TECHNICAL SPECIFICATION

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Photography — Archiving systems — Image quality analysis —

Part 1:
Reflective originals

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

Partie 1: Documents réfléchissants

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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.

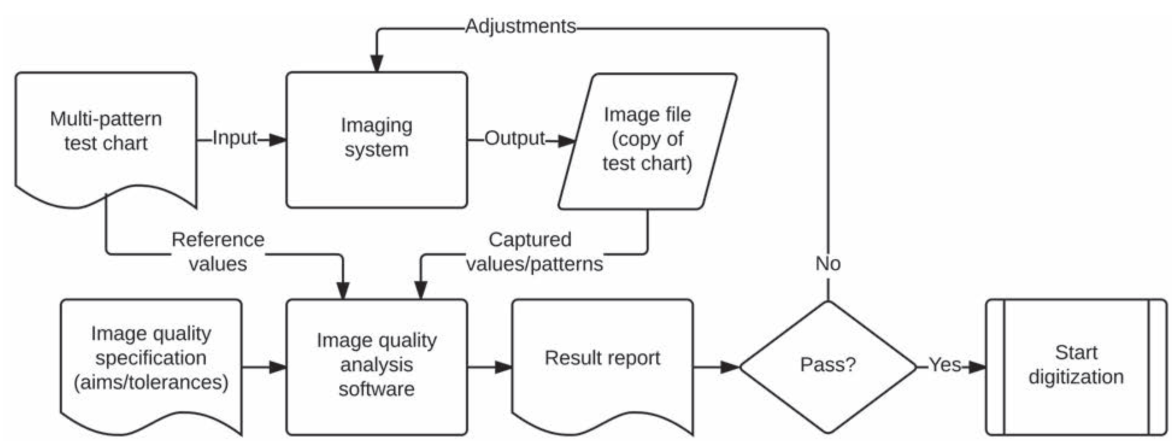

Figure 1 — Schematic representation of imaging systems quality analysis procedure

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. The tables also include aim values for optimal imaging systems quality. Annex B contains aims and tolerances for producing accurate and acceptable digital reproductions.

The image characteristics are grouped according to the basic metric they relate to: Tones and Noise (tone reproduction, gain modulation, dynamic range, noise, banding, defect pixels), Colour (white balance, colour reproduction), Details (sampling rate, resolution, sharpening, acutance), and Geometry (illumination non-uniformity, colour mis-registration, distortion, reproduction scale).

Even though this document details a specific multi-pattern chart, these values can also be measured using the charts outlined in the different standards, e.g. in ISO 12233, or other charts that fulfil the requirements described in the standards.

6.2 Tones and noise

Characteristic	**Tone reproduction**
Description	The opto-electronic conversion function (OECF) describes the relationship between the input light levels and the corresponding digital output levels for an opto-electronic digital image capture system. To produce an accurate reproduction it is important that this curve is shaped in a way that the luminance (CIE L^*) levels of the original are transferred into digital values that represent the same L^* values in the selected colour encoding of the image.
Related standards	ISO 14524 (cameras) ISO 21550 (scanners)
Measurement	Tone reproduction/response curve (TRC) Measurement in L^* values and tolerances for L^* differences between original and captured image
Reference target	Grey scale (spectrally neutral) in a test chart as defined in Annex A that is ideally equally spaced in L^* values.
Aim	The smaller the deviation between the L^* of the patches in the reference target and the L^* values represented by the digital code values the more accurate the tone reproduction. Correct tonal capture is expected from L^* 95 to ≈ L^* 5
Notes	Also known as tone response.

