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Information technology — Office equipment — Measurement of image quality attributes for hardcopy output — Monochrome text and graphic images

Technologies de l'information — Équipement de bureau — Mesurage des attributs de qualité d'image — Texte monochrome et images graphiques

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Foreword

ISO (the International Organization for Standardization) and IEC (the International Electrotechnical Commission) form the specialized system for worldwide standardization. National bodies that are members of ISO or IEC participate in the development of International Standards through technical committees established by the respective organization to deal with particular fields of technical activity. ISO and IEC technical committees collaborate in fields of mutual interest. Other international organizations, governmental and non-governmental, in liaison with ISO and IEC, also take part in the work. In the field of information technology, ISO and IEC have established a joint technical committee, ISO/IEC JTC 1.

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 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 ISO/IEC JTC 1, *Information technology*, Subcommittee SC 28, *Office equipment*.

This first edition of ISO/IEC 24790 cancels and replaces ISO/IEC TS 24790:2012 and ISO/IEC 13660:2001, which have been technically revised.

Introduction

This document is designed to help a quality control engineer evaluate the image quality of prints from office imaging systems.

In traditional imaging systems (such as ink-on-paper printing), an image is evaluated by comparison to an original or master version of that image. In many electronic imaging systems, however, the image is created digitally within the system. There is no hardcopy master and so there can be no evaluation by comparison in the ordinary way.

Often, those who operate electronic imaging systems ensure good image quality by controlling the imaging process. They use test targets and reference images to evaluate the performance of the system.

If it is not possible to control image quality by controlling the imaging process and if no test target or reference image is available, we can rely only on direct evaluation of properties of the image itself.

To perform intrinsic evaluations of image quality, consider the nature of an image that is an output. An image is some organization of information in space. We assume that these signals have some purpose or are making some attempt at communication. Good image quality means that the image is legible (the organization and information can be interpreted) and that it has a pleasing appearance.

Our goals in developing this document were to compile a list of image quality attributes that (taken together) correlate to human perception of print quality and to develop measurement methods for these attributes that can be automated and carried out on a simple system.

Legibility and appearance have several aspects:

— detail can be detected easily;

— image elements are well isolated from the background;

— the image has a minimum of gross defects;

— the imaging system has good geometric fidelity.

Not all these factors can be covered by evaluation of intrinsic, quantitative image quality attributes. Many of them have a large psychological or cultural component that is difficult to evaluate.

A print made with large optical reduction or one that is out of focus can still have excellent edge quality (and be totally lacking in gross defects, banding, noise, etc.) and yet be illegible. This could occur primarily because of the high process gamma (contrast) that is characteristic of many xerographic processes. Thus, the process can produce apparently sharp edges in spite of the loss in resolution. Without a resolution target of some kind, the extent of the resolution loss, and hence legibility, may not be known.

The purpose of this document is to present a set of objective, measurable attributes that give some correlation to the perceived quality of an image to a human observer at a standard viewing distance. This document allows a user of printed material to sort samples into several groups, from excellent to bad.

The attributes and methods for their assessment are based on several assumptions:

— the image represents an attempt at communication;

— there is uniformity within identifiable image elements;

— character images, symbols and graphic elements are regular (that is, they are intended to be identical when they have multiple, similar occurrences);

— samples with extreme gross defects have been screened out.

This document applies to monochrome images made up of text, graphics and other image objects with two tone levels of a single colour (typically black image on white paper) or halftones, images with more nominal gray levels. This document does not cover continuous tone images, colour images and so on.

Image quality measurement can be thought of as divided into diagnostic (high resolution) and visual scale (low resolution) procedures. Diagnostic measurements typically use precision test targets and instrumentation and are key to much engineering work. The present procedure, by contrast, is limited to phenomena visible to the naked eye and does not permit test patterns.

The working group has taken the approach of selecting simple and (in our judgment) effective metrics, rather than attempting to prove that our method of doing a given job will always be the most exact.

How will this document actually be implemented? A complete evaluation system has four components: an image capture device, evaluation software, application-specific quality standards and sampling plan. The end user may choose to develop all these parts himself or he may choose to purchase one or more components from a commercial supplier.

