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Technical Guidelines for Digitizing Cultural Heritage Materials

Creation of Raster Image Files

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Technical Guidelines for Digitizing Cultural Heritage Materials: Creation of Raster Image Master Files *http://www.digitizationguidelines.gov/guidelines/FADGI_Still_Image-Tech_Guidelines_2010-08-24.pdf*	Don Williams and Michael Stelmach
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The FADGI Conformance Program

The FADGI digitization program consists of three elements:

- Technical Guidelines and Parameters
- Best Practices
- Digital Imaging Conformance Evaluation (DICE)

These three elements, when implemented together, form a FADGI compliant digitization environment. FADGI conformance is a process of continuous validation to known and accepted standards, best practices, and adhering to the technical guidelines as detailed in this document. While it is possible to create FADGI compliant images in a physical environment that does not conform to the recommendations in this document, conformance to FADGI recommendations related to the physical environment is highly recommended.

Digital Imaging Conformance Evaluation (DICE) Process Monitoring

The Digital Imaging Conformance Evaluation program (DICE) provides the measurement and monitoring component of a FADGI compliant digitization program. DICE consists of two components:

- Image Targets, both reflective and transmissive
- Analysis Software

The DICE targets have been designed to comply with various ISO specifications, and the parameters as defined in the FADGI program have been validated through years of use at participating Federal agencies.

There are other targets and measurement programs available, but these have not been evaluated and cannot be substituted for use in a FADGI compliant environment.

Certification of FADGI conformance must be measured using DICE targets and analysis software.

DICE Evaluation Parameters

The FADGI guidelines establish quality and performance goals for the four levels of the star ranking system. The DICE conformance testing tool, when used with appropriate testing targets, provides the user with a precise and repeatable analysis of the imaging variables that comprise FADGI star ratings.

The following parameters are evaluated by the DICE program[2]:

Sampling Frequency

This parameter measures the imaging spatial resolution, and is computed as the physical pixel count in pixels per inch (ppi), pixels per mm, etc. This parameter informs us about the size of the original and also provides part of the data needed to determine the level of detail recorded in the file. ISO 12233:2014 defines the resolution measurements.

Tone Response (OECF)

Opto-Electronic Conversion Function (OECF) is a measure of how accurately the digital imaging system converts light levels into digital pixels. ISO 14524:2009 defines the OECF measurement.

White Balance Error

This is a measurement of the color neutrality of the digital file. Ideally, an image of a white reflective object would be recorded digitally as even values across red, green and blue channels, with a value

[2] The implementations can be seen in Appendix A.

approaching the limit of the file format to define white. These specific values are defined in each section of the guidelines.

Illuminance Non-Uniformity

Both lighting and lens performance contribute to this measurement. Ideally, there should be a perfectly even recording of a neutral reference from center to edge and between points within the image. ISO 17957:2015 defines the shading measurements. Specific values are defined in each section of the guidelines.

Color Accuracy

There is no perfect imaging system or perfect method of color evaluation. Color accuracy is measured in DICE by computing the color difference (ΔE2000) between the imaging results of the standard target patches and their pre-measured color values. By imaging the DICE target and evaluating through the DICE software, variances from known values can be determined, which is a good indicator of how accurate the system is recording color. Dice measures the average deviation of all color patches measured (the mean). Refer to ISO 13658:2000 for additional documentation on color accuracy measurement.

Color Channel Mis-Registration

All lenses focus red, green, and blue light slightly imperfectly. This parameter measures the spread of red, green, and blue light in terms of pixels of mis-registration. This parameter is used in the evaluation of lens performance.

MTF/SFR (Modulation Transfer Function / Spatial Frequency Response)

Modulation Transfer Function is a measurement of the contrast difference between the original image and the digital image. MTF is defined as the modulation ratio of the output image and the ideal image. Spatial Frequency Response measures the imaging systems ability to maintain contrast between increasingly smaller image details. Using these two functions, an accurate determination of resolution can be made as it relates to sampling frequency. ISO 12233:2000, ISO 16067-1:2003, and ISO 16067-2:2004 define MTF/SFR measurement.