Characteristic	**Gain modulation**
Description	The gain is a measure for the slope of the OECF. The gain modulation describes the variation of the slope in an *L** original versus *L** output curve. If the gain changes significantly it can happen that even with the tone reproduction being within tolerances the slope is too flat to differentiate tonal values that are close to each other.
Related standards	ISO 21550
Measurement	Calculation of the incremental gain from the tone reproduction curve (TRC) is done for grey scale steps with a tonal difference of at least 10 *L** values. For a grey scale with an increment between the patches of 5 *L** values every other patch of the grey scale will be compared. This means the gain is calculated for patch i = 1 and 3, 2 and 4, 3 and 5 ... $$g_i = \frac{L^*_{\mathrm{img}\ i+2} - L^*_{\mathrm{img}\ i}}{L^*_{\mathrm{org}\ i+2} - L^*_{\mathrm{org}\ i}}$$
Reference target	Grey scale (spectrally neutral) in a test chart as defined in Annex A that is ideally equally spaced in *L** values.
Aim	g_i is supposed to be 1 from *L** 95 to ≈ *L** 5
Notes	

Characteristic	**Noise**
Description	Noise is unwanted variations in the response of an imaging system. It is introduced into the system by the camera originating from the sensor, the electronics, or the image processing. Also referred to as visual noise.
Related standards	ISO 15739 (cameras) ISO 21550 (scanners)
Measurement	Noise is measured in uniform areas of an image and expressed as standard deviation of the signal in these areas. ISO 15739 describes the method to measure the visibility of noise in images based on the human visual system. This method shall be used to determine the noise for each grey patch in the grey scale. To describe the visibility of noise the viewing conditions for the image need to be defined. The images shall be viewed on a monitor in a viewing environment that satisfies ISO 3664 and the geometric viewing conditions shall be a 100 % viewing (1 pixel in the image equals one pixel on the screen) on a monitor with a resolution of 100 ppi viewed from 0,5m distance.
Reference target	The grey scale patches of the target defined in Annex A are used to determine the noise at varying signal levels.
Aim	The maximum noise level should be low enough so that noise is not visible in the images.
Notes	Signal to Noise Ratio (SNR), according to ISO 15739 and ISO 21550, is not measured by this document.

Characteristic	**Dynamic range**
Description	Dynamic range in this case describes the ratio of the brightest patch in the original that is not clipped and the darkest patch that is above the noise (SNR of 1)
Related standards	ISO 21550, ISO 15739
Measurement	$d = d_{max} - d_{min}$ The dynamic range is measured from a grey scale where d_{min} is the density of the brightest patch where the output signal of the OECF appears to be unclipped and d_{max} is the density of the patch with a signal to noise ratio of 1 (see ISO 21550 for details).
Reference target	Grey scale (spectrally neutral) in a test chart as defined in Annex A that is ideally equally spaced in L^* values with a contrast exceeding that of the image capture device.
Aim	d shall be as large as possible but at least exceed the contrast range of typical objects that are digitized with the image capture device.
Notes	

Characteristic	**Banding**
Description	Unwanted stripes or bands that occur in a digital image. Often times these structures occur as a regular pattern in an image. The origin can be a characteristic of the sensor, the power supply or other electronic influences on the image capture. Mistakes in the image processing can also be a source for Banding.
Related standards	unknown
Measurement	A quantization of Banding is difficult but averaging the columns of multiple lines in a uniform area and displaying the digital values of the average line helps determining potential Bands. A frequency analysis performed on that line identifies regular structures by providing a peak at the frequency of the banding structure.
Reference target	To be measured on uniform grey, white, and black stripes in chart as defined in Annex A.
Aim	The mean value for the columns of each of the stripes shall be in the range of expected fixed pattern noise. Max and min values of the signal deviation for the averaged lines should be defined. A max value for a single frequency peak should be defined.
Notes	Vertical and horizontal but sometimes also diagonal. Averaging several lines or columns perpendicular to measured direction

