Federal Agencies
Digital Guidelines Initiative

September 2016

Technical Guidelines for Digitizing Cultural Heritage Materials

Creation of Raster Image Files

Document Information

Title	*Editor*
Technical Guidelines for Digitizing Cultural Heritage Materials: Creation of Raster Image Files	Thomas Rieger
Document Type	Technical Guidelines
Publication Date	September 2016

Source Documents

Title	*Editors*
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
Document Type	Technical Guidelines
Publication Date	August 2010
Title	**Authors**
Technical Guidelines for Digitizing Archival Records for Electronic Access: Creation of Production Master Files – Raster Images *http://www.archives.gov/preservation/technical/guidelines.pdf*	Steven Puglia, Jeffrey Reed, and Erin Rhodes U.S. National Archives and Records Administration
Document Type	Technical Guidelines
Publication Date	June 2004

Adjusting Image Files

There is a common misconception that image files saved directly from a scanner or a digital camera are pristine or unmolested in terms of image processing. Even "raw" files from scanners or digital cameras are adjusted. All digital image files have a range of image processing applied during scanning, and prior to saving, in order to produce digital images with good image quality.

Because of that misconception, many people argue that one should not perform any post-scan or post-capture adjustments on image files because the image quality might be degraded. We disagree. The only time we would recommend saving unadjusted files is if they meet the exact tone and color reproduction, sharpness, and other image quality parameters that are required. Otherwise, we recommend doing minor post-scan adjustment to optimize image quality and bring all images to a common rendition. Adjusting master files to a common rendition provides significant benefits in terms of being able to batch process and treat all images in the same manner. Well-designed and calibrated scanners and digital cameras can produce image files that require little or no adjustment. However, based on our practical experience, there are very few scanners/cameras that are this well designed and calibrated.

Also, some people suggest that it is best to save raw image files, because no "bad" image processing has been applied. This assumes that one can do a better job adjusting for the deficiencies of a scanner or digital camera than the manufacturer, and that one has a lot of time to adjust each image. Raw image files will not look good on screen, nor will they match the appearance of originals. Raw image files cannot be used easily; this is true for inaccurate unadjusted files as well. Every image, or batch of images, will have to be evaluated and adjusted individually. This level of effort will be significant, making both raw files and inaccurate unadjusted files inappropriate for master image files.

We believe that the benefits of adjusting images to produce the most accurate visual representation of the original outweigh the insignificant data loss (when processed appropriately), and this avoids leaving images in a raw unedited state. If an unadjusted/raw scan is saved, future image processing can be hindered by unavailability of the original for comparison. If more than one version is saved (unadjusted/raw and adjusted), storage costs may be prohibitive for some organizations, and additional metadata elements would be needed. In the future, unadjusted or raw images will need to be processed to be used and to achieve an accurate representation of the originals, and this will be difficult to do.

Overview

We recommend using the scanner/camera controls to produce the most accurate digital images possible for a specific scanner or digital camera. Minor post-scan/post-capture adjustments are acceptable using an appropriate image processing workflow that will not significantly degrade image quality.

We feel that the following goals and tools are listed in priority order of importance.

1. Accurate imaging - use scanner controls and reference targets to create grayscale and color images that are:
    - Reasonably accurate in terms of tone and color reproduction.
    - Consistent in terms of tone and color reproduction, both image-to-image consistency and batch-to-batch consistency.
    - Reasonably matched to an appropriate use-neutral common rendering for all images.
2. Color management – as a supplement to accurate imaging, use color management to compensate for differences between devices and color spaces:
    - If needed to achieve best accuracy in terms of tone, color, and saturation, use custom profiles for capture devices, and convert images to a common wide-gamut color space to be used as the working space for final image adjustment.
    - Color transformation can be performed at time of digitization or as a post scan/digitization adjustment.
3. Post scan/digitization adjustment - use appropriate image processing tools to:
    - Achieve final color balance and eliminate color biases (color images).
    - Achieve desired tone distribution (grayscale and color images).

- Sharpen images to match the appearance of the originals, and compensate for variations in originals and the digitization process (grayscale and color images).

The following sections address various types of image adjustments that we feel are often needed and are appropriate. The amount of adjustment needed to bring images to a common rendition will vary depending on the original, on the scanner/digital camera used, and on the image processing applied during digitization (the specific scanner or camera settings).

