

From the Electronic Media Group: Digital Documentation: We Are There, but Enter with Care

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The use of digital imaging has great potential to improve professional conservation documentation on a variety of levels, as Paul Messier and Tim Vitale described in their excellent assessment of this issue (Messier and Vitale 2000). But the authors also brought out that its practical application was compromised by questions of affordable, satisfactory image quality, and of records permanence with respect to our profession's ethical requirements. Now, two-and-a-half years later, technological developments are resolving these questions so that the transition to digital documentation has become a truly viable alternative, provided that appropriate measures are taken and ethical concerns are given consideration.

This transition is inevitable, and has already occurred in many areas of professional photography and increasingly in amateur photography. Whether we embrace it enthusiastically or reluctantly, it is important that we draw upon our ethically driven conservatism in assessing the incorporation of new materials and techniques into commonly accepted conservation practice.

To begin, we need a benchmark from which to measure—one that at least matches currently accepted minimum standards of practice. For photographic documentation, we can use 35 mm general-purpose color transparency film because this seems to be the most common photographic medium among conservators. Accessible and affordable digital systems are currently available that meet (and in some ways exceed) our benchmark with respect to factors that are relevant to conservation documentation.

PERMANENCE AND ACCESSIBILITY

Issues of permanence and accessibility form a cornerstone in our Code of Ethics and Guidelines for Practice. Ethic VII denotes our professional obligation to document our work and to do this by creating permanent records and reports. These two basic ethical precepts are further amplified by five of our twenty-nine Guidelines for Practice (Guidelines 24–28). Guideline 28, which deals specifically with preservation of documentation, provides rationale for the latter precept, as well as additional admonitions for the

creation and maintenance of permanent records of conservation practice.

The recommendations for minimum accepted practice denoted in the Commentary on Guideline 28 have a very specific bearing to digital documentation: "Documentation must be produced on and with permanent, stable media, and be legible. Storage only on electronic media is unacceptable." Since we have agreed as conservation professionals that our files of record are stable hardcopy, we have agreed that we must print out on stable media what we have created digitally—or at least enough to fulfill the needs of minimum standards of documentation for the activity in which we are involved.

We know from Henry Wilhelm's research that dark-stored, non-frozen Ektachrome will likely remain accurate in color for 100 years (Wilhelm and Brower 1993). Until very recent years, however, it was not possible to create similarly permanent printed hardcopy of digitally captured images. For this reason, I personally have been slow to accept digital capture as a viable alternative to film for conservation records.

However, we now know that there is affordable printed output that will likely maintain color accuracy for more than 100 years. Not all printers and ink and paper combinations can do this, and only those that do should be used to produce these records. While there is still some work to be done on standardizing testing procedures, Henry Wilhelm's recent research indicates, for example, that the moderately priced Epson 2000P printer using Epson 6-color pigmented inks on several Epson photo papers will produce photographic-quality prints that will remain unfaded for more than 100 years (Wilhelm 2002). At the PMG session at the AIC Annual Meeting in Miami this past June, he also indicated that permanence is now a driving force in the marketing of consumer and professional printers, so that the range of affordable permanent high-quality digital printing options is destined to broaden and become still more affordable.

While the importance of producing stable hardcopy prints from digital files cannot be emphasized strongly enough, our handling of the digital files is also of great importance. As Commentary 28 notes, they can be "useful

adjuncts” to our permanent records. In fact, as Paul Messier and Tim Vitale indicated, they can be far more than this because of the improved access to information they provide and the ability of the technology to analyze or usefully reconfigure the information they hold. Thus, it is critically important that we think ahead and strive to maintain and organize digital records with the same rigor as we do our hardcopy records.

It is essential to store digital image files appropriately so that they are accessible in the future, and inextricably linked to accessible metadata that identifies and describes them. There are a number of such programs designed for this task (called digital asset management systems, or DAMS). Among the most commonly used are Claris’ *FileMaker Pro*, Canto’s *Cumulus*, and Extensis’ *Portfolio*. They should be carefully chosen and fully operational before vast numbers of files are created. Databases can be one of the great assets of digitizing conservation records, if properly organized and operated.

