance of different imaging systems. Imaging systems' quality analysis is also used for setting up and calibrating imaging systems as well as for enhancing their performance. Finally, imaging systems' quality analysis is used for assessing accuracy and controlling imaging consistency over time. Note, that while the need to ensure imaging systems' quality is generic, the required level of imaging systems' quality and accuracy is use-case specific. For example, when digitizing watercolours it is usually essential to reach a high degree of accuracy in the capture of the colour information, while this is not normally equally critical when digitizing newspapers. Also, some image processing programs, such as Optical Character Recognition (OCR), are more accurate if the contrast is enhanced during imaging.

In practice, imaging systems' quality is analysed by digitizing a physical reference target (test chart) with known (measured) values and comparing these reference values to the corresponding captured values represented in the digital image file (see Figure 1).

The use of a test chart ensures that the imaging systems' quality characteristics can be determined objectively. However, to be usable the quality of the target needs to exceed the performance of the imaging system. For example, to determine the resolution of an imaging system, the target needs to have a technical pattern with more details than the system is capable of resolving. Imaging systems' quality analysis reports how accurately the imaging system reproduces the reference target. Therefore, if the original record differs significantly from the target, e.g. with respect to tone, tonal range, colours, details, and light reflectance/absorbance, this may, in spite of a well performing system, compromise the accuracy of the reproduced image. See also References [29] and [32] Ideally, the targets should resemble the nature of the original material. However, given the many different types of original records this is often not practical or technically impossible. Even though systems may perform differently on the different types of originals this document provides tools to verify if a system is accurately calibrated and in general performs well on a selected type of original. This is sufficient in most cases because systems are usually designed to handle various types of originals (being close to the Luther condition[42]) Performance on specific types of originals however can only be verified if the tools are made of that material. It is also important to note that an accurate reproduction usually requires subsequent processing to render a visually pleasing image.

There are ISO standards for objectively measuring different performance characteristics of imaging systems, e.g. resolution, noise, dynamic range, tone and colour reproduction (see Clause 2). This document combines all of the standards that relate to the imaging systems quality analysis for cultural heritage and defines a tool set to apply them to these devices and workflows. These tools are based on the use of a test chart with multiple technical patterns coupled with software that allows the user to analyse several imaging systems' quality characteristics simultaneously and receive comprehensive results. However, these tools are not based on a standardized image quality analysis method, which has caused confusion among users. With the publication of this specification imaging systems' quality analysis tools can refer to an ISO document.

To support this document a standard with a glossary including all relevant terms and definitions has been developed (ISO 19262). Further this document is accompanied by a Technical Report (ISO/TR 19263-1) that provides practical guidance on how to use this document.

Photography — Archiving systems — Imaging systems quality analysis —

Part 1: Reflective originals

1 Scope

This document describes a method for analysing imaging systems quality in the area of cultural heritage imaging. The method described analyses multiple imaging systems quality characteristics from a single image of a specified test target. The specification states which characteristics are measured, how they are measured, and how the results of the analysis need to be presented.

This specification applies to scanners and digital cameras used for digitization of cultural heritage material.

NOTE This document addresses imaging of reflective originals, a future part two will address imaging of transparent originals.

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 12233, *Photography — Electronic still picture imaging — Resolution and spatial frequency responses*

ISO 14524, *Photography — Electronic still-picture cameras — Methods for measuring opto-electronic conversion functions (OECFs)*

ISO 15739, *Photography — Electronic still-picture imaging — Noise measurements*

ISO 16067-1, *Photography — Spatial resolution measurements of electronic scanners for photographic images — Part 1: Scanners for reflective media*

ISO 17957, *Photography — Digital cameras — Shading measurements*

ISO 21550, *Photography — Electronic scanners for photographic images — Dynamic range measurements*

ISO/CIE 11664-4, *Colorimetry — Part 4: CIE 1976 L*a*b* colour space*

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
acutance
numerical value that correlates to some extent with subjective image sharpness

[SOURCE: ISO 19262:2015, 3.1]

3.2
banding
unwanted stripes or bands that occur in a digital image

Note 1 to entry: Bands are usually caused by fixed pattern noise of sensors in scanners, interference problems between electronic parts of a camera, or by too-coarse quantization.