Color Management

Digitization is the conversion of analog color and brightness values to discrete numeric values. A number, or set of numbers, designates the color and brightness of each pixel in a raster image. The rendering of these numerical values, however, is dependent on the device used for capture, display, or printing. Color management provides a context for objective interpretation of these numeric values, and helps to compensate for differences between devices in their ability to render or display these values, within the many limitations inherent in the reproduction of color and tone.

Color management does not guarantee the accuracy of tone and color reproduction. Color management cannot compensate for poor imaging and/or improper device calibration.

Every effort should be made to calibrate imaging devices and to adjust scanner/digital camera controls to produce the most accurate images possible in regard to tone and color. Calibration will not only improve accuracy of capture, but will also ensure the consistency required for color management systems to function by bringing a device to a stable, optimal state. Methods for calibrating hardware vary from device to device, and are beyond the scope of this guidance.

International Color Consortium (ICC) Color Management System

ICC-based color management is the most widely implemented approach. It consists of four components that are integrated into software (both the operating system and applications).

- PCS (Profile Connection Space)
  - Typically, end users have little direct interaction with the PCS. It is one of two device-independent measuring systems for describing color based on human vision, and is usually determined automatically by the source profile. The PCS will not be discussed further.
- Profile
  - A profile defines how the numeric values that describe the pixels in images are to be interpreted, by describing the behavior of a device or the shape and size of a color space.
- Rendering Intent
  - Rendering intents determine how out-of-gamut colors will be treated in color space transformations.
- CMM (Color Management Module)
  - The CMM performs the calculations that transform color descriptions between color spaces.

Profiles

Profiles are sets of numbers, either a matrix or look up table (LUT), that describe a color space (the continuous spectrum of colors within the gamut, or outer limits, of the colors available to a device) by relating color descriptions specific to that color space to a PCS.

Although files can be saved with any ICC-compliant profile that describes an input device, output device or color space (or with no profile at all), it is best practice to adjust the color and tone of an image to achieve an accurate rendition of the original in a common, well-described, standard color space. This minimizes future effort needed to transform collections of images, as well as streamlines the workflow for repurposing images by promoting consistency. Although there may be working spaces that match more efficiently with the gamut of a particular original, maintaining a single universal working space that covers most input and output devices has additional benefits. Should the profile tag be lost from an image or set of images, the proper profile can be correctly assumed within the digitizing organization, and outside the digitizing organization it can be reasonably found through trial and error testing of the small set of standard workspaces.

Some have argued that saving unedited image files in the input device space (profile of the capture device) provides the least compromised data, and allows a wide range of processing options in the future; but these files may not be immediately usable and may require individual or small batch transformations. The data available from the scanner has often undergone some amount of adjusting beyond the operator's control, and may not be the best representation of the original. We recommend the creation of master image files using a standard color space that will be accurate in terms of color and tone reproduction when compared to the original.

The RGB color space for master files should be gray-balanced, perceptually uniform, and sufficiently large to encompass most input and output devices. Color spaces that describe neutral gray with equal amounts of red, green, and blue are considered to be gray-balanced. A gamma of 2.2 is considered perceptually uniform because it approximates the human visual response to stimuli.

The Adobe RGB 1998, ProPhoto and ECIRGBv2 color space profiles adequately meet these criteria and are recommended for storing RGB image files. These color spaces have reasonably large color gamuts, sufficient for most purposes when saving as 48-bit RGB files. Using these large gamut color spaces with low-bit (8 bit per channel) files can cause quantization errors, therefore wide gamut color spaces may be more appropriate when saving high-bit or 48-bit RGB files. Gray Gamma 2.2 (16 bit) is recommended for grayscale images.

An ideal workflow would be to scan originals with a calibrated and characterized device, assign the profile of that device to the image file, and convert the file to the chosen workspace. Not all hardware and software combinations produce the same color and tonal conversion, and even this workflow will not always produce the best results possible for a particular device or original. Different scanning, image processing, and printing applications have their own interpretation of the ICC color management system, and have varying controls that produce different levels of quality. It may be necessary to deviate from the normal, simple color managed workflow to achieve the best results. There are many options possible to achieve the desired results, many of which are not discussed here because they depend on the hardware and software available.