This issue of maintaining electronic records over the long term as the technology develops—with respect not only to the files themselves, but also to the standardization and form of metadata linked to them—is complex and as yet unresolved. There are several national and international groups working on this issue (see “Organizations Involved in the Creation of Standards for Digital Files”). And as the Commentary on Guideline 28 counsels us, we “should strive to keep informed about and to follow practices for the preservation and organization of records currently recommended by archives professionals.” Many AIC members who are specialists in this area are also contributing to the work of such groups.

There are some basic measures we can take now to ensure the greatest likelihood for long-term preservation of the highest-quality digital file. In terms of images, archiving a file in a lossless and widely accepted format such as TIFF (Tagged Image File Format) is a sound practice, as is maintaining a file archive on an external hard drive rather than just on removable media, such as CD or DVD, for which technological development is much more volatile.

In sum, with respect to the permanence and accessibility of our documentation, we should all continue to strive toward ensuring that our records can be accessed at least one or better, two treatment generations from now, i.e., 50–100 years. This always means producing stable hardcopy from data created by either digital or analogue methods, and maintaining the digital records created in a well-organized digital archive, in standardized formats, on standardized stable media, and with a well-conceived plan for long-term maintenance.

IMAGE QUALITY

Resolution

To determine digital resolution requirements, two variables must be known: the size of largest print one general-

ly uses or can envision using for conservation work or records, and printing resolution. For most printers, a printing resolution of around 300 dots per linear inch (dpi) will read as photographic quality with smooth transitions and sharp edges at both normal viewing distances and under slight magnification.

We can use this figure to calculate the resolution required of commonly available 35 mm format digital cameras (i.e., digital cameras with photosensitive arrays approximately the same size and proportion as the 35 mm film format). This resolution is determined by the number of individual recording elements, or pixels, covering the camera’s photosensitive array.

A brief review of the basic calculation to determine a minimum required camera resolution: Assume the largest printout we need is a small image, the same size as the camera’s 35 mm array, (about 1 in. x 1½ in.). The response of each pixel is expressed on the printout paper by a small area of applied ink, a unit called a dot. Thus the maximum number of pixels in the camera’s array that can be fully resolved by a 300 dots per inch printer would be 300 in the 1 in. direction and 450 in the 1½ in. direction. By multiplying 300 x 450, we calculate that the camera’s array needs only a total of 135,000 pixels or a little more than 0.1 million or 0.1 megapixels (MP) covering its surface. But, to create a photographic quality print twice this size, 2 in. x 5 in., with each pixel resolved again by one dot would require the camera’s array to have 600 pixels squeezed into the 1 in. dimension and 900 in the 1½ in. dimension for a total of 540,000 or about 0.5 MP.

To continue these calculations for more useful output sizes gives us the following: a 4 x 6 in. print requires at least a 2 MP array; 5 x 7.5 in., 3 MP; 6 x 9 in., 5 MP. There are several cameras now available with 5 MP arrays with costs less than \$1,000, made by Sony, Olympus, and Nikon, among others. While limited in versatility by their point-and-shoot designs, they are, nevertheless, perfectly adequate for most general conservation documentation purposes.

For greater resolution, quality, and versatility, there are a variety of other options in digital capture equipment: 6 MP

Organizations Involved in the Creation of Standards for Digital Files

- NISO (National Information Standards Organization; www.niso.org)
- CLIR (Council on Libraries and Information Resources; www.clir.org)
- RLG (Research Library Group; www.rlg.org/rlg.html)
- MCN (Museum Computer Network; www.mcn.edu)
- I3A (International Imaging Industry Association; www.i3a.org)

single-lens-reflex cameras that allow for the use of standard 35 mm SLR lenses and adapters such as those for microscopes (\$2,000–\$4,000); 6 MP 35 mm format arrays in camera backs that can be mounted on medium- and large-format camera bodies (\$15,000–\$25,000); similar camera backs with “medium-format,” inch and a half square arrays—about 55% larger than a 35 mm array (\$20,000–\$30,000); and finally, for maximum resolution, large-format scanning backs, such as those made by BetterLight and Phase One (\$14,000–\$25,000) in which, like a flatbed scanner, the image projected by the camera lens is scanned by a high-resolution linear array.