Any equipment capable of gathering data appropriate to these measurements is understood to have a complex instrument function. Rather than attempting to explore the relationship among these instrument functions, the working group has defined reference images and target values for them. If these target values are achieved by an instrument, calibration will be acceptably good.

This is not an attempt to break new ground in image science. It is an attempt to provide suppliers and customers for copies/prints with a practical and objective way to communicate about basic image quality parameters.

ISO/IEC 13660 was developed and standardized by the point of view described above. ISO/IEC 13660 is currently the only available systematic image quality attribute measurement standard. ISO/IEC 13660 has had a great influence on related industries and image quality measurement instruments based on ISO/IEC 13660 are already marketed. However, due to the limited development time, it was standardized with many issues unresolved and therefore, ISO/IEC 13660 has not been adopted as widely as expected. The main issues are listed as following:

a) the test chart and methods for measurement system conformance are only specified for some of character and line attributes. For large area graphic image quality attributes, neither test charts nor methods are specified. Eight items of image quality attribute for character and line image and six items of image quality attribute for large area graphic image are defined, and each measuring method is specified. Of the 14 image quality attributes, the conformance test method, the conformance test chart and the targeted value for measurement apparatus conformance are specified for only four of the character and line image quality attributes, leaving 10 of the image quality attributes with no conformance specifications;

b) physical measures (line width, large area voids) and psychophysical factors (darkness, graininess, etc.) are intermingled and are all defined as image quality attributes;

c) the goal values for measurement system conformance are available for only four character and line attributes, and the allowances are very large;

d) when one measures the character and line image quality attributes according to ISO/IEC 13660, the resulting values have large variation and they do not correspond well with subjective evaluations.

This document added the following content to ISO/IEC 13660 to resolve the issues which ISO/IEC 13660 had and to improve the measurement accuracy.

a) Banding which is a common image quality defect of the hard copy output in a printer or a copying machine is added as one of the image quality attributes of a large area graphic image.

b) Conformance test charts and the goal values for measurement system qualification are specified for three character and line image quality attributes and seven large area graphic image quality attributes.

c) The fundamental resolution of the scanner for measurement was increased from 600 spi to 1 200 spi to reduce the measurement variation.

d) Nearly all of the image quality attributes defined in ISO/IEC 13660 have been redefined in ISO/IEC 24790 to eliminate intermingling physical measures and psychophysical factors.

e) In order to improve the correspondence between image quality attributes and subjective evaluations, an image quality attribute measurement evaluation experiment was conducted on seven items (graininess, mottle, banding, line width, character darkness, blurriness and raggedness) of image quality attributes to select prediction algorithms for image quality attributes that have the highest correlation with subjective evaluation. The measurement evaluation experiment was conducted by five countries which includes Japan, U.S.A, China, South Korea and the Netherlands.

According to the measuring method of the image quality attributes chosen in the measurement evaluation experiment, the conformance chart was revised and a measurement tool which can measure automatically all the image quality attributes specified in this document was developed. An initial set of conformance chart goal values were defined using those tools, and ISO/IEC TS 24790 was published in 2012.

Experience with the use of the published Technical Specification over the following three years led to a second revision of the conformance chart, a revision of the conformance evaluation methods and a revision of the measurement tool. An international conformance chart measurement experiment was conducted to refine the conformance chart goal values and to establish realistic measurement tolerances for these goal values. This document is the result of this collective development and measurement experience.

Information technology — Office equipment — Measurement of image quality attributes for hardcopy output — Monochrome text and graphic images

1 Scope

This document specifies device-independent image quality attributes, measurement methods and analytical procedures to describe the quality of output images from hardcopy devices. This document is applicable to human-readable monochrome documents produced from printers and copiers.

The attributes, methods and procedures rely on measurable properties of printed text and graphic images. Special targets or reference images are not required, but image elements are useful for adequate measurements only if they meet some minimal requirements, e.g. on size or number present. This document is not applicable to images on media other than hardcopy (e.g. images on a visual display) or to images that are intended to be machine readable only (e.g. bar codes).

