Digital Imaging: Ethics

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Introduction to Image Editing Ethics:

This topic is increasingly on people's minds given that image manipulation "tricks" that used to take considerable skill in a darkroom now can be done quite easily by anyone using one of the powerful image editing programs that are available. A user does not even have to be intentionally malicious to alter an image in an unethical manner. Unfortunately, many users are unaware of the issues or the effects of their actions.

Journalists have grappled with the credibility problems created by altered images since the early days of photography (see: **Faking Images in Photojournalism** http://commfaculty.fullerton.edu/lester/writings/faking.html). In western society a photograph is typically assumed to be an accurate representation of reality, unless it is patently obvious that it has been altered (e.g., SPY Magazine's cover photo of a "pregnant" Bruce Willis in September 1991). Most readers seem to understand and expect that widely respected sources of information will adhere to a higher standard of photojournalistic ethics than sources such as "tabloid newspapers".

Scientists are usually considered to be respected sources of information and there is the understanding within the scientific community that data must not be inappropriately manipulated. Unfortunately, there seem to be very few well defined "ground rules" for what is an appropriate level of digital image manipulation and what is not. In an effort to start a dialog about this topic, the author of this essay would like to offer some observations and suggestions.

Digital Imaging Guidelines:

1. **Scientific digital images are data.**
   The data are arranged spatially in an XY matrix (or grid) and each individual element (pixel) has a numerical value that represents a grayscale or RGB intensity value. These data are a numerical sampling of the sample as presented by the data acquisition system (e.g., microscope) to the sensor (e.g., CCD camera). The data acquisition system and sensor are subject to all the limitations and aberrations that physics and instrument design may impose on the two devices. To the observer's eye the image data may appear to accurately represent what can be seen, however, it is the user's responsibility to understand the limitations of the particular instrument.

2. **Digital images that will be compared to one another should be acquired under identical conditions.**
   Any processing of images that are to be compared should be identical, especially if they will be published as a group of images in a single figure. If there is a compelling reason that the images in a figure were processed differently, this <u>must</u> be explained in the publication or figure legend. Honesty is the best policy.

   If background subtraction or white-level balancing (to compensate for uneven illumination, etc) was performed, this should be acknowledged in the methods section.

3. **Intensity measurements of digital images should be performed on raw data and the data should be calibrated to a known standard.**
   Be aware that some instruments (e.g., fluorescence microscopes of many types) are subject to a number of known fluctuations over time as well as having other physics/electronics limitations. <u>If you are unaware of, or can't account for, the limitations of the acquisition instrument, you should not be performing intensity measurements.</u>

4. **Manipulation of digital images should <u>always</u> be done with a copy of the raw image data.**
   The original raw data file is the standard to which the final image can be compared. Maintaining a copy of the unaltered original image is the user's only protection against accusations of misconduct. This is also the only way that users can recover from a mistake in image processing.

5. **Simple adjustments to the entire image are usually acceptable.**
This would include techniques that are similar to standard darkroom techniques (e.g., different contrast grades of paper, changes in development time). With digital images this would include performing "reasonable" adjustments of the levels and gamma settings. Small adjustments to the brightness and contrast are usually acceptable, however, large adjustments are not recommended.

6. **Cropping an image is usually acceptable.**

7. **Manipulations that are specific to one area of an image and are not performed on other areas are questionable.**
This would include techniques analogous to "dodging" and "burning" in a photographic darkroom. This is a disputed issue. Purists would state that selective enhancement should never be performed; however, there are occasions when it is legitimate to enhance a specific area in an image. Honesty is the best policy. If portions of an image for publication were selectively enhanced, the author should state it clearly in the figure legend.

8. **Use of software "filters" to improve image quality is usually not recommended for biological images.**
Commercial software designed for desktop publishing cannot be counted on to appropriately and scientifically manipulate the data in a digital image. Digital image filters are typically mathematical functions (convolution kernels) that numerically change the data in the image. If the filters are not used carefully, they may create artifacts in an image that can lead to misinterpretation of the data. If filters must be used, they should be noted in the figure legend of published images. The note should include software version, specific filters and any special settings that were used.