Reproduction Scale Accuracy (Future Implementation)

This parameter measures the relationship between the size of the original object to the size of that object in the digital image. This parameter is measured in relation to the pixels per inch (ppi) or pixels per mm (ppmm) of the original digital capture. For example, capturing an image of a ruler at 400 ppi will digitally render at the correct size when displayed or printed at 400 ppi. It is critically important in cultural heritage imaging to maintain the relationship to the original size of the object.

The original size of microfilmed documents can only be determined if the filming “reduction ratio” is known. The scale is referred to as 8x or 10x (or other) reduction, indicating that the magnification of the image on the microfilm is 1/8th or 1/10th the size of the original document. This may or may not be known when digitizing microfilm. Unless noted in metadata, the scale of the original will be lost when microfilm is digitized. Microfilm is digitized at the same ppi resolution, regardless of the original “reduction ratio.”

Photographic film cannot be related to a reproduction scale, unless there is a physical measurement in the image to scale to. Photographic film is digitized to appropriate resolutions relative to the size of the film.

Sharpening

Almost all digital imaging systems apply sharpening, often at a point where the user has no control over the process. Sharpening artificially enhances details to create the illusion of greater definition. DICE

Figure 2. Target regions of interest for imaging quality factor measurements

Tone Response (Opto-Electronic Conversion Function)

Given the input target gray patch (DICE target patches 10 – 21, Colorchecker SG target patches E5 – J6, see Figure 2) density values, OpenDICE draws the OECF curves for each of the RGB and luminance channels. The patch density values may be obtained from the manufacturer's specifications or measured by the users. The desired intensity values are computed as
$I = 255*(10^{-D/\gamma} - b)/a$. OpenDICE provides the interface for users to change the parameter settings. The default values are γ (gamma) = 2.2, gain (a) = 1, and offset (b) = 0.

The imaging intensity values are then compared with the desired values for the difference, which is drawn according to the user pre-selection of the FADGI criteria level.