[SOURCE: ISO 19262:2015, 3.9, modified — addition of "or by too-coarse quantization" in the Note 1 to entry.]

3.3
checkerboard
regular squared dark and bright structure on a surface like the one used on a chess board

[SOURCE: ISO 19262:2015, 3.18]

3.4
colour misregistration
colour-to-colour spatial dislocation of otherwise spatially coincident colour features of an imaged object

[SOURCE: ISO 19262:2015, 3.42]

3.5
digitization
act of generating a digital (quantized) representation of a continuous signal

[SOURCE: ISO 20998-1:2006, 2.7, modified — The Note 1 to entry has been deleted.]

3.6
distortion
geometric distortion
displacement from the ideal shape of a subject (lying on a plane parallel to the image plane) in the recorded image

Note 1 to entry: It basically derives from variation of lateral magnification in the image field of a camera lens and results in straight lines being rendered as curves. There are other factors to induce geometric distortion, for example rotational asymmetry of a camera lens or position shift processing in a camera imaging process.

[SOURCE: ISO 19262:2015, 3.82]

3.7
dynamic range
difference, over a given luminance range, between maximum and minimum signal levels, expressed in decibels, contrast ratios or f-stops

Note 1 to entry: The minimum signal level needs to be greater than a specified usable signal level.

Note 2 to entry: This definition is derived from IEC 702-04-23 but was altered to match the imaging and archiving application.

[SOURCE: ISO 19262:2015, 3.87]

3.7.1
ISO scanner dynamic range
difference of the maximum density where the incremental gain is higher than 0,5, as determined according to ISO 21550 to the minimum density that appears unclipped

[SOURCE: ISO 21550:2004, 3.13]

3.8
exposure
H
<photographic> total quantity of light allowed to fall upon a photosensitive emulsion or an imaging sensor

Note 1 to entry: The exposure is measured in lux per second.

[SOURCE: ISO 10934-1:2002, 2.50, modified — A symbol, the field of application and a note to entry have been added.]

3.9
fast scan direction
scan direction corresponding to the direction of the alignment of the addressable photoelements in a linear array image sensor

[SOURCE: ISO 16067-1:2003, 3.7]

3.10
gain modulation
variation of the gain over the signal level

Note 1 to entry: One example for a gain modulation is the application of a gamma to an image.

[SOURCE: ISO 19262:2015, 3.109]

3.11
grey scale pattern
test chart consisting of test pattern based on spectrally neutral or effectively spectrally neutral, and consists of a large number of different reflectance or transmittance values in a prescribed spatial arrangement

Note 1 to entry: Grey scale patterns are typically used to measure opto-electronic conversion functions.

3.12
limiting resolution
value of that portion of a specified *resolution* (3.21) test pattern, measured in line widths per picture height, which corresponds to an average modulation value equal to some specified percentage of the modulation value at a specified reference frequency

Note 1 to entry: The limiting resolution could be the test pattern value, in line widths per picture height (w_l/h_p), corresponding to a camera output modulation level of 10 % of the camera output modulation level at a reference frequency of 10 w_l/h_p.

3.13
modulation
difference between the minimum and maximum signal levels divided by the sum of these levels

[SOURCE: ISO/IEC 29112:2012, 3.17]

3.14
noise
unwanted variations in the response of an imaging system

[SOURCE: ISO 15739:2013, 3.9]

3.15
opto-electronic conversion function
OECF
relationship between the log of the input levels and the corresponding digital output levels for an opto-electronic digital image capture system

Note 1 to entry: If the input log exposure points are very finely spaced and the output noise is small compared to the quantization interval, the OECF possibly has a step-like character. Such behaviour is an artefact of the quantization process and needs to be removed by using an appropriate smoothing algorithm or by fitting a smooth curve to the data.

[SOURCE: ISO 17321-1:2012, 3.3]

3.16
original-referred
scene-referred
image state associated with image data that represents the colour-space coordinates of the elements of a two dimensional hardcopy or softcopy image, typically produced by scanning artwork, photographic transparencies or prints, or photomechanical or other reproductions

Note 1 to entry: When the phrase "original-referred" is used as a qualifier to an object, it implies that the object is in an original-referred image state. For example, original-referred image data are image data in an original-referred image state.

Note 2 to entry: Original-referred image data are related to the colour-space coordinates of the original, typically measured according to ISO 13655, and do not include any additional veiling glare or other flare.