9. **Cloning objects into an image, or from other parts of an image, is very questionable.**
Users often consider using the technique of cloning sections of an image to "clean up" a dirty preparation. If the image requires this much processing, the best solution is to go back and take another image from the sample or a new sample prepared under the same conditions. The use of cloning techniques to create objects in an image that did not exist there originally *(e.g., "creating" a new gel band)* is completely unethical.

10. **Avoid the use of lossy compression.**
There are very few good reasons to use the JPEG file format on scientific digital images *(other than displaying an image on a web page)*. JPEG compression uses the discrete cosine function to reduce the file size, however, it also changes the XY resolution of the image and the intensity value of any given pixel. If you must use JPEG, perform the compression as the last thing that is done to an image. With most image manipulation programs, opening and closing a JPEG image multiple times runs the compression algorithm on the image multiple times, further degrading the image each time.

The Joint Photographic Expert Group (JPEG) states "In addition, many aspects of scientific and industrial usage involve subsequent processing of a digital image, for example to enhance features or count items. Using any form of lossy compresion for images in this context may create problems - after all the information thrown away during lossy compression is generally that information that is imperceptible to a human eye - not necessarily showing the same characteristics as computer image processing software." See: <http://www.jpeg.org/apps/scientific.html>

Dr. John Russ, author of The Image Processing Handbook, states "The reason for recording images in scientific studies is not to keep remembrances of familiar objects and scenes, but to record the unfamiliar. If it is not possible to know beforehand what details may turn out to be important, it is not wise to discard them. And if measurement of features is contemplated (to measure size, shape, position or color information), then lossy compression, which alters all of those values, must be avoided." pg 48 of Seeing the Scientific Image, published on-line at <http://drjohnruss.com/downloads/seeing.pdf>

An editorial in The Journal of Cell Biology (JCB 164:11, 2004) states "It is tempting to acquire your image files in JPEG format to save disk space, but doing so compromises your data. Always use TIF format."

An excellent tutorial demonstrating the problems with using JPEG for scientific images is available at Florida State University's Molecular Expressions website: <http://micro.magnet.fsu.edu/primer/java/digitalimaging/processing/jpegcompression/>

11. **Resolution and magnification issues.**
Digital images of real world objects sample an object in a way such that each pixel in the image has a scale. This scale may be in meters per pixel for satellite images or in tenths of microns per pixel for microscope images. Ideally the scale is the same in both the X and Y dimensions; however, this is not always the case. This leads to several important points:

The ability of microscope to resolve (separate two small, adjacent objects) is limited by the wavelength of light used and the numerical aperture of the objective lens (Rayleigh criterion). "In most cases, to ensure adequate sampling for high-resolution imaging, an interval of 2.5 to 3 samples for the smallest resolvable feature is desirable."[1] Note that this statement means 2.5-3 samples/pixels in both the x and y dimensions. Undersampling (using too few pixels to describe a feature in a sample) can lead to artifacts masquerading as real structures. Oversampling is not as problematic, however, it should be noted that oversampling does not yield any additional resolution information from the specimen.
(ref 1 - http://micro.magnet.fsu.edu/primer/java/digitalimaging/processing/samplefrequency/index.html)

This is an important technical point, for more information see:
http://www.olympusconfocal.com/theory/resolutionintro.html
http://micro.magnet.fsu.edu/primer/java/digitalimaging/processing/spatialresolution/

The magnification of the image is determined by the difference between the original scale of the pixel and the scale of the pixel in its final form (e.g., paper printout, projected on the wall of a large lecture hall). Since it is often impossible to know in advance what the final magnification will be, a scale bar of known size is the best way to express the magnification. Journals may resize your image, so providing a numerical magnification number in a figure legend may result in errors.

12. **Be careful when changing the size (in pixels) of a digital image.**
Changing the size of an image (the number of pixels in X and Y) can introduce resampling artifacts. Decreasing the image size (downsampling) can cause the XY resolution in an image to be greatly reduced. If the size reduction is not by a power of two, the software program has to be "creative" in determining the intensity values of each pixel (guessing). Increasing the image size (upsampling) causes the software to interpolate (guessing) to "create" pixels in between the existing pixels. Upsampling an image does not increase the resolution, in fact it may make it more difficult to resolve features because of aliasing artifacts. In either case, users should insert a magnification scale bar prior to resampling (magnification may be nearly impossible to calculate afterwards).