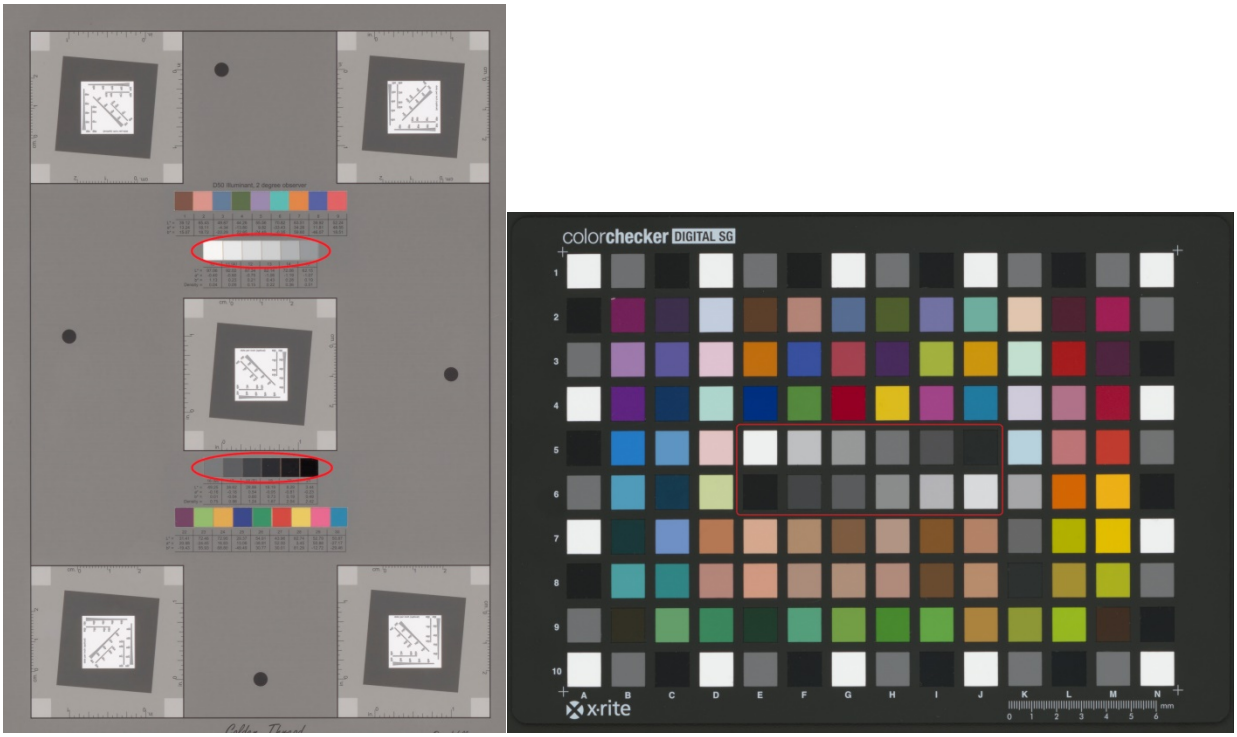

Figure 3. Target gray patches for OECF, white balance, and noise measurements

White Balance Error

Given the input target gray patch (Figure 3) intensity values, OpenDICE computes the channel differences as the white balance error, i.e., B – R, G – R, and G – B.

Illuminance Non-uniformity

Given the input target gray patch (Figure 4) intensity values, OpenDICE computes the non-uniformity metric as: (maxI – minI)/meanI, where the maximum, minimum, and mean intensity values are obtained separately for different locations on the target image. For example, DICE target uses the light gray patches at the top left, top right, center, bottom left, and bottom right locations to compute this metric (see Figure 4), which are different from the gray patches used for tone response, noise, and white balance error computation. The Colorchecker SG target does not support this function.

Documents (Unbound): Manuscripts and Other Rare and Special Materials

Performance Level:

	1 Star	2 Star	3 Star	4 Star
Master File Format		TIFF, JPEG 2000, PDF/A	TIFF, JPEG 2000, PDF/A	TIFF, JPEG 2000, PDF/A
Access File Formats		All	All	All
Resolution		300 ppi	300 ppi	400 ppi
Bit Depth		8	8 or 16	16
Color Space		Adobe 1998, ProPhoto, ECIRGBv2	Adobe 1998, ProPhoto, ECIRGBv2	Adobe 1998, ProPhoto, ECIRGBv2
Color		Color	Color	Color
Measurement Parameters				
Tone Response (OECF) (Luminance)		± 9 count levels ≤ 8	± 6 count levels ≤ 5	± 3 count levels ≤ 2
White Balance Error (Luminance)		± 6 count levels ≤ 6	± 4 count levels ≤ 4	± 3 count levels ≤ 2
Illuminance Non-Uniformity		<5%	<3%	<1%
Color Accuracy (Mean ΔE 2000)		<8	<5	<3
Color Channel Misregistration		<.80 pixel	<.50 pixel	<.33 pixel
MTF10 (10% SFR)		sampling efficiency > 70% and SFR response at half sampling frequency < 0.4	sampling efficiency > 80% and SFR response at half sampling frequency < 0.3	sampling efficiency > 90% and SFR response at half sampling frequency < 0.2
MTF50 (50% SFR)		50% of half sampling frequency: [30%,85%]	50% of half sampling frequency: [35%,75%]	50% of half sampling frequency: [40%,65%]
Reproduction Scale Accuracy		<+/- 3% of AIM	<+/- 2% of AIM	<+/- 1% of AIM
Sharpening (Maximum MTF)		<1.2	<1.1	<=1.0
Noise ΔL* St. Dev (Luminance)		<5 count levels < 3	<4 count levels < 2	<3 count levels < 1

Count values are expressed as 8 bit equivalents

Documents (Unbound): Manuscripts and Other Rare and Special Materials

Rare and special materials represent manuscripts, illustrations of special artistic or graphic interest; also documents with poor legibility or diffuse characters, e.g., carbon copies, Thermofax, etc.

Recommended Technologies

- Planetary scanners – manually operated
- Digital cameras

Not Recommended Technologies

- Lighting systems that raise the surface temperature of the original more than 4 degrees F (2 degrees C) in the total imaging process.
- Sheet fed scanning systems that contact the recto (face) or verso (back) of the original in any way.