Note 3 to entry: The characteristics of original-referred image data that most generally distinguish them from scene-referred image data are that they refer to a two-dimensional surface, and the illumination incident on the two-dimensional surface is assumed to be uniform (or the image data corrected for any non-uniformity in the illumination).

Note 4 to entry: There are classes of originals that produce original-referred image data with different characteristics. Examples include various types of artwork, photographic prints, photographic transparencies, emissive displays, etc. When selecting a colour re-rendering algorithm, it is usually necessary to know the class of the original in order to determine the appropriate colour re-rendering to be applied. For example, a colourimetric intent is generally applied to artwork, while different perceptual algorithms are applied to produce photographic prints from transparencies, or newsprint reproductions from photographic prints. In some cases the assumed viewing conditions are also different between the original classes, such as between photographic prints and transparencies, and will usually be considered in well-designed systems.

Note 5 to entry: In a few cases, it can be desirable to introduce slight colourimetric errors in the production of original-referred image data, for example to make the gamut of the original more closely fit the colour space, or because of the way the image data were captured (such as a Status A densitometry-based scanner).

[SOURCE: ISO 22028-1:2016, 3.32, modified — A term has been slightly modified and second one added.]

3.17
output-referred
image state associated with image data that represents the colour-space coordinates of the elements of an image that has undergone colour-rendering appropriate for a specified real or virtual output device and viewing conditions

Note 1 to entry: When the phrase "output-referred" is used as a qualifier to an object, it implies that the object is in an output-referred image state. For example, output-referred image data are image data in an output-referred image state.

Note 2 to entry: Output-referred image data are referred to the specified output device and viewing conditions. A single scene can be colour-rendered to a variety of output-referred representations depending on the anticipated output-viewing conditions, media limitations, and/or artistic intents.

Note 3 to entry: Output-referred image data can become the starting point for a subsequent reproduction process. For example, sRGB output-referred image data are frequently considered to be the starting point for the colour re-rendering performed by a printer designed to receive sRGB image data.

[SOURCE: ISO/TS 22028-3:2012, 3.16]

3.18
profiling
creation of (ICC) colour profiles for imaging devices in order to enhance the accuracy in colour reproduction

[SOURCE: ISO 19262:2015, 3.197]

3.19
reference target
arrangement of test patterns designed to test particular aspects of an imaging system

Note 1 to entry: See examples in ISO 12233:2017, ISO 16067-1 and ISO 16067-2.

[SOURCE: ISO 19262:2015, 3.207]

3.20
reproduction scale
ratio of the size of an object in a digital image and the size of the original object

[SOURCE: ISO 19262:2015, 3.215]

3.21
resolution
measure of the ability of a camera system, or a component of a camera system, to depict picture detail

Note 1 to entry: Resolution measurement metrics include resolving power, limiting resolution, spatial frequency response (SFR), MTF and OTF.

[SOURCE: ISO 12233:2017, 3.22, modified — Two new terms and a Note 1 to entry have been added.]

3.22
sampling rate
number of samples per unit of time, angle, revolutions or other mechanical, independent variable for uniformly sampled data

[SOURCE: ISO 18431-1:2005, 3.13]

3.23
scene referred
image state image state associated with image data that represents estimates of the colour-space coordinates of the elements of a scene

Note 1 to entry: When the phrase “scene-referred” is used as a qualifier to an object, it implies that the object is in a scene referred image state. For example, scene-referred image data are image data in a scene-referred image state.

Note 2 to entry: Scene-referred image data can be determined from raw DSC image data before colour-rendering is performed. Generally, DSCs do not write scene-referred image data in image files, but some do so in a special mode intended for this purpose. Typically, DSCs write standard output-referred image data where colour-rendering has already been performed.

Note 3 to entry: Scene-referred image data typically represents relative scene colourimetry estimates. Absolute scene colourimetry estimates can be calculated using a scaling factor. The scaling factor can be derived from additional information such as the image OECF, F-number or ApertureValue, and ExposureTime or ShutterSpeedValue tags.

Note 4 to entry: Scene-referred image data can contain inaccuracies due to the dynamic range limitations of the capture device, noise from various sources, quantization, optical blurring and flare that are not corrected for, and colour analysis errors due to device specific spectral sensitivities. In some cases, these sources of inaccuracy can be significant.

