RAW Benefits in Forensic Science

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OVER THE PAST FEW YEARS, numerous crime scene investigators as well as latent print examiners have asked a very similar question: Is it better to capture images using a camera RAW format or is JPG good enough? The typical answer is "RAW is always better," which is then followed up by the question, "Why do you ask?" In this article, we hopefully will provide you with sufficient information to make an informed decision when it comes to deciding what works best for you.

In the non-law enforcement world, the answer to the question of shooting in JPG or RAW usually depends upon your needs as a photographer. More specifically, if you are taking pictures to share with your friends over the Internet, such as email or a post on Facebook, then smaller, compressed JPG files are probably your best solution. Typically, you would use a camera that captures enough information so that when the image is compressed, you can still have a good-quality image.

On the other hand, if you want high-quality images and you are using a "high-end" digital single-lens reflex (DSLR) camera, you are probably processing and printing your own photographs. It also means that you probably want to adjust exposure or white-balance settings. In this case, the flexibility and control of the RAW format is basically a requirement.

Control

The original "data" from the imaging sensor is preserved in RAW files, which allows you to adjust color values, white balance, and exposure. As a result, you have complete control over the final product. On the other hand, when using a JPG format, the camera automatically "corrects" the images by applying a linear conversion, processing color information using a demosaicing process, adjusting white balance, color values (saturation), and contrast (exposure), as well as automatically sharpening the image—thus forever altering the original values from the imaging sensor.

In addition, the camera software automatically reduces the bit depth of the image, compresses the image, and encodes the image using device-dependent color settings (commonly referred to as color space)—which ultimately puts the camera in control.

Dynamic Range (aka Bit Depth)

The imaging sensors for almost all digital cameras do not capture color information. Color values are created based upon a Red-Green-Blue silicon color filter array (commonly known as a "Bayer Pattern" or "Bayer Matrix") that is placed over the imaging sensor. (Except for multi-layer sensors, such as the Foveon imaging sensors in the Sigma DP Series cameras.) Using this technique, the pixel color values are based upon the intensity of the light that strikes the photo receptors on the imaging sensor together with the values from its nearest neighbors, as shown in *Figure 1*. Therefore, the ability of the imaging sensor to provide a wider array of intensity is crucial for accurate color interpretations.

The imaging sensor in most semi-professional/professional DSLR cameras captures either 12-bit grayscale (4,096 shades of gray) or 14-bit grayscale (16,384 shades of gray). The RAW file format saves the full dynamic range of grayscale values captured by the imaging sensor. In contrast, JPG files are reduced to only 8-bit grayscale, which produces a dynamic range of only total of 256 different shades.

NOTE: When RAW image files are converted to a standard image file format, such as a TIF file format, the image data is converted to a standard 16-bit format (JPG images can only be saved as 8-bit images) as most, if not all, computer operating systems can only read 8-bit or 16-bit file formats. One key point to remember is that 16-bit images are twice as large as 8-bit images. For example, a RAW image captured using a 6 megapixel (MP) digital camera opened as a 16-bit image will create an image file that is 34.4 MB; when opened as an 8-bit image, the image file would be 17.2 MB.

Having the additional bit depth can be extremely beneficial if your image processing is focused on shading and shadows, and lighting in the image after it has been photographed. For example, the additional bit depth can make the difference in visualizing details in darker (shadows) and lighter (highlights) areas. The loss of bit-depth in JPG images can also result in "posterization", which appears as color breaks where the image should have smooth, uniform transitions in shadows and highlights.

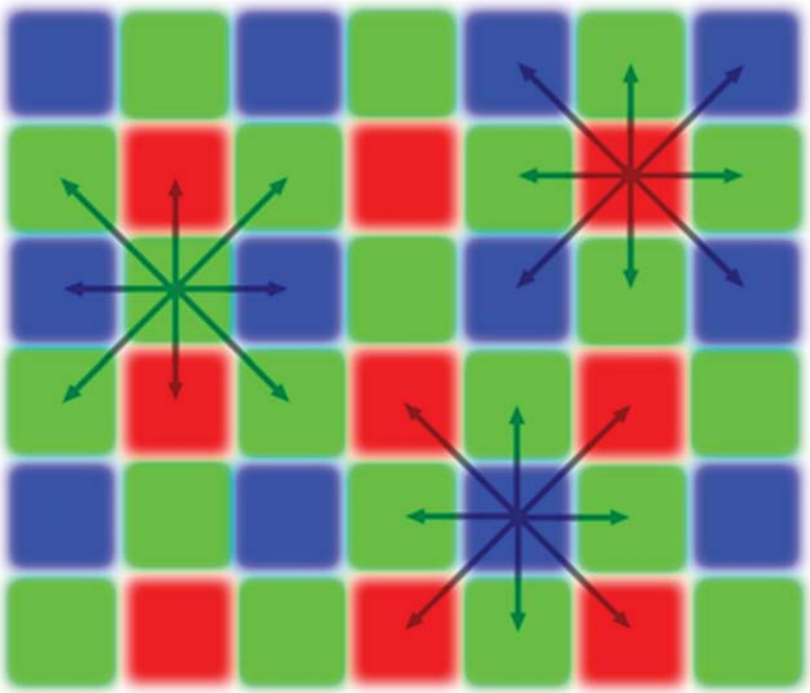

Figure 1*—During the demosaicing process, individual pixel color values are derived from the light intensity of its own filtered value as well as the light intensity of the neighboring photo receptor values, which are filtered with a red, green, or blue filter.*

Image Quality

Compression artifacts can occur in many digital-imaging formats, but the loss of image quality begins inside the camera when using a JPG format. These artifacts result from a data compression scheme that discards some of the actual (original) values that was captured by the imaging sensor in the digital camera.

There are several types of artifacts that can be visualized, especially when the image is enlarged (zoomed). *Figure 2* illustrates the artifacts that are customary for lossy JPG compression.

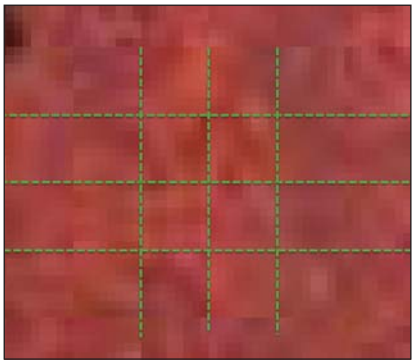

Figure 2*—When zoomed into the image, artifacts that are characteristic of lossy JPG compression (such as the checkerboard-like blocking, blurring and color distortion) are clearly visible. Green dotted lines have been added to help identify the 8 pixel by 8 pixel blocking grid that is customary for lossy JPG compression. You can also see the blurring and color distortion throughout the grid caused by this process as well.*

RAW: the original, unprocessed image data from the photo receptors (picture elements, aka "pixels") on the imaging sensor (such as a charge-coupled device (CCD) or complementary metal-oxide semiconductor sensor (CMOS) that captures light and then converts it into electrical signals) inside the camera.

JPG or JPEG: an acronym for the Joint Photographic Expert Group (typically seen as the file-format extension ".jpg"), that is the group that developed the image file standard that provides a tradeoff between file size and image quality.

In addition, each time a compressed JPG image file is opened, edited, and re-saved, the image is once again compressed, resulting in additional loss of image detail and quite possibly a loss of image quality.

The primary reason why JPG compression is used is to reduce file size, where the loss of image detail is an acceptable tradeoff for a reduced file size. Unfortunately, many law enforcement agencies encourage the use of a higher compression for smaller image file size as the smaller image file size allows more image files to be stored on the memory card in the camera. Plus, the smaller image files are easier to download to a computer or server, which can minimize the stress and strain on many agency or departmental intranets.

The following recommendations provide a basic guideline when choosing what compression rate to use:

❑ **Low image quality**—Most compression (good for viewing on the Internet, such as web pages, emailing, downloading, etc., but not good for printing unless printed as a small image, such as a wallet size image or thumbnail).

❑ **Medium image quality**—Medium compression (good for printing 3 x 5 prints and perhaps 5 x 7 prints, and can be emailed or downloaded easily).

❑ **High image quality**—Least compression (good for printing 8 x 10 prints and can still be emailed or downloaded easily).

Another advantage of JPG files in the law enforcement community is that most law enforcement officers don't have the time—or inclination—to process their images; images captured using a RAW format must be processed or at least converted to a standard image file format, such as TIF or JPG. Furthermore, some lower-end (aka "consumer-grade" or "point-and-shoot") cameras do not provide a RAW format option.

In contrast, RAW image files provide a function much like a negative: like a negative, the RAW image file must first be processed before it can be printed. Also, RAW image files preserve all of the original data from the imaging sensor much like a negative, thus providing higher-quality pictures.

Figures 3 and *4* demonstrate the difference in image quality between a processed image from a standard (default) JPG image file (*Figure 3*) and the same image from a RAW file (*Figure 4*).

Image Integrity

While image reliability and repeatability are essential for demonstrating the integrity of processed image files, there is also an inherent benefit in maintaining the original RAW file format: you can start with the original image data at any point in the future if you (or someone else who thinks they might be able to do a better job processing the image) want to reprocess the image. You can readjust white balance, contrast, color values, and much more.

RAW image files, like negatives, also help maintain image integrity since RAW image files are read only, which means that they cannot be

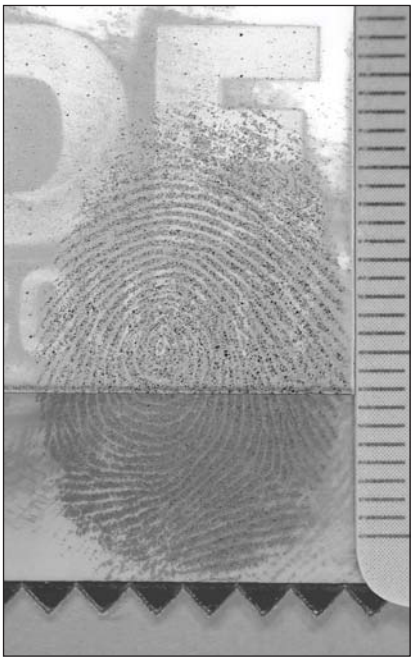

***Figure 3**—Using a standard default JPG setting, the background of the image is more visible in the processed image, and there is a good amount of noise throughout the image.*

***Figure 4**—The processed RAW image provides better contrast throughout the image, with less background noise to interfere with the identification and analysis of individual fingerprint characteristics.*

overwritten. This prevents not only inadvertent image manipulation but it also prevents intentional manipulation.

As stated earlier, the RAW image "data" must first be converted to a standard image format. Since all RAW file formats currently are based on manufacturer-specific proprietary file formats, image editing programs cannot write back to the original file. This means that the converted image files must be saved as a separate file using a JPG, TIF, BMP, etc. format. Unfortunately, standard image files using these standard formats can be opened in almost any image editing program and can be manipulated easily.

Standards and Guidelines

The Scientific Working Group for Imaging Technologies (SWGIT) has defined two categories of digital images for use in the criminal justice system throughout the United States: Category 1 and Category 2 images (SWGIT Guidelines, Section 11, Best Practices for Documenting Image Enhancement, Version 1.3

2010.01.15, pages 1-2). Category 1 images are those images that are considered to be documentation (illustrative or demonstrative in their use) and are not used for image analysis by subject matter experts. Category 2 images, on the other hand, are considered evidentiary in nature, and are typically used for analysis.

In addition to recommending the use of different file formats, SWGIT also has defined different processing guidelines for these two categories.

Briefly, Category 1 images may be acquired using a JPG file format. In addition, a detailed processing history is not required for Category 1 images. In lieu of a detailed processing history, the agency can specify in its standard operating procedures (SOPs) precisely what image-editing functions may be used to process Category 1 images.

