# Increasing the Versatility of Digitizations through Post-Camera Flat-Fielding

***Joel Witwer and Roy S. Berns; Studio for Scientific Imaging and Archiving of Cultural Heritage; Program of Color Science, Rochester Institute of Technology, New York/USA***

## Abstract

*Capturing images of paintings is a challenging field where the photographer must struggle between the balance of evenly illuminating the painting and using extreme lighting angles to enhance the painting's physical attributes. Flat-fielding is a scientific technique that has the ability to preserve the enhanced physical attributes of the painting while also providing uniform illumination across the scene. When the flat-fielding is done in post-camera processing, the non-flat-fielded image is preserved and can be used in conjunction with the flat-fielded image to illustrate the varying degrees between directional lighting, typical of a gallery environments, and the uniform illumination often seen in archiving studios.*

## Background

Sources such as the Technical Guidelines for Digitizing Cultural Heritage Materials put out by the Federal Agencies Digitization Initiative (FADGI) and the Metamorfoze Preservation Imaging Guidelines published by the National Library of the Netherlands advocate uniform illumination of artwork when capturing digital representations [1, 2]. Both propose a five-point analysis method where the illumination is recorded at the center of the artwork and at each of the four corners. Neither guideline offers a methodology on how to uniformly illuminate the artwork, but both insist on its importance.

Flat-fielding is a post-capture calibration technique often used in scientific imaging in order to achieve uniform illumination across the image plane and account for differences in pixel photometric sensitivity. Two images are captured: one of the object and one of a spatially uniform neutral, e.g. white foam core or Color-aid GRAY paper mounted on a flat substrate, that fills the entire field of view. The neutral image captures the distribution of light across the scene. Flat-fielding is achieved by dividing the object image by the neutral image and, if required, rescaling, resulting in an image of the scene with uniform illumination. When materials are not perfectly spatially uniform, low-pass spatial filtering, successive imaging and averaging with small displacements of the material, or defocusing can be used to minimize the lack of spatial uniformity.

Imaging systems used for archiving may offer in-camera flat-fielding options. This tends to be used to correct small amounts of non-uniform lighting and pixel sensitivity non-uniformity, particularly important when building camera profiles and meeting FADGI and Metamorfoze guidelines. When lighting is collimated and away from the object's normal angle, such as a raking light, additional lights or reflectors are used to both achieve more uniform lighting and reduce harsh shadows. If desired, in-camera flat-fielding can correct remaining non-uniformity.

The imaging workflow in the Studio for Scientific Imaging and Archiving of Cultural Heritage always includes post-capture flat-fielding. Thus, we have the opportunity to archive the object before and after flat-fielding, or the equivalent, the object before flat-fielding and the scene illumination. This leads to several opportunities described in this publication. The first is improving workflow efficiency by reducing the time required to physically achieve uniform lighting. The second is using images before and after flat-fielding to accentuate or mask the lighting non-uniformity, perhaps useful for revealing the surface properties of artwork by giving the viewer lighting cues as would be present in a gallery viewing environment.

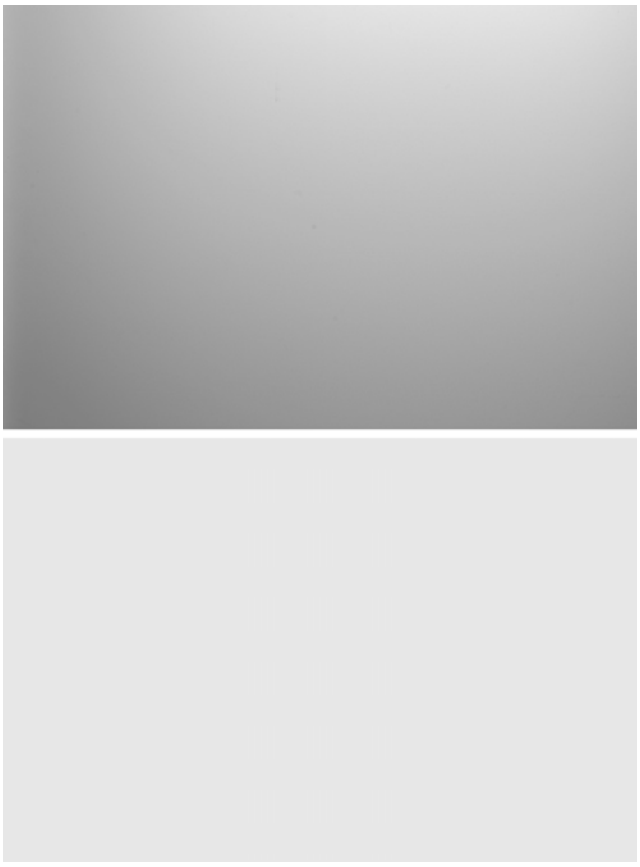

***Figure 1***. Image of white foam core before (top) and after (bottom) flat-fielding. Images are presented in grayscale in order to emphasize the illumination gradient.