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 2470-1, *Paper, board and pulps — Measurement of diffuse blue reflectance factor — Part 1: Indoor daylight conditions (ISO brightness)*

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

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

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

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:

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

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

3.1
background area
region outside the edge of any *image element* (3.16)

3.2
background darkness
appearance of shade in *background area* (3.1) due to presence of unintended colourant particles that cannot be resolved as individual marks

3.3
background extraneous mark
colourant particle or agglomeration of colourant particles in the *background area* (3.1) that is visible at a viewing distance of 25 cm to 40 cm with the unaided eye

3.4
banding
appearance of one dimensional bands within an area that should be homogeneous

3.5
blurriness
appearance of being hazy or indistinct in outline, a noticeable transition of darkness from line element to background substrate whose intended transition width is zero (i.e. ideally sharp)

3.6
boundary
contour by *reflectance threshold* (3.35)

3.7
character darkness
appearance of blackness of a line or character image

3.8
character surround area
region runs from the outer edge of the character image or other *image element* (3.16) out 500 micrometres

3.9
character surround area haze
colourant particles or agglomerations of colourant particles within a *character surround area* (3.8) that are visible, but not resolvable as distinct marks

3.10
character surround area extraneous mark
colourant particle or agglomeration of colourant particles within a *character surround area* (3.8) that is visible at a viewing distance of 25 cm to 40 cm with the unaided eye as a distinct mark

3.11
character void
appearance of homogeneity of darkness within the *boundary* (3.6) of a line segment, character image or other glyph image

3.12
edge threshold
level in the reflectance gradient profile of an edge that is at 40 % of the transition from the *minimum reflectance factor* (R_{min}) (3.33) to the *maximum reflectance factor* (R_{max}) (3.31) as: $R_{40} = R_{min} + 40\ \% (R_{max} - R_{min})$.

3.13
graininess
appearance of unintended microscopic, but visible aperiodic fluctuations of lightness

Note 1 to entry: Microscopic means: variations with spatial frequencies greater than about 0,4 cy/mm.

3.14
graphic image
images except a character and a symbol

3.15
image area
region inside portion of *inner boundary* (3.17)

3.16
image element
single, evidently intentional, object not connected to other objects

3.17
inner boundary
contour of points of an *image element* (3.16) where edge gradient profiles cross a reflectance level that is at 10 % of the transition from the *minimum reflectance factor* (R_{min}) (3.33) to the *maximum reflectance factor* (R_{max}) (3.31) as: $R_{10} = R_{min} + 10\ \% (R_{max} - R_{min})$.

3.18
large area darkness
appearance of blackness of a large area graphic image element

3.19
large area
image area (3.15) of graphical element or background that has a minimum size of 12,7 mm in both dimensions

Note 1 to entry: Equivalent to 600 pixels when sampling resolution is 1 200 spi.

3.20
large area void
visible hole or gap within a solid *image area* (3.15) that is large enough to be individually distinguished at a viewing distance of 25 cm to 40 cm

3.21
line image
line at least 1 mm long

3.22
line image density
average *optical density* (3.27) within the R_{25} *boundary* (3.6)

Note 1 to entry: The average optical density should be converted from average reflectance factor.

3.23
line width
average stroke width, where the stroke width is measured from edge to edge along a line normal to the center line of the *image element* (3.16)

3.24
metric
measure of image quality attribute

3.25
monochrome image
image perceived as achromatic colour

3.26
mottle
measure of the appearance of unintended, aperiodic macroscopic fluctuations of lightness

Note 1 to entry: Macroscopic means: variations with spatial frequencies less than about 0,4 cy/mm.

3.27
optical density
negative logarithm to the base 10 of the *reflectance factor* (3.30), measured using a 0/45-degree geometry, Illuminant A and ISO visual density calibration as specified in ISO 5-1, ISO 5-3 and ISO 5-4 with an instrument using no polarization filters

3.28
outer boundary
contour of points of an *image element* (3.16) where edge gradient profiles cross a reflectance level that is at 70 % of the transition from the *minimum reflectance factor* (R_{min}) (3.33) to the *maximum reflectance factor* (R_{max}) (3.31) as: $R_{70} = R_{min} + 70\ \% (R_{max} - R_{min})$.

3.29
raggedness
appearance of geometric distortion of an edge from its ideal position

Note 1 to entry: An ideal edge should be absolutely straight along the length of the line.