Typically, these are basic processing techniques that are used to improve the overall appearance of the image, such as:

- ❑ Adjusting brightness and contrast
- ❑ Adjusting color balance
- ❑ Adjusting hue and saturation
- ❑ Adjusting white balance
- ❑ Basic image sharpening or blurring
- ❑ Cropping
- ❑ Rotating

Category 2 images are another matter entirely. These images should be captured using a non-compressed file format such as RAW or TIF, and a detailed processing history must be maintained for all images. In addition, basic processing techniques must be documented as these techniques can affect the results when used with advanced processing techniques on the same digital image.

Some of the commonly accepted advanced processing techniques include:

- ❑ Tonal range corrections
- ❑ Color channel selection and subtraction
- ❑ Fourier Analysis (pattern identification and extraction)
- ❑ Noise reduction
- ❑ Advanced image sharpening (such as Unsharp Mask and Smart Sharpen)

In addition to maintaining a sequence of the steps used during image processing, you must also record the settings and parameters used for each step. The information must be sufficiently detailed so that a person with comparable skills, training, expertise, and experience could repeat the process and achieve a comparable result.

This does not mean that the digital image must be reproduced pixel for pixel, value for value. The results should be "visually indistinguishable", which means that the content of the image should be compared, not the individual pixel values.

Additional considerations for processing both Category 1 and Category 2 digital images includes:

1) All digital images of must be preserved in their original file format exactly as they came from the digital camera (SWGIT Guidelines, Section 5, Guidelines for Image Processing, Version 2.1 2010.01.15, page 1). This "original" electronic file must be available if requested for discovery or court.

2) Processing must be performed on a copy (duplicate) of the original image (Ibid.). The parent-child relationship between the original and processed images should also be maintained so that the images can be identified properly in accordance with Federal Rules of Evidence 901. You should also be able to authenticate the processed image and demonstrate that the image and the processes used to generate it are accurate and reliable.

3) The chain of custody must be maintained for Category 2 digital images, especially those images of evidence that is deemed "non-recoverable". (Note: ASCLD-LAB Supplemental Requirement to ISO 17025, 5.8.4.4 states: "When evidence, such as latent prints and impressions, can only be recorded or collected by photography and the impression itself is not recoverable, the photograph or negative of the image shall be treated as [physical] evidence.") Access to digital images stored on a workstation or server that is accessible by a number of individuals must be controlled. You should control user rights and permissions to include, but not limited to, privileges for viewing, printing, copying, exporting, archiving, deleting, and so forth.

Conclusion

There are a number of considerations for which image file format should be used in the criminal justice community. Most likely, the first question to ask is how will the images be used? Will they be used for analysis or will they be used as documentation? If they are to be used for analysis by subject matter experts, you really don't have any other option.

If the images are to be used for documentation, you have a few more questions to answer. Will I be processing (converting) all of the images? What is the level of detail that I need to accurately depict a crime scene, traffic incident, death investigation, etc. In some cases, those questions may be easy to answer. However, in other situations, the answer may be less obvious. During a death investigation, you may not know if the images will or will not be used for analysis, such as images with possible blood stains (blood spatter analysis) or shell casings for firearms analysis, etc. In those instances, you would want the highest possible quality images for accurate, detailed analysis even though the images will also be used for documentation.

Of course, there is always the issue of what camera to use. Does it even allow you to capture images using a RAW file format? In this case, the only real question is how much detail you want to capture, which would determine what JPG compression setting to use.

The bottom line is that your decision should be made based on best practices to ensure the highest level of detail and image quality. Those practices should also be defined in your agency's SOPs so that you don't have to try to make these decisions at the scene or in the lab.

About the Author

David Menor Witzke (better known as Ski) has more than 20 years of AFIS and forensic digital imaging experience and has conducted hundreds of digital imaging training programs for law enforcement agencies throughout the U.S. and Canada.

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