Note 5 to entry: The transformation from raw DSC image data to scene-referred image data depends on the relative adopted whites selected for the scene and the colour space used to encode the image data. If the chosen scene adopted white is inappropriate, additional errors will be introduced into the scene-referred image data. These errors can be correctable if the transformation used to produce the scene-referred image data are known, and the colour encoding used for the incorrect scene-referred image data has adequate precision and dynamic range.

Note 6 to entry: The scene can correspond to an actual view of the natural world, or be a computer-generated virtual scene simulating such a view. It can also correspond to a modified scene determined by applying modifications to an original scene to produce some different desired scene. Any such scene modifications need to leave the image in a scene referred image state, and need to be done in the context of an expected colour-rendering transform.

[SOURCE: ISO/TS 22028-3:2012, 3.18]

4 System setup and calibration

4.1 General

The image capture system needs to be carefully set up to ensure consistent, repeatable, and high quality results. Prior to checking or confirming the quality of the system, it always needs to be accurately calibrated and adjusted. For a more detailed description on how to set up and calibrate an imaging system prior to imaging systems quality analysis see ISO/TR 19263-1.

4.2 System configuration

The camera needs to be mounted on a solid stand that does not move during exposure. Any ambient light that does not originate from the desired illumination shall be avoided.

4.3 Camera/scanner settings

The lowest sensitivity and lowest image compression rate, i.e. the highest image quality, should be selected.

4.4 Exposure

The exposure shall be adjusted so a diffuse white flat surface (a test chart may be used for this) is captured and recorded using encoding values that have an L^* value equal to the actual L^* value of the diffuse white flat surface. In the case of a three-dimensional original the placement and orientation of the diffuse white flat surface are left to the photographer, but should result in a reasonable image appearance (when displayed accurately) compared to viewing the original. The user needs to make sure that the dark areas are also not clipped. If clipping in the black areas is encountered, the user needs to ensure that the system is able to capture the dynamic range of the original referring to the measurement described in ISO 21550.

4.5 White balancing

The white balance shall be measured on a grey card or a white card (without optical brighteners) to ensure correct and consistent results. This grey reference is required to be spectrally neutral in reflection and the surrounding shall not have a dominating colour. These settings shall be stored and used for production afterwards. This process shall be repeated on a regular basis to compensate for the spectral change of the light source over its lifetime. Depending on the type of light source the interval in which this needs to be done varies.

White balance performed on different tonal levels can vary. Highlights are generally more sensitive to errors. To check the variances of a system, it is best to use a grey scale and try different tonal levels.

4.6 ICC Profiling

If the originals are captured using a colour imaging system, an ICC profile should be created to characterize the system. For the purpose of ICC profiling, an ideal colour test chart reflects the type of originals to be digitized in terms of matching material and colourants.

If the software does not support ICC colour management, it is critical to determine if the system sensor, or any internal calibration, reaches accurate colour reproduction in the desired encoding before you decide to purchase or use the system.

4.7 Focusing

The system shall correctly be focused on the original. It depends on the tools the system has available how a good focus level can be achieved. Auto focus systems are often not reliable and may have problems focusing on certain originals without the introduction of focus aids.

4.8 Colour encoding

The desired colour encoding should be selected based on the intended application requirements and workflow preferences. In ISO 22028-1:2016, Annex B lists the characteristics and source standards for a number of standard colour encodings and Annex C provides criteria for selection of colour encodings.

In general, original- and scene-referred encodings are most appropriate for digital archiving systems. Examples of original-referred images are provided in ISO 12640-3, and examples of scene-referred images are provided in ISO 12640-5. However, at the time of the drafting of this document, very few scanners and digital cameras or raw processing applications supported either original- or scene-referred encodings, making it necessary to adapt output-referred encodings to this use.

When adapting output-referred encodings for the purpose of digital archiving, several changes to normal practice should be made in the processing, encoding, interpretation and display of the image data:

a) When processing the image data for encoding, any colour rendering should be turned off to the extent possible, so that the image colourimetry encoded accurately represents the colourimetry of the original object, with chromatic adaptation to the encoding white point. Particular attention should be paid to processing controls that apply nonlinear tone reproduction, or black or white clipping.

b) If it is not possible to turn off the colour rendering in the processing, profiling should be used to undo it to the extent possible, and the resulting profile assigned to the image, instead of the profile normally associated with the colour encoding used. For example, if a camera captures an Adobe RGB image, and the scanner or camera has been profiled, which this document recommends, the profile assigned to the image should be the appropriate scanner or camera profile rather than the Adobe RGB profile.