***Figure 2***. Image of painting before (top) and after (bottom) flat-fielding.

## Experimental

A painting was placed on an easel and a Broncolor Pulso G xenon strobe was positioned at a 70° near-grazing angle from the object plane normal angle. The painting was a 24 x 36" still life in the style of Vincent van Gogh having pronounced impasto. The camera and light were oriented so the illumination would appear to come from overhead as is often the lighting environment in galleries.

Three images were captured using a Sinar rePro with a Sinarback eVolution 86 H and a Sinar 100 mm lens at F/8.0. The three images were an image of the painting, an image of an Xrite Color Checker SG, and an image of white foam core that filled the entire field of view. The raw file format was DNG and Matlab software was used to convert the 14-bit data to double-precision floating point.

Both the painting and the Color Checker SG images were divided by the white image in order to flat-field. Following flat-fielding, the image data were rescaled to R = G = B = 0.9, the nominal luminance factor ($Y/Y_n$) of the foam core. The flat-fielded Color Checker SG image was used to color manage the imaging system.

The non-flat-fielded image was rescaled so its "brightest" pixel matched the flat-fielded image at the same location. The image was color managed also using the Color Checker SG image.

All the images were encoded as 16-bit ProPhoto RGB Tiff. The images in this publication were converted to sRGB using the media-relative colorimetric rendering intent.

## *Results and Discussion*

The flat-fielding technique successfully achieved uniform illumination across the foam core image even with the use of a light source at near grazing, shown in Figure 1. The extent of the fall off is readily seen in the image of the white foam core.

The results seen in Figure 1 are mirrored when the painting image is flat-fielded, shown in Figure 2. The image without flat-fielding is properly exposed in the top right corner and falls off into noticeable underexposure by the bottom left and right corners as well as the top left corner. Flat-fielding the image corrects the underexposed areas by the amount indicated in the white foam core image. This results in an evenly illuminated image as is seen at the bottom of Figure 2. The image without flat-fielding gives a better sense of the light source and geometry, similar to what would be seen in a gallery environment, while the flat-fielded image gives a more balanced view of the painting enabling more accurate comparisons as one would expect in a studio or archiving environment.

Illuminating at a grazing angle, while producing uneven illumination, does emphasize physical attributes of the painting such as impasto. This in turn gives the observer more information about the painting as they view it. Studio setups with more even illumination, such as the one used to capture the image seen in Figure 3 (top), meet archiving illumination criteria, but can result in de-emphasized physical attributes if not the outright destruction of any perception of depth in the reproduction. Flat-fielding an image captured using grazing illumination, as shown in Figure 2 and Figure 3 (bottom), allows for the preservation of these attributes while maintaining the mandated even illumination.

***Figure 3.*** Close up of the painting under even (dual flashes of equal strength, both located at 45 degrees from the painting normal) illumination (bottom) and under grazing, but flat-fielded illumination (bottom).

FADGI and Metamorfoze require even illumination for archiving, but depending on the intended use of the image, directional illumination can provide valuable information to the viewer. One of the benefits of post-camera flat-fielding is that both the flat-fielded image and the non-flat-fielded, or directionally lit, image are available for use. Seeing that the two images are derived from the same initial image, they can easily be layered in any photo manipulation software and the opacity altered in order to achieve the degree of directional lighting desired. The images seen