Rendering Intents

When converting images from one color space to another, one of four rendering intents must be designated to indicate how the mismatch of size and shape of source and destination color spaces is to be resolved during color transformations: perceptual, saturation, relative colorimetric, or absolute colorimetric. Of the four, perceptual and relative colorimetric intents are most appropriate for creation of master files and their derivatives. In general, we have found that perceptual intent works best for photographic images, while relative colorimetric works best for images of text documents and graphics. It may be necessary to try both rendering intents to determine which will work best for a specific image or group of images.

When perceptual intent is selected during a color transformation, the visual relationships between colors are maintained in a manner that looks natural, but the appearance of specific colors is not necessarily maintained. As an example, when printing, the software will adjust all colors described by the source color space to fit within a smaller destination space (printing spaces are smaller than most source or working spaces). For images with significant colors that are out of the gamut of the destination space (usually highly saturated colors), perceptual rendering intent often works best.

Relative colorimetric intent attempts to maintain the appearance of all colors that fall within the destination space, and to adjust out-of-gamut colors to close, in-gamut replacements. In contrast to absolute colorimetric, relative colorimetric intent includes a comparison of the white points of the source and destination spaces and shifts all colors accordingly to match the brightness ranges while maintaining the color appearance of all in-gamut colors. This can minimize the loss of detail that may occur with absolute colorimetric in saturated colors if two different colors are mapped to the same location in the destination space. For images that do not contain significant out of gamut colors (such as near-neutral images of historic paper documents), relative colorimetric intent usually works best.

Color Management Module

The CMM uses the source and destination profiles and the rendering intent to transform individual color descriptions between color spaces. There are several CMMs from which to select, and each can interact differently with profiles generated from different manufacturers' software packages. Because profiles cannot provide an individual translation between every possible color, the CMM interpolates values using algorithms determined by the CMM manufacturer and each will give varying results.

Profiles can contain a preference for the CMM to be used by default. Some operating systems allow users to designate a CMM to be used for all color transformations that will override the profile tag. Both methods can be superseded by choosing a CMM in the image processing application at the time of conversion. We recommend that a CMM that produces acceptable results for project-specific imaging requirements be chosen, and switched only when unexpected transformations occur.

Image Processing

After capture and transformation into one of the recommended color spaces (referred to as a "working space" at this point in the digitization process), most images require at least some image processing to produce the best digital rendition of the original. The most significant adjustments are color correction, tonal adjustment, and sharpening. These processes involve data loss and should be undertaken carefully since they are irreversible once the file is saved. Images should initially be captured as accurately as possible. Image processing should be reserved for optimizing an image, rather than for overcoming poor imaging.

Color Correction and Tonal Adjustments

Many tools exist within numerous applications for correcting image color and adjusting the tonal scale. The actual techniques of using them are described in many excellent texts entirely devoted to the subject. There are, however, some general principles that should be followed.

Properly calibrated systems for reflective capture should require little post-scan correction. This guidance would always apply to color and b&w film negatives for appropriate rendering.

- As much as possible, depending on hardware and software available, images should be captured and color corrected in high bit depth.
- Images should be adjusted to render correct highlights and shadows usually neutral (but not always) of appropriate brightness, and without clipping detail. Also, other neutral colors in the image should not have a color cast (see aimpoint discussion above).
- Avoid tools with less control that act globally, such as brightness and contrast, and that are more likely to compromise data, such as clipping tones.
- Use tools with more control and numeric feedback, such as levels and curves.
- Despite the desire and all technological efforts to base adjustments on objective measurements, some amount of subjective evaluation may be necessary, and will depend upon operator skill and experience.
- Do not rely on "auto correct" features. Most automatic color correction tools are designed to work with color photographic images and the programmers assumed a standard tone and color distribution that is not likely to match your images. This is particularly true for scans of text documents, maps, plans, etc.
- Color correction and tonal adjustments can only be accurately performed on a graphic workstation with a calibrated monitor capable of displaying the appropriate color space, and under controlled environmental conditions.

Cropping

We recommend the entire object be scanned, without cropping. A small border should be visible around the entire document or photographic image. Placement of documents on flatbed scanners will require the originals to be away from platen edge. Including the edge of the object in the digital image provides an assurance that the entire image was scanned.

For photographic records - If there is important information on a mount or in the border of a negative, then scan the entire mount and the entire negative including the full border. Notch codes in sheet film are often considered important to retain. Typical film carriers cover a small portion of the film area, ruling out imaging all the way to the edge of the film. The alternate approach is to image between sheets of glass, introducing the possibility of Newton's rings, dust and other artifacts. Imaging without glass generally will result in a superior scan, and is therefore preferred if possible.