It should be noted that most output-referred RGB encodings use encoding 0 to represent the encoding reference medium black point, as opposed to an absolute black. This can cause several problems:

— In some cases, converting to the encoding could result in clipping of tones darker than the reference medium black point, which should be avoided. When original- or scene-referred images are stored using output-referred encodings, the reference medium should be ignored, and encoding 0 should be considered to represent absolute black.

— Likewise, in some cases converting from an output-referred encoding could cause a lightening of the dark tones, if the code values are interpreted as representing colours above the encoding reference medium black, as opposed to above absolute black.

— When displaying images, operating systems and application software may apply black point compensation, where the encoding black point is scaled to the display black point. This may be desirable in some cases, even with digital archive images, to avoid clipping of tones darker than the display black point. However, it should be noted that when black point compensation is applied, the dark tones will be displayed somewhat lighter and with lower contrast than they appear on the original. Applications with sophisticated colour management interfaces may offer the option to turn black point compensation on or off. However, it should also be noted that many display profiles set the display black point to 0, in which case turning black point compensation off will still not result in correct rendition of the dark tones.

Hopefully in the future support for original- and scene-referred colour encodings will become more widespread, avoiding most of these issues.

4.9 Reproduction scale

If a camera system with an area sensor is used the reproduction scale depends on the focal length as well as the object distance. This may need to be adjusted in the final image.

5 Imaging system quality analysis procedure

To determine the quality of an imaging system according to this document one or more test charts as described in the Annexes A and C needs to be digitized with the system that has been set up and calibrated according to the aspects described in the previous paragraph.

The digital image is then analysed according to the individual quality aspects mentioned in Clause 6. For some of the measurement procedures (e.g. colour reproduction) reference data for the test chart is required. There are commercially available software tools that can do the analysis, see Figure 1.

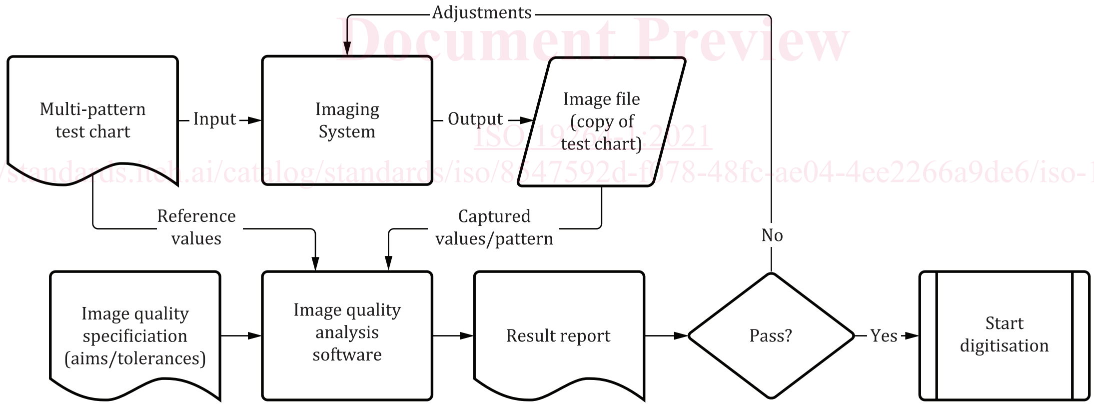

Figure 1 — Schematic representation of imaging systems quality analysis procedure

In order to decide whether or not the quality of the system is sufficient for the intended application a set of aims and tolerances is required. Annex B describes three tolerance levels A, B and C, which can be used or combined into a customized list for aims and tolerances for a specific project or application.

6 Imaging systems quality characteristics and metrics

6.1 General

The following tables describe the image characteristics that should be used to analyse the quality of a digital image. Each table provides a description of the image characteristic, references the related standards used to measure the characteristic, states a summary of the measuring method, and a specification of which technical patterns of the reference target should be used for the measurement.