Characteristic	**Defect pixels**
Description	Pixel or subpixel that operates in a way other than the one in which it is driven. (ISO 9241-302)
Related standards	ISO 9241-302
Measurement	Due to the different characteristics of defect pixels the measurement needs to be performed on a black image, a grey image, and a white image. For the black image the sensor does not get exposed to light during the image capture. This can be done by closing the lens cap or for scanners by switching off the light. For the grey and the white image the sensor needs to uniformly be exposed to light so that the digital output level reaches a value close to the centre value of the digital output value range (e.g. 127 for an 8 bit image) for grey and close to the maximum output level for white. A range around the typical noise values needs to be defined for those pixels that are ok and all other pixels outside the range (outliers) are then specified as defect.
Reference target	Uniform light source or target like an integrating sphere or a uniformly illuminated white target.
Aim	Identification of single pixels or clusters that do not represent the original respectively are out of the expected value range. The smaller the amount of these pixels the better.
Notes	This may not be required for every imaging system's quality check because it is mostly taken care of by the manufacturer of the capture device. Only if pixels occur that show problems this may be evaluated. Determining defect pixels is not part of the required measurements for imaging systems quality analysis.

6.3 Colour

Characteristic	**White balance**
Description	Adjustment of electronic still picture colour channel gains or image processing so that radiation with relative spectral power distribution equal to that of the scene illumination source is rendered as visually neutral (see ISO 14524). This ensures that neutral greys in the original are visually neutral in the image.
Related standards	ISO 14524
Measurement	Calculated from tone reproduction/response curve (TRC) with values in $L^*a^*b^*$. $$WB = \max_{1 \le i \le n} \left[\sqrt{\left(a_i^2 + b_i^2\right)} - \sqrt{\left(a_{i,\mathrm{ref}}^2 + b_{i,\mathrm{ref}}^2\right)} \right]$$ The image needs to be converted from RGB to $L^*a^*b^*$ using the colour encoding description of the colour encoding the image is in (like sRGB, Adobe RGB, ...).
Reference target	Grey scale patches in the target defined in Annex A.
Aim	The smaller the white balance the more accurate the reproduction. Tolerances to be defined in ΔC^*.
Notes	The CIE C^* approach has been selected over an RGB approach because CIE C^* better describes the visibility of colour casts.

Characteristic	**Colour reproduction**
Description	The difference between selected physically measured input colours and their intended output rendering for a given colour space. This expresses how well an imaging system captures and encodes colours. In digital cameras colours are captured and encoded as combinations of Red (R), Green (G) and Blue (B). The colour encoding selected describes how these RGB values are related to CIELab values. Since none of the cameras or scanning systems matches the colour matching functions of the human visual system, the colour reproduction can strictly speaking only be optimal for a specific set of colours for which the system has been calibrated (profiled). Currently there are only two sets of commonly used colours to profile scanners and cameras. One is the IT8 Target according to ISO 12641 and the other one is the ColourChecker SG (Semi Gloss surface) target. However there are other targets that are available and may be used. After profiling the system by using these targets the targets are scanned again and the colour difference is measured using CIE ΔE 2000 (CIE 015:2004) approach with SL = 1 (ΔE 2000 SL1) which gives equal weight to the entire grey scale. The mean and max ΔE 2000 values for all patches shall be determined.
Related standards	CIE 15
Measurement	CIELAB colour difference measure (ΔE) according CIE 15 specs.
Reference target	Colour patches of Target defined in Annex A.
Aim	The smaller the colour differences ΔE (L*a*b) the more accurate the colour reproduction.
Notes	This measurement only provides useful information if the system has been calibrated and profiled correctly for colour reproduction. It does not provide a colour reproduction quality estimation for other than the chart colours and may show inaccurate colour reproduction for certain types of originals. For monitoring the system with a test chart other than the above-mentioned profiling charts a reference scan can be made using the chart described in Annex A right after the verification. Each monitoring scan can then be compared to the reference scan.