While affordable digital cameras are now available that offer 3 MP to 5 MP and even 6 MP resolution that will allow for photographic quality prints in sufficient sizes, what digital resolution fully matches that of our benchmark? We conducted tests here in Buffalo, presented at the PMG session at the 2002 AIC Annual Meeting in Miami, comparing identical details from a high-resolution 4000 ppi (pixels per inch) scan of an Ektachrome 160 tungsten 35 mm transparency (a moderately fast and slightly grainy film commonly used by conservators) and from direct digital captures of the same subject at various resolutions. This pragmatic comparison indicated that a resolution equivalent to that of a 6 MP 35 mm array matched and perhaps exceeded the resolution of the Ektachrome slide (to match slower, less grainy films would likely require somewhat greater resolution than this). Similarly, large format film (Kodak Plus-X 4 x 5 in. sheet film) was compared with the BetterLight 6000 large format digital back. The resolution of the digital capture at 48 MP was clearly equal to that of the sheet film, despite the fact its actual capture format (2.73 in. x 3.78 in.) is 50% smaller.

A Note on Scanning

Given the cost of equipment and the time commitment needed to climb the steep learning curve required to gain proficiency in digital photography, it is perfectly reasonable that one might choose to take advantage of the many benefits of digital records by scanning, or digitizing, the slides rather than by primary digital capture.

Working with scanned 35 mm film images, the same resolution concepts used for direct digital image capture apply. Thus if your maximum print size is 6 x 9, you need a scanner that can provide a true optical—not extrapolated—resolution of at least 1800 ppi; 5 x 7.5 inch requires 1500 ppi; 6 x 9 inch, 1800 ppi. While flatbed scanners with transparency adapters can be used, they rarely have the optical resolution nor the dynamic range (a minimum of 3.6) needed for optimum 35 mm scanning, and are not as efficient for the task as a dedicated unit.

Another, and simpler option for obtaining high-quality scanned images of transparencies is to request a Kodak PhotoCD at the time of processing. The CD will contain several scans of each slide up to 2100 ppi resolution.

It should be noted that in some situations, such as the

digitization of collections, flatbed scanners have actually been used for primary capture of some types of artifacts (e.g., photographs and prints) rather than digital cameras (Frey and Reilly 1999).

Exposure Latitude or Dynamic Range

This is the range of brightness in your subject that can be recorded with full color and textural information. This is the greatest weakness of general-purpose color transparency film, and has always made it a poor medium for documentation.

Slide films produce a very high contrast image and can handle at most a range of about 3 stops of brightness. For reference, a well-saturated painting, for example, can easily have a range of 4 to 5 stops. Negative films, both black and white, which have acceptable permanence, and color which does not, are better and have much greater latitude, usually around seven stops. Digital cameras have exposure latitude that may range from seven up to ten or eleven or so stops with very easy adjustments possible. Thus, the necessity to bracket exposures is minimized and the extent of information that can be recorded in a single image is substantially increased. This is one of digital camera's great advantages over slide film.

It should be mentioned, however, that there is one color transparency film that does provide a broad latitude of around seven stops. Slide-duplicating film, Kodak Ektachrome EDUPE, a relatively slow tungsten balanced film, can provide excellent documentation and is worth considering if you are planning to continue with film as your primary capture medium.

Color Accuracy

The digital imaging chain has a number of links in it, and much has been made of the difficulty of calibrating color from link to link—from capture to monitor to print-out. The range of colors that each link is capable of reproducing (its color gamut) varies and satisfactory translation of those colors not held in common between links is the crux of the problem. Color management systems (CMS) are often used so that the colors observed on the monitor are the same as those ultimately printed out. Some are included in computer operating systems such as Apple's ColorSync and Windows Integrated Color Management. Adobe Photoshop also provides Adobe Gamma and Color Settings. Hardware-based systems are also available that include a colorimeter for precise measurement of monitor display colors, such as the Pantone Colorvision Spyder colorimeter with OptiCal and ProfilerPLUS software; these provide maximum accuracy and greater convenience, but at higher cost.

Despite complexities, color management is possible and can provide results that match that of slide film in accuracy and reliability, even if done only to at a minimally satisfactory level. Those who have struggled through advanced

color management calibrations in order to realize the technology's great potential for color accuracy and reliability should gain much satisfaction from remembering that in actual practice, color transparency film, our benchmark, is a pretty unreliable medium, victim to the vagaries of variations in processing, lighting flaws, filtration errors, reciprocity failure shifts, etc.; and once compromised, cannot be corrected without going to a second generation with its accompanying loss of data.

This ability to be corrected without generational transfer and loss is another great advantage of digital technology. However, this capacity for correction and manipulation makes it critically important that a reliable photographic referent, such as a photographic gray scale be included in the image, as is recommended in the Commentaries, in addition to date, ID information, size scales, lighting indicators, etc. And it is also important that we are careful to minimize variables both in capture and in manipulation of digital information.

VERSATILITY

“Virtual” Imaging

Digital files can be used to create images of artifacts in virtual reality that can be helpful in discussions, treatment planning, research, etc. Examples of this application were presented at the poster session of the 2002 AIC Annual Meeting, and there are numerous other citations to this and to related applications of the technology in the conservation literature.

Ultraviolet Examination

Digital cameras work extremely well for the recording of visible fluorescence induced by ultraviolet irradiation. Because they do not exhibit the reciprocity failure that plagues film at extremely low light levels, exposure times are relatively short and the images exhibit accurate color with minimal filtration. Only a UV-absorbing filter (e.g., Wratten 2E) is required to absorb the reflected longwave ultraviolet to which the CCD array is slightly sensitive. Because of the low level of visible light emitted, an area array camera is required.

The imaging of reflected longwave ultraviolet (UVA) is possible as well, using an 18A filter on the camera and a longwave ultraviolet source for illumination of the artifact. Because of the CCD's low level of UVA sensitivity, this also is best done with a solid array camera rather than a scanning back.

Infrared Examination

Digital CCD arrays exhibit extensive sensitivity in the near infrared, across a spectral range equivalent to, or slightly greater than that of infrared film. (The image produced is therefore properly called a reflected [or transmitted] infrared digital photograph.) This range, while not as wide

as typical IR vidicons and solid state imagers is, however, quite sufficient for most infrared documentation and examination purposes. For normal photography, however, this sensitivity to the infrared interferes with color accuracy; thus, most digital cameras have infrared-absorbing filters in them. Fortunately, the filters in most cameras will transmit sufficient infrared to permit the creation of a slightly noisy, but high-quality image. Internal IR absorbing filtration varies among cameras, and testing is required. Level adjustments and noise and sharpening filters in Adobe Photoshop can be used to optimize the image.

Optimum infrared work, however, is done with equipment that permits the removal of this filter when desired. Using a high-resolution BetterLight 6000 back without its IR absorbing filter, we have been able to capture in a single exposure the entire underdrawing of moderately sized paintings in the finest detail, with no need to spend hours mosaicking, and without the graininess of infrared film. Additionally, because the images are made without the impediment of internal IR absorbing filtration, exposure times are very short, and the image is extremely clean and free of noise.

This sensitivity to the near IR also makes imaging of IR luminescence, a technique that can aid in materials identification or differentiation, relatively easy to do, with exposure times much shorter than with film. In brief, the subject is illuminated with an infrared-free visible light source and the camera lens covered with an infrared transmitting filter. IR luminescence technique is much better realized with equipment that allows for the removal of the internal IR absorbing filter such as is permitted by a scanning back. But workable results can be obtained on other equipment.

IR sensitivity of digital cameras also allows for the creation of false-color infrared images very similar to those obtained with Ektachrome infrared film, a specialty film that is difficult to obtain, expensive, and difficult to process. Briefly the film's blue sensitive layer is made to record only infrared radiation, while the red and green sensitive layers absorb visible light as normal. The result is a false color image combining reflectance and absorbance characteristics, in both visible light and infrared wavelengths, that can aid, for example, in materials identification or differentiation (especially pigments). For a digitally captured false-color infrared photograph, Adobe Photoshop is used; the three layers (B[IR], R, and G) are colored respectively cyan, magenta, and yellow, and then combined using the layers-option multiply-mode.

Radiography

The expanded exposure latitude of digital cameras allows for very high-quality recording of radiographic images; these are very difficult subjects because of their extremely large dynamic range. This is especially effective when done by large-format scanning backs because of their high resolution, but smaller radiographic images or details can be very successfully digitized with 35 mm format digital cameras. A transmission scanner can also be very effective.

tive, but for this purpose must have a dynamic range as close to 4.0 as possible.

Image Analysis

Using freely accessible programs such as NIH image or any of a large number of proprietary image analysis programs, digitized images can be analyzed, distilled, and reintegrated in a multitude of ways to assist, for example, in characterization and understanding of materials and structure.

WORKING EFFICIENCY

Assessing efficiency in the creating and maintaining of digital records versus that of slide film documentation is difficult; and such an assessment is best made with respect to individual needs and working practices. The transition to digital involves a considerable investment in time (especially the steep learning curve) and equipment costs. However, there is great potential for recouping this investment through increased efficiencies in the imaging process, in access to the records, and in enhanced versatility.

An important advantage is that digital photography allows us to view and judge the quality of the image immediately after capture. This ensures that a satisfactory record has been produced and virtually eliminates the need to reshoot. This is a major improvement over transparency film, not only in efficiency, but in improved quality of the documentation, and in safety for the artifact.

CLIMBING THE LEARNING CURVE

If one chooses to make the transition to digital imaging, a sound knowledge of film-based photographic technique is a decided advantage. The basic photographic issues of exposure, lighting, lenses, ISO speed, color balance, filtration, contrast, etc. still remain in the digital world, and the conceptual basis of many aspects of image processing software, such as the curves adjustment and the unsharp mask filter, are based directly on film technology. But there is much new material to learn and many new techniques and tools to master. Gaining proficiency takes time and effort, just as in learning film technique. A number of books are available that can be of great help (see "Some Useful and Practical Instructional Manuals That Have Been Published Most Recently"), and a confusing plethora of web-based resources as well. If one makes a concerted effort to study and understand the basic concepts as quickly as possible, the applied practice that follows will rapidly lead to greater understanding.

CONCLUDING THOUGHTS

The use of digital technology for documentation in conservation practice is appropriate if proper measures are taken, especially those regarding hardcopy and file management. Not only can the technology now meet the minimum quality and permanence standards of our current accepted

documentation methods, but it promises to provide us with the ability to create more accurate, more functional, and more accessible records than ever before, with potentially less risk to the artifact. Additional assets include infrared capabilities and enhanced dynamic range of capture devices. For conservators, there is still a need for more standardization in the technology itself and in the methodology of creating and maintaining digital records. Although we are coming closer to meeting this need (indeed many in this organization are involved directly in the effort) for the foreseeable future, current precepts in our Guidelines for Practice and Commentaries should remain as they are.

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Note: This article is based on a presentation from the EMG session at the 2002 AIC Annual Meeting.

Some Useful and Practical Instructional Manuals That Have Been Published Most Recently

Ben Long, *Complete Digital Photography*, Hingham, Mass.: Charles River Media, 2001.

Adrian Davies and Phil Fennessy, *Digital Imaging for Photographers*, 4th edition, Boston: Focal Press, 2001.

Adobe Systems, *Adobe Photoshop 7.0: Classroom in a Book*, San Jose: Adobe Systems, 2002 (or the edition appropriate for the version of Photoshop you own).