Note 2 to entry: A ragged edge appears rough or wavy rather than smooth or straight.

3.30
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

3.31
maximum reflectance factor
R_{max}
highest *reflectance factor* (3.30) measured by a slit aperture in the *background area* (3.1), typically of the substrate

3.32
region of interest
ROI
area (inside defined boundaries) that the user wants to analyse

Note 1 to entry: ROI for character and line image attribute includes *image element* (3.16) and *background area* (3.1).

Note 2 to entry: ROI for large area graphic image attribute is within *image area* (3.15).

Note 3 to entry: The difference between ROI for character and *line image* (3.21) and large area graphic image is shown in Annex D.

3.33
minimum reflectance factor
R_{min}
lowest *reflectance factor* (3.30) measured by a slit aperture in the *image element* (3.16), typically of the image

3.34
spots per inch
spi
spots per 25,4 mm

3.35
reflectance threshold
level in the reflectance gradient profile of an edge that is at some specified percentage of the transition from the *minimum reflectance factor* (R_{min}) (3.33) to the *maximum reflectance factor* (R_{max}) (3.31) as: $R_p = R_{min} + p\ \% (R_{max} - R_{min})$.

4 Report of results and sampling scheme

4.1 Report of results

4.1.1 Test identification information

The report shall include the date of the measurements, the identity of the test operator, lot identifications, etc.

4.1.2 Instrument system

The report shall include a description of the instrument system used, noting any of Clause 5, attribute measurement specifications that are emulated or deviated from in any way.

4.1.3 Conformance

Report the results of the conformance tests, Instrument, specs, Instrument OECF, Instrument dynamic range, Large area attributes: (7) large area darkness, background darkness, graininess, mottle, background extraneous mark, large area void, banding, Character and line attributes: (7) line width, character darkness, blurriness, raggedness, character void, character suround area extraneous mark, character surround area haze (see Clause 6 and Annex B).

4.1.4 Sampling scheme

The report shall include a complete description of the sampling scheme (4.3) used to select the pages and images.

4.1.5 Results

For each attribute, the report shall include the number of samples per page and the mean, standard deviation and range of the results for each page and for the entire lot.

Table 1 — Sample report of an evaluation

ORIGINATOR Test Description Date of Report Test Operator	XYZ Printing Company Results of March 15, 2012 print set April 2, 2012 RJC
INSTRUMENTATION Type Measurement and analysis software Instrument OECF compensation software Instrument dynamic range measurement software	XYZ Optical Company, Model XXX 1 200 dpi flatbed scanner ISO 24790 ANALYZER by ABC Inc. Auto OECF by ABC Inc. Auto DR by ABC Inc.
CONFORMANCE TESTS Density Measurements Spatial Measurements Line Attributes Measurements Graininess & Mottle Measurements SAMPLING SCHEME	within the tolerance within the tolerance within the tolerance within the tolerance Random Sampling
LARGE AREA IMAGE QUALITY ATTRIBUTES *large area darkness* *background darkness* *graininess* *mottle* *background extraneous mark* *large area void* *banding* *CHARACTER AND LINE IMAGE QUALITY ATTRIBUTES* *line width* *character darkness* *blurriness* *raggedness* *character void* *character surround area extraneous mark* *character surround area haze*	*# of samples/page Mean Std* *# of samples/page Mean Std*

4.2 Sampling of pages

The pages chosen shall be taken from a homogeneous lot. They shall all (as far as can be determined) be on the same substrate, produced with the same process and be of the same age.

The number of pages to be sampled depends on the user's optimal balance between risk and cost and on the uniformity of the process that produced the lot.

Any sampling scheme selected shall allow for the screening of pages with defects beyond the scope of this document (such as physical damage to pages) and pages with defects which would be unacceptable to practically all observers. These pages should not be evaluated.

4.3 Sampling of images

4.3.1 General

Three sampling schemes and the information required to specify them in the report of results are given below. Use one of these three schemes. The report shall contain enough specific information that the sampling scheme can be duplicated exactly.

4.3.2 Discretionary sampling

In discretionary sampling, a human operator intervenes to select features for analysis, based on some subjective criteria.