Characteristic	**Colour mis-registration**
Description	Colour-to-colour spatial dislocation of otherwise spatially coincident colour features of an imaged object.
Related standards	ISO 12233 (resolution measurement) ISO 19084 (chromatic displacement)
Measurement	Determination of edge location on a per channel basis for all slanted edges over the imaging field.
Reference target	Slanted edges in the test chart defined in Annex A.
Aim	Geometric distance between the edge location in the different colour channels shall be as small as possible.
Notes	If a dislocation of the edges in different colour channels is uniform over the field a standard colour mis-registration is present. If it varies over the field e.g. from centre to corners a chromatic aberration is present. For a line scanner it may be visible in just one direction. For a line scanning system there may also be a dislocation that comes and goes due do inconsistent motion.

6.4 Details

Characteristic	**Sampling rate (obtained)**
Description	Sampling rate in pixels per unit of space determined from imaging a test chart with known geometric structures.
Related standards	
Measurement	Determine the number of pixels for a block with a given geometric size in the image of a test chart and convert to number of pixels per inch.
Reference target	Checkerboard structure on Target defined in Annex A.
Aim	The obtained sampling rate should be as close as possible to the claimed sampling rate provided in the metadata of the image file.
Notes	Also known as sampling frequency. Sampling rate should not be confused with limiting resolution. The sampling rate of a digital reproduction can be used to calculate the size of the physical record if stored in an uncompressed format. The sampling rate limits the maximum possible resolution of an imaging system. According to the Nyquist theorem, it is necessary to have at least two detecting points (pixels) on a cycle of a harmonic signal to be able to reproduce the signal. In other words, to scan a black-and-white test structure, you should have at least one pixel for the white part and one pixel for the black part to be able to reproduce the structure.

Characteristic	**Resolution (limiting resolution)**
Description	Measure of the ability of a camera system, or a component of a camera system, to depict picture detail (see ISO 12233).
Related standards	ISO 12233, ISO 16067-1
Measurement	Analysis of the edge spread function in a slanted edge target. Use the sampling frequency at 10 % modulation threshold for limiting resolution.
Reference target	The slanted edge structures in the target defined in Annex A are designed for SFR (spatial frequency response) measurements.
Aim	Reaching a frequency as high as possible but not higher than Nyquist (to avoid aliasing) for the 10 % modulation threshold (limiting resolution). Depending on the sampling rate the max. resolution that can be reached varies. The resolution should be constant over the field of imaging and the difference in different directions (horizontal and vertical respectively slow scan and fast scan direction) should be as small as possible.
Notes	Also known as true optical resolution. Note that resolution measurements based on slanted edge analysis requires uncompressed and unsharpened data. The ratio between the limiting resolution and the theoretical Nyquist limit is based on the obtained sampling rate.

Characteristic	**Sharpening**
Description	Amplification of the spatial frequency response by means of image processing to achieve sharper appearing images. Also, a class of image processing operations that enhances the contrast of selective spatial frequencies, usually visually important ones.
Related standards	ISO 12233, ISO 16067-1
Measurement	Analysis of the edge spread function in a slanted edge target. For an image without sharpening the SFR should at no frequency significantly exceed the value of 1.

Reference target	The slanted edge structures in the Target defined in section 6 are designed for SFR (spatial frequency response) measurements.
Aim	The SFR should not significantly exceed the value of 1.
Notes	

Characteristic	**MTF 50 (limiting resolution)**
Description	Measure of frequency based on the SFR measurement where a 50 % contrast level is reached (see ISO 12233). This is an indicator for the sharpness of an image.
Related standards	ISO 12233, ISO 16067-1
Measurement	Analysis of the edge spread function in a slanted edge target. Use the sampling frequency at 50 % modulation threshold as a sharpness indicator.
Reference target	The slanted edge structures in the target defined in Annex A are designed for SFR (spatial frequency response) measurements.
Aim	Reaching a frequency as high as possible but not higher than Nyquist (to avoid aliasing) for the 50 % modulation threshold.
Notes	