Notes

- To be FADGI compliant, all imaging performed on special collections materials must be done by personnel with advanced training and experienced in the handling and care of special collections materials. FADGI compliance requires proper staff qualifications in addition to achieving the performance levels defined in this document. It is out of the scope of this document to define proper staff qualifications for cultural heritage imaging.
- Special collections materials will often contain colors that are outside of the gamut of current color reproduction systems and will require special imaging techniques to approximate the original in digital form. Alternative imaging techniques, including but not limited to texture lighting, multiple light source exposure, and multispectral/hyperspectral imaging may be used to best reproduce the original. These techniques should be accomplished as single exposures, not blends of multiple exposures. An “image cube” of multiple single exposures may be considered an archival master file, but a single base image must meet the specifications in the chart above for FADGI compliance in all respects. Note that color accuracy is measured against the color test target, not the artifact.

  This topic will be addressed in more detail in future revisions of these guidelines.
- If a backing sheet is used, it must extend beyond the edge of the page to the end of the image on all sides of the page.
- Single exposure total area capture scanning systems are considered the most appropriate technologies when imaging special collections materials. However, FADGI permits the use of other technologies that may be appropriate as long as none of the stated restrictions are compromised by the use of that technology.
- When imaging materials that are sensitive to rapid moisture absorption, matching temperature and humidity between storage and imaging conditions is critical.
- Special collections materials should not be placed in contact with glass or other materials in an effort to hold originals flat while imaging, without the approval of a paper or book conservator. This technique can lead to physical damage to the original. Spatulas or other implements to assist in holding pages flat for imaging may be used, but must not obscure informational content. If used, these should not be edited out of master files.
- Holding down an original with the use of a vacuum board should also be approved by a paper or book conservator. Air forced through the original over the vacuum ports can permanently degrade some originals.
- No image retouching is permitted to master files.
- Image processing techniques are approved for the creation of access files in FADGI.

- For master files, documents should be imaged to include the entire area and a small amount beyond to define the area. Access files may be cropped.
- At 4*, no software de-skew is permitted. Images must be shot to a +/- 1 degree tolerance.
- Image capture resolutions above 400 ppi may be appropriate for some materials, but imaging at higher resolutions is not required to achieve 4* compliance.
- Single exposure total area capture scanning systems are considered the most appropriate technologies when imaging special collections materials, including documents. However, FADGI permits the use of other technologies that may be appropriate as long as none of the stated restrictions are compromised by the use of that technology.

Aimpoint Variability

Reference color calibration targets are surrogates for the colors in the actual collections. While current color management systems do well in connecting target colors to actual object colors, inaccuracies are inevitable due to metamerism[6] and other factors. Careful calibration of a digitization system using a DICE reference target (for reflection copy), or an appropriate color target for transmission originals, provides a best compromise calibration for most digitization.

[6] https://en.wikipedia.org/wiki/Metamerism_(color)

Prints and Photographs

Performance Level:

	1 Star	2 Star	3 Star	4 Star
Master File Format	TIFF	TIFF	TIFF	TIFF
Access File Formats	All	All	All	All
Resolution	100 ppi	200 ppi	400 ppi	600 ppi[1]
Bit Depth	8	8	8 or 16	16
Color Space	Grey Gamma 2.2 SRGB Adobe 1998 ProPhoto ECIRGBv2	Grey Gamma 2.2 SRGB Adobe 1998 ProPhoto ECIRGBv2	Adobe 1998 ProPhoto, ECIRGBv2	Adobe 1998 ProPhoto, ECIRGBv2
Color	Grayscale or Color	Grayscale or Color	Color	Color
Measurement Parameters				
Tone Response (OECF) (Luminance)	± 9 count levels ≤ 8	± 7 count levels ≤ 6	± 5 count levels ≤ 4	± 3 count levels ≤ 2
White Balance Error (Luminance)	± 8 counts ≤ 8	± 6 counts ≤ 6	± 4 count levels ≤ 4	± 3 count levels ≤ 2
Illuminance Non-Uniformity	<8%	<5%	<3%	<1%
Color Accuracy (Mean ΔE 2000)	<10	<6	<4	<2
Color Channel Misregistration	<1.2 pixel	<.80 pixel	<.50 pixel	<.33 pixel
MTF10 (10% SFR)	sampling efficiency > 60% and SFR response at half sampling frequency < 0.4	sampling efficiency > 70% and SFR response at half sampling frequency < 0.4	sampling efficiency > 80% and SFR response at half sampling frequency < 0.3	sampling efficiency > 90% and SFR response at half sampling frequency < 0.2
MTF50 (50% SFR)	50% of half sampling frequency: [25%,95%]	50% of half sampling frequency: [30%,85%]	50% of half sampling frequency: [35%,75%]	50% of half sampling frequency: [40%,65%]
Reproduction Scale Accuracy	<+/- 3% of AIM	<+/- 3% of AIM	<+/- 2% of AIM	<+/- 1% of AIM
Sharpening (Maximum MTF)	<1.3	<1.2	<1.1	<=1.0
Noise ΔL* St. Dev (Luminance)	>6 count levels < 4	>5 count levels < 3	>4 count levels < 2	>3 count levels < 1