ADOBE PHOTOSHOP TIP: If you are only changing the dpi of the image for different output devices (e.g., printers), uncheck the resample image box found at the bottom of the window that appears when invoking the IMAGE|IMAGE SIZE menu item. By doing this you change the scale of the image (72 dpi, 300 dpi, etc) without changing the number of pixels in the width or height boxes.

Microscopy Society of America position on Ethical Digital Imaging:

"Ethical digital imaging requires that the original uncompressed image file be stored on archival media (e.g., CD-R) without any image manipulation or processing operation. All parameters of the production and acquisition of this file, as well as any subsequent processing steps, must be documented and reported to ensure reproducibility."

"Generally, acceptable (non-reportable) imaging operations include gamma correction, histogram stretching, and brightness and contrast adjustments. All other operations (such as Unsharp-masking, Gaussian blur, etc.) must be directly identified by the author as part of the experimental methodology. However, for diffraction data or any other image data that is used for subsequent quantification, all imaging operations must be reported."

Microscopy Society of America, resolution adopted at the 2003 summer council meeting - Microscopy Today Nov/Dec 2003, p61.

Journal of Cell Biology - Instructions to Authors (2004):

"No specific feature within an image may be enhanced, obscured, moved, removed, or introduced. The grouping of images from different parts of the same gel, or from different gels, fields, or exposures must be made explicit by the arrangement of the figure (e.g., using dividing lines) and in the text of the figure legend. Adjustments of brightness, contrast, or color balance are acceptable if they are applied to the whole image and as long as they do not obscure or eliminate any information present in the original. Nonlinear adjustments (e.g., changes to gamma settings) must be disclosed in the figure legend."

From **J. Cell Biology 166 (1):11–15** (see full citation below)

*Note, this document **(Digital Imaging: Ethics)** is a work of the author (Mr. Cromey) and endorsement by the Microscopy Society of America or The Journal of Cell Biology should not be implied.*

Additional reading material (scientists)

- **What's in a picture? The temptation of image manipulation** (2004) M. Rossner and K. M. Yamada, J. Cell Biology 166 (1):11–15.
- **Editorial - Gel slicing and dicing: a recipe for disaster** (2004) Nature Cell Biol. 6(4):275.
- **The Ethics of Digital Manipulation in Scientific Images** (2000) J. E. Hayden, Network Journal of Biomedical Illustration 5-4:11-18 *(first published in J. Biocommunications 27, 2000)*. Available on-line at: http://www.biographics.org/media/ethicsfinal.pdf
- **Easy-to-Alter Digital Images Raise Fears of Tampering** (1994) C. Anderson, Science 263:317-318.

Additional reading material (journalists)

- **Ethics in the Age of Digital Photography**, J. Long, (National Press Photographer's Association, September 1999) http://www.nppa.org/professional_development/self-training_resources/eadp_report/
- **Photographs that lie: Welcome to journalism's newest ethical nightmare: digital enhancement**, J.D. Lasica (Washington Journalism Review, June 1989) http://jdlasica.com/articles/WJR.html
- **Photography in the Age of Falsification**, K. Brower, (Atlantic Monthly, May 1998, *this content is now only available to subscribers*)
- **Every Picture can tell a Lie**, D. Shenk, (Wired News, 1997) http://www.wired.com/news/culture/0,1284,7815,00.html

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Mr. Cromey is the manager of the Cellular Imaging Core, a service that provides training & technical expertise to SWEHSC investigators interested in using microscopy and scientific imaging in their research. The SWEHSC is funded by the NIEHS, grant # ES06694. The Cellular Imaging Core is also host to **Microscopy & Imaging Resources on the WWW**, located at: http://swehsc.pharmacy.arizona.edu/exppath/

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Available on the WWW at: http://swehsc.pharmacy.arizona.edu/exppath/micro/digimage_ethics.html

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