Characteristic	**Acutance**
Description	The visual perception of sharpness that describes the quality of being crisp or of containing detail.
Related standards	
Measurement	The acutance measure is the SFR weighted with the contrast sensitivity function (CSF) of the human eye for a given viewing condition. The used viewing condition in this specification shall be the 100 % viewing (e.g. on a computer monitor) with a 100 ppi pixel pitch viewed from 0,5 m distance. $\text{Acutance} = \dfrac{A}{A_r}$ where $A = \int_0^\infty SFR_L(v) \times CSF(v)dv$ $A = \int_0^\infty CSF(v)dv$
Reference target	The slanted edge structures in the target defined in Annex A are designed for SFR (spatial frequency response) measurements.
Aim	The acutance shall be as close as possible to the max value of 1.
Notes	The CSF shall be calculated and applied as described in ISO 15739 with the viewing condition being a 100 % viewing on a monitor with 100 Ppi viewed from a 0,5 m distance.

6.5 Geometry

Characteristic	**Illumination non-uniformity**
Description	The illuminance non-uniformity consists of two components: it depends on how evenly the scene to be captured is illuminated, and on the degree of shading introduced by the imaging system.
Related standards	ISO 17957 (shading measurement)
Measurement	Capture of a uniform white original and analyse for luminance shading according to ISO 17957 and determine the L^* value at at least 1 200 points equally spread over the field of view and report the ΔL^* between the max and the min L^* value.
Reference target	Uniform white paper or derived from checkerboard pattern in the target defined in Annex A on which only the patches with the same reflectance (e.g. white patches) are analysed.
Aim	The illuminance should be as uniform as possible.
Notes	Make sure no part in the image is clipped. Surrounding light should be avoided to not influence the measurement.

Characteristic	**Chrominance non-uniformity**
Description	Depending on the type of device, the infrared cut-off filter, sensor geometry and angle of incidence there can be a colour shift in the image that gets extremely visible in case of a uniform white or grey original.
Related standards	ISO 17957 (shading measurement)
Measurement	Capture of a uniform white original and analyse for colour shading according to ISO 17957 and determine the chrominance deviation from the average for each block at at least 1 200 points equally spread over the field of view. Report the maximum value of the chrominance deviation as the chrominance non-uniformity D_C.
Reference target	Uniform white paper or derived from checkerboard pattern in the target defined in Annex A on which only the patches with the same reflectance (e.g. white patches) are analysed.
Aim	The chrominance non-uniformity should be as small as possible.
Notes	Make sure no part in the image is clipped. Surrounding light should be avoided to not influence the measurement.

Characteristic	**Distortion**
Description	Displacement from the ideal shape of a subject (lying on a plane parallel to the image plane) in the recorded image. The distortion measured can originate from three different aspects: lens geometric distortion, scanner motion distortion, image processing distortion.
Related standards	ISO 17850
Measurement	For a regular grid of dots, crosses or line intersections the locations are evaluated on a sub pixel accuracy basis. These locations are compared to a regular grid generated from the central area of the image.
Reference target	The chart can be a dedicated dot or cross chart or the chart as specified in Annex A.
Aim	The distortion shall be as small as possible.
Notes	Distortion can usually be characterized and compensated. Evaluation may be done with activated compensation if system allows for such compensation.

Characteristic	**Reproduction scale**
Description	Describes how far a given geometric distance in the original is represented in the image
Related standards	
Measurement	Is reflected in the claimed versus obtained sampling rate.
Reference target	Derived from checkerboard pattern in the target defined in Annex A.
Aim	Should be as close as possible to the original. Tolerances are project dependent.
Notes	The reproduction scale relates to dimensional accuracy.

7 Reporting results

7.1 General

Together with the list of results the following information shall be reported:

— Camera/scanner manufacturer, model and serial number

— Lens manufacturer, model and serial number (if applicable)

— Lighting (if applicable)

— Date, Time, Location of the measurement