Compensating for Minor Deficiencies

Scanning at higher than the desired resolution and resampling to the final resolution can minimize certain types of minor imaging deficiencies such as minor color channel mis-registration, minor chromatic aberration, and low to moderate levels of image noise. Conceptually, the idea is to bury the defects in the fine detail of the higher resolution scan, which are then averaged out when the pixels are resampled to a lower resolution. This approach should not be used as a panacea for poorly performing scanners/digital cameras. Generally it is better to invest in higher quality digitization equipment. Before using this approach in production, tests should be run to determine if there is sufficient improvement in the final image quality to justify the extra time and effort. Similarly, for some flatbed and planetary scanners, it can be better to find and utilize the sweet spots for resolution, where the mechanics of the system operate at peak capability.

Stitching

Often originals cannot be captured at the desired resolution with one capture, even with the highest resolution devices. In addition, lenses have limited resolving capability when tasked with imaging very large and detailed materials like maps. The practical answer is to capture the image in multiple overlapping sections, imaging small areas of the original with the full area of the sensor. The image segments are then reassembled in software that "stitches" the segments back together. This technique can achieve images with resolution limited only by the limits of digital file sizes. Even this limit can be extended by breaking up the files to logical segments appropriate for the final output device.

This technique requires stability of all elements of the imaging system including even lighting, precise movement and positioning of the image between segments, and consistent exposure. When done properly, the results can be exceptional and reveal every detail in the original without breaking up under magnification. This technique is not new, it traces its roots to optical techniques used in the film era. In the era before digital printing, extreme enlargements were made in mural strip sections, each with their own large format negative of just the area related to that segment. This technique reduced the magnification required, and also reduced the grain of the film on the final mural. In the digital era, the highest resolution scan devices also use this technique. Drum scanners capture one pixel at a time and place them next to each other in columns and rows. The highest resolution professional flatbed scanners focus their sensors on a small section of the image and capture the whole in a series of tiles that are then stitched together in the scanner software.

This same technique can be accomplished using a digital camera, capturing small portions of an original a section at a time, and reassembling the whole in software.

When using stitching, the set of individual stitches should be considered the archival master. The assembled version is considered the production master.

Scanning Text

Guidelines have been established in the digital library community that address the most basic requirements for preservation digitization of text-based materials. This level of reproduction is defined as a "faithful rendering of the underlying source document" as long as the images meet certain criteria. These criteria include completeness, image quality (tonality and color), and the ability to reproduce pages in their correct (original) sequence. As a faithful rendering, a digital master will also support production of a printed page facsimile that is a legible facsimile when produced in the same size as the original (that is 1:1). See the Digital Library Federation's *Benchmark for Faithful Digital Reproductions of Monographs and Serials* at http://www.diglib.org/standards/bmarkfin.htm for a detailed discussion.

The Quality Index (QI) measurement was designed for printed text where character height represents the measure of detail. Cornell University has developed a formula for QI based on translating the Quality Index method developed for preservation microfilming standards to the digital world. The QI formula for scanning text relates quality (QI) to character size (h) in mm and resolution (dpi). As in the preservation microfilming standard, the digital QI formula forecasts levels of image quality: barely legible (3.0), marginal (3.6), good (5.0), and excellent (8.0). However, manuscripts and other non-textual material representing distinct edge-based graphics, such as maps, sketches, and engravings, offer no equivalent fixed metric. For many such documents, a better representation of detail would be the width of the finest line, stroke, or marking that must be captured in the digital surrogate. To fully represent such a detail, at least 2 pixels should cover it. (From *Moving Theory into Practice: Digital Imaging for Libraries and Archives,* Anne R. Kenney and Oya Y. Rieger, editors and principal authors. Research Libraries Group, Mountain View, CA: 2000).

Optical character recognition, the process of converting a raster image of text into searchable ASCII data, is not addressed in this document. Digital images should be created to a quality level that will facilitate OCR conversion to a specified accuracy level. This should not, however, compromise the quality of the images to meet the quality index as stated in this document.

Optical Character Recognition

Optical Character Recognition (OCR) is the process of converting a raster image of text into searchable ASCII data. FADGI three star imaging generally produces image files capable of high quality conversion, but given the variety of OCR software available and the variability of source materials, testing should be done to determine the most efficient imaging settings.