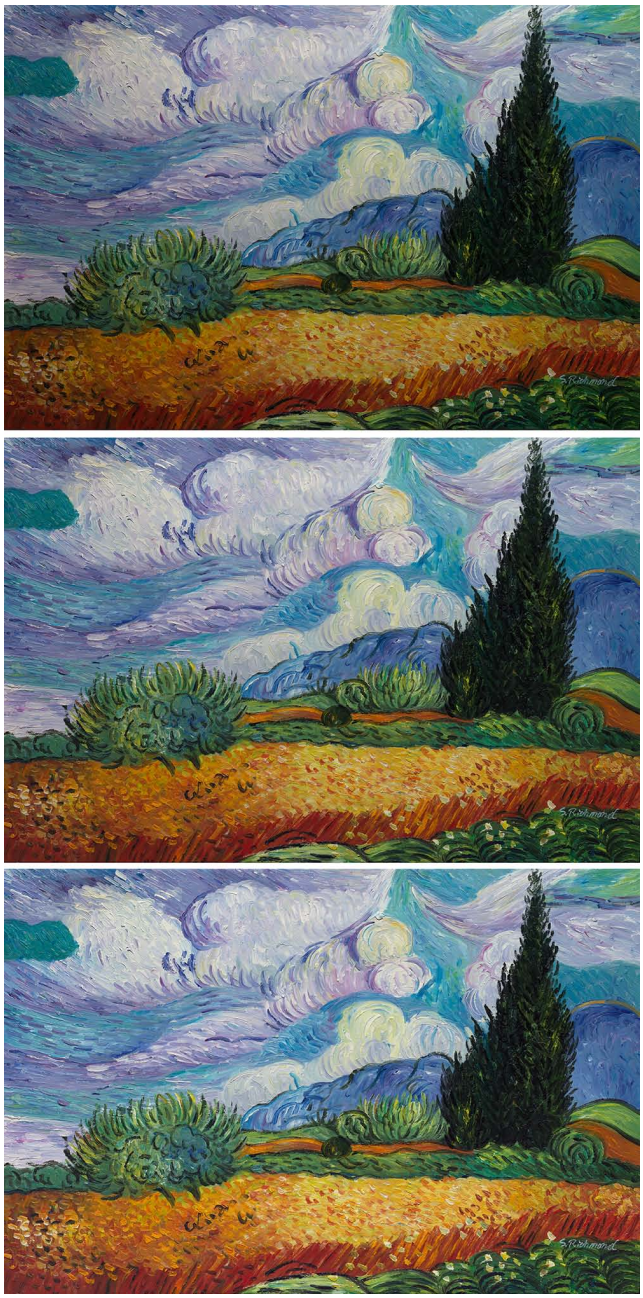

***Figure 4***. Directionally lit image layered on top of the flat-fielded image and the opacity adjusted to 90% (top), 50% (middle) and 10% (bottom)

in Figure 4 were created by layering the non-flat-fielded image on top of the flat-fielded image in Adobe Photoshop and adjusting the top layer's opacity to 90%, 50%, and 10%.

## *Conclusion*

Flat-fielding is a useful technique that has the ability to create uniform illumination in an image while emphasizing physical attributes of the painting. Processing the image outside of the camera offers the user control over the process while also increasing the possible uses of the image set. Then, depending on whether the resulting digitization is intended to replicate either gallery or archiving studio environments, the flat-fielded image can be used in conjunction with the un-flat-fielded image to display varying levels of even illumination and directional lighting information.

Finally, flat-fielding does not offer an excuse or "quick fix" for poor lighting technique, but rather provides a tool for illumination optimization. If the lighting produces excessively harsh shadows, these will persist following flat-fielding and be reflected in lower color accuracy.

## References


[1] Hans van Dormolen, Metamorfoze Preservation Imaging Guidelines | Image Quality, Version 1.0, January 2012. pg. 21

[2] Steven Puglia, Jeffrey Reed, Erin Rhodes, "Technical Guidelines for Digitizing Cultural Heritage Materials: Creation of Raster Image Master Files" Federal Agencies Digitzation Initiative - Still Image Working Group - August 2010. pg. 19 http://www.archives.gov/preservation/technical/guidelines.pdf


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## Author Biography

*Joel Witwer is a graduate student at Rochester Institute of Technology where he is currently pursuing his Master's degree in Color Science.*

*Roy S. Berns holds the Richard S. Hunter Professorship in Color Science at Rochester Institute of Technology (RIT). He has directed the Munsell Color Science Laboratory and graduate programs in Color Science at RIT. He is the director of the Andrew W. Mellon sponsored Studio for Scientific Imaging and Archiving of Cultural Heritage. Berns is an IS&T Fellow.*