1. In rare cases, resolutions higher than 600 ppi may be needed to resolve fine details.

Prints and Photographs

Includes photographic prints, graphic-arts prints (intaglio, lithographs, etc.), drawings, some paintings, (e.g., water colors), and some maps.

Recommended Technologies

- Planetary scanners
- Digital cameras
- Flatbed scanners

Not Recommended Technologies

- Drum scanners
- Lighting systems that raise the surface temperature of the original more than 4 degrees F (2 degrees C) in the total imaging process

The intent in scanning photographs is to maintain the smallest significant details. Resolution requirements for photographs are often difficult to determine because there is no obvious fixed metric for measuring detail such as quality index. Additionally, accurate tone and color reproduction in the scan play an equal, if not more, important role in assessing the quality of a scan of a photograph.

The recommended scanning specifications for photographs take into account the intended uses of the four star levels. In general, 300 ppi at the original size is considered minimum to reproduce the photograph well at the size of the original. For photographic formats in particular, it is important to carefully analyze the material prior to scanning. Because every generation of photographic copying involves some quality loss, using intermediates, duplicates, or copies inherently implies some decrease in quality and may also be accompanied by other problems (such as improper orientation, low or high contrast, uneven lighting, etc.).

Notes

- “Prints and Photographs” encompass a wide range of technologies and processes that have been used to create reflective images. For many of these, subtle texture, tone and color differences are an essential part of their character. While it is not possible to preserve all of these subtle physical differences in digital form, we can approximate some of their unique qualities. It is for this reason that all master files from both color and black and white originals are to be imaged in 16 bit color at or above 3 star performance.
- The use of glass or other materials to hold an image flat during capture is allowed, but only when the original will not be harmed by doing so. Care must be taken to assure that flattening a photograph will not result in emulsion cracking, or the base material being damaged. Tightly curled materials must not be forced to lay flat.
- There are a variety of visible degradations that occur with photographs, many of which can be minimized using special imaging techniques. The application and use of these techniques are beyond the scope of this document but can be found in contemporary photography literature. Alternate imaging techniques are approved for FADGI imaging. The use of these techniques can result in multiple images of the same photograph. These images must be referenced as a group in file naming and embedded metadata. The group of files is considered the master image.
- If alternate lighting techniques are used and the resulting master file is a single image, the alternate imaging technique must conform to the FADGI specifications. If using alternate imaging techniques results in multiple files of the same original, one of the images must conform to the FADGI specifications, and this image must be identified as the base.
- FADGI allows the use of flatbed scanners when imaging photographs, but the user should be aware that images may render differently on a flatbed scanner than if imaged using a camera or

planetary scanner and traditional copy lighting. Additionally, when using a flatbed scanner, dust and dirt on the scanner glass and optical system can result in dust and dirt in the file.

- Dust removal is not allowed on master images, and digital dust removal techniques during the scanning process are also not approved.
- Color, tone enhancement or restoration is not allowed on master images.
- Photographic print processes vary widely in their response to digital sensors. A reference target should be imaged with each exposure and retained in the master file. Color and tone adjustments must be made to the target data, not the photograph.
- Adjustments to correct or enhance the image may be made to access versions, and noted as such in embedded metadata and file naming.