Best Practices for Image Resolution:
300, 600, 1000 or 1200 PPI

Documentation versus Evidentiary Imaging

Forensic experts in every impression evidence discipline (latent prints, palm prints, bite marks, tool marks, footwear impressions, blood spatter, tire marks, etc.), use digital imaging technologies to capture a variety of images every day. The challenge is how to capture digital images with the highest possible resolution (quality) captured with the highest degree of color accuracy (clarity).

In accordance with *Section 11, "Best Practices for Documenting Image Enhancement" of the* Scientific Working Group for Imaging Technologies (SWGIT) guidelines for forensic digital imaging, there are two fundamental end uses for images encountered in the legal system:

- ***Category 1*** – used to demonstrate what the photographer or recording device witnessed but are not analyzed by subject matter experts; and
- ***Category 2*** – used by subject matter experts for scientific analysis.

Typically, Category 1 images may be captured with a lower resolution, and may be saved using high-quality JPG compression. Conversely, Category 2 images should be captured at the highest possible (and/or reasonable) resolution, and should be saved using a non-destructive image file format, such as TIF. (Some scanners convert 8-bit color values per channel – aka 24-bit color – to indexed color, which can significantly reduce the number of color values when a BMP (Bit-mapped) file format is used. Therefore, it is not recommended that you use a BMP file format when scanning images.)

When photographing or scanning items that are of evidentiary value, it is strongly recommended (encouraged) that a minimum of two images be captured: an "overall" photograph or scan of the object, and a close-up photograph or scan of just the "subject area" (i.e., fingerprint, palm print, etc.)

The Resolution of Digital Photography

When an overall object is photographed, it is recommended that a scale be included with the image. Even if an object is scanned, it is recommended that a scale be included with the image. Including a scale in the overall object image allows you to verify and validate the size of the object as well as the size of the subject area.

When photographing a subject area, it is important to pay attention to the position of the imaging sensor in the camera in relationship to the object that is being photographed. It is equally important to position the scale in the image strategically so that the camera can be positioned as close to the image as possible.

It is imperative that the camera lens be positioned as close to the subject area being captured as possible. The further the lens is from the subject area being captured, the lower the resolution.

The distance from the object is measured by the Inverse Square Law, meaning that the further the sensor is from the object being captured, the resolution drops by a minimum of 75%, and then decreases exponentially from that point.

For instance, capturing an area that is one inch by one inch equals one square inch. Capturing an area that is two inches by two inches is four square inches, where one square inch is only 25% of the total area or a loss of 75% reduction of resolution relative to the imaging sensor. Capturing an area that is three inches by three inches is nine square inches, where one square inch is only 11% of the total area or a loss of 89% reduction of resolution. Capturing an area that is four inches by four inches is 16 square inches, where one square inch is only 6% of the total area or a loss of 94% reduction of resolution. The bottom line is that you ***must*** fill the frame with the object and a scale when capturing an object with a digital camera to get the highest possible resolution.

Failure to optimize image resolution creates problems when attempting to suppress background patterns, such as backgrounds on checks or money orders where gradient color values are used as a means of security. As the size of the area of capture increases, the camera must be moved further back from the object, and a single photoreceptor must capture a larger area, using all the color values in the area covered by that single sensor and the light intensity to determine the resulting pixel value recorded by that photoreceptor. By capturing a smaller area, the area covered by each photoreceptor is minimized, which also means better color management and a greater opportunity to suppress background patterns and noise.

Capturing an area that is too large for the imaging sensor can create moiré patterns, which occurs when multiple colors are "processed" by the camera's optics to create a single pixel value in a grid pattern. In some cases, it may be necessary to take an overall photograph of the entire area of interest and then take separate close-ups of individual areas within the area of interest to optimize image resolution.

In digital imaging, resolution and color go hand in hand. The higher the resolution, the better the image quality because resolution helps to maintain color values and keep them separated, and color values provide better image detail/color separation.

When capturing a small subject area, such as a latent print, palm print, bite mark, or tool mark, set the lens for its ***closest*** focusing point. Then, move the camera as close to the object as possible using the distance between the lens to the object as the ***primary*** method for focusing. This allows the camera to be as close to the image as possible, filling the entire frame with the object and ensuring the highest possible resolution for image capture. Then, use the focus ring on the lens for fine-tuning the focus of the image.

The Resolution of Scanned Images

The first "photocopy" was created by an amateur inventor by the name of Chester Carlson. He used static electricity with a handkerchief, light and dry powder to make the first "copy" on October 22, 1938. However, the first commercially available copier was not available until 1959. The core technologies in the copier were later transferred to laser prints and scanners, and they have remained basically the same since the 1930s.

The core component of a flatbed scanner is its Charge-Coupled Device (CCD) array, which may have either a single row of sensors which requires three passes for a single image or the scanner may have three rows of sensors for a single-pass scanner.

Scanners also have a single “lamp” that is used to illuminate the document. The lamp is either a cold cathode fluorescent lamp or a xenon lamp. These lamps have only one wavelength / light intensity that can negatively impact color (RGB) values significantly. While the single wavelength can affect the brightness (aka lightness) values of a grayscale image, the impact is significantly more noticeable (and more of a disadvantage) in a color environment, such as when capturing a ninhydrin print overlaying a dark (black) background.

Scanners also vary in resolution and sharpness, which is determined by the number of sensors in a horizontal, single row (x-directional sampling). The stepper motor, which moves the scan head vertically down the page (y-directional sampling), also affects the resolution. For maximum quality, it is important to use a scanner that uses a matching x- and y-directional sampling.

Historically, the quality of the copier (scanner) was determined based upon the number of dry powder “dots” that could be accumulated on the surface of the paper using static electricity (printing). Unfortunately, the output quality of scanners today is still defined in terms of “dots per inch” (DPI); however, the output quality of scanners today is measured by the number (density) of the sensors on the CCD.

The sensors on the CCD are used to capture a Red, Green and Blue Sample. (In a single-pass scanner, each row in the three rows of sensors captures a specific color sample.) These color samples are then used to create the bit depth of the color value for each pixel in a scanned digital image. Therefore, Samples Per Inch (SPI) – the number of individual Red, Green and Blue (RGB) or grayscale samples that are taken in the space of one linear inch – is the “true” measurement of the resolution (image quality and clarity) of a flatbed scanner.

NOTE: The file-size specifications provided in this section are based on the use of an Epson Perfection V700 or V800 series flatbed scanners. For use with other scanners, please contact David “Ski” Witzke, at ski@foray.com .

While both digital cameras and flatbed scanners use a CCD, the size of the CCD in the digital camera is a fixed size (resolution) will not vary regardless of the size of the subject area being digitally photographed. In contrast, flatbed scanners have a constant resolution that remains fixed over a variable-size subject area. Therefore, the issue of concern when using a flatbed scanner to capture a digital image is file size. ***For best practices, the file size should not ever exceed a file size of 50 to 60 MB. In fact, it is preferable to keep the file size as close to 25 MB as possible due to memory limitations of individual workstations as well as network bandwidth limitations.***

For instance, scanning a subject area in 24-bit color (RGB) that is 8 inches by 10 inches at 1200 PPI would result in a file size that is approximately 329.6 MB. Not only is this file size excessively huge, it is unmanageable and exceeds the memory requirements for most computer as well as exceeds the bandwidth availability of most network infrastructures. Even at 600 PPI, the file size for an 8 x 10 image would be 82.4 MB, which is still larger than is reasonable and/or acceptable, and is outside the realm of best practices for digital image file size.

However, scanning a subject area in 24-bit color (RGB) that is 1 inch by 1 inch at 1200 PPI would result in a file size that is approximately 4.12 MB; scanning a subject area that is 2 inches by 2 inches at 1200 PPI would result in a file size that is approximately 16.5 MB; scanning a subject area that is 3 inches by 3 inches at 1200 PPI would result in a file size that is approximately 37.1 MB; and scanning a subject area that is 4 inches by 4 inches at 1200 PPI would result in a file size that is approximately 65.9 MB, which is at the top end of the “desirable” file sizes.

In accordance with ISO guidelines and best practices, all evidentiary items should be photographed both for documentation purposes as well as evidentiary purposes. More specifically, for large items, such as checks, money, money orders, full-size pages, the image should be photographed, ensuring that any excess space around the area of interest is minimized as much as possible. In addition, a second photograph should be taken where the subject area is photographed with the camera as close to the object as possible with ***only*** the subject area and scale visible in the view finder.

If large items are scanned, they may be scanned for demonstrative or illustrative purposes (aka documentation) at either 600 PPI and saved using a maximum quality JPG (i.e., least amount of compression). The specific areas of interest should then be isolated using the marquee tool and scanned at a higher resolution, such as 1200 PPI; or, in the event of a very poor quality impression that can be isolated to a 1-inch by 1-inch or 2-inch by 2-inch area, the subject area may be scanned using a resolution of 2400 PPI.

Digital Camera or Flatbed Scanner?

One frequently asked question is: When should I use a flatbed scanner instead of a digital camera?

The first step in choosing which device to use is to determine the size of the object (also commonly referred to as the area of interest) to be captured. This will help determine the final resolution of the captured image and help identify the best technique for capturing the digital images.

For example, the ***maximum*** coverage area that could be captured using a Nikon D750 digital single-lens reflex camera (DSLR), which has a full-frame, 24 MP (4016 pixels high by 6016 pixels wide) imaging sensor, would measure four (4) inches high by six (6) inches wide and still comply with the ***minimum*** resolution of 1000 PPI.

NOTE: The "1000 PPI requirement" is only applicable as either (1) a minimum image capture resolution for latent impressions (fingerprints and/or palmprints) or (2) an output (export) resolution (defined in the FBI's CJIS Electronic Biometric Transmission Specification (EBTS) documentation) as a "transmission" standard for interoperability between dissimilar digital imaging systems. The reason why this standard was established was to ensure 1:1 (life-size) accuracy. For example, if an image with a resolution of 750 PPI were compared to an image with a resolution of 1000 PPI, the 750 PPI image would be only 75% of the size of the corresponding image. Thus, the minutiae plotting of the smaller image would not "match" the larger image because of the difference in size.

As mentioned earlier, flatbed scanners have a fixed resolution over the entire size (area of capture) of the image. Therefore, the determination about what resolution to use must be based on the hardware (aka optical) resolution. To ensure the highest fidelity of downsampled resolutions (due to hardware activities – computational efficiency – that include pixel averaging, decimation, transcoding and spectral truncation), the resolution should be adjusted based upon a 2:1 resampling rate. (See also NISTIR 7839, Examination of Downsampling Strategies for Converting Fingerprint Imagery.)

For example, scanning a 3 x 5-inch lift card using an Epson Perfection V700 flatbed scanner that has a hardware (optical) resolution of 4800 PPI would create a file size that is 988.8 MB, which is excessive and significantly larger than the desired (workable) file size. To determine the appropriate resolution (and file size), divide the hardware resolution by two (2), which provides a resolution of 2400 PPI and a file size of 247.2 MB. Again, this is excessive and larger than the desired file size. Dividing the value of 2400 PPI by two (2) would provide a resolution of 1200 PPI and a file size of 61.8 MB. While this file size is not excessive, it is larger than the desired file size. Therefore, for appropriate documentation of the 3 x 5-inch lift card, the lift card should be scanned at 600 PPI (1200 PPI divided by 2), which would provide a file size of only 600 PPI. Individual impressions that are of value for analysis on the lift card would, of course, be scanned at 1200 PPI.

Similarly, exemplars (ten-print cards) should be scanned for documentation purposes with a resolution of 600 PPI (***<u>maximum</u>***). Scanning a standard 8-inch x 8-inch tenprint card at 1200 PPI would result in a file size that is 263.7 MB. As stated previously, this file size is excessively large and does not conform to best practices for digital image file sizes. If a single impression on the exemplar needs to be scanned for comparison purposes, then the 1.6 x 1.5 fingerprint block can be scanned at 1200 PPI, producing a file size of 9.89 MB.

NOTE: Only ten-print cards from "certified" Fingerprint Card Print Systems should be used for scanning purposes! These systems include specialized print drivers to generate 10-print cards with sufficient image quality to support fingerprint analysis and comparison. Typical laser printer drivers do not meet the standards for fingerprint image quality specified in Appendix F and PIV-071006. Scanning low-resolution 10-print card output at a higher resolution only amplifies the artifacts caused by the printing process. For example, a black and white laser printer has only one color of toner: black. The scanner can distinguish between 256 shades of gray. Since the printer can generate only an extremely limited number of shades of gray using a series or cluster of black dots, the scanner tries to smooth (blur) the white space between the dots for continuous-tone pixel values. Because of the limited grayscale output capability of the printer, a ridge and an adjacent furrow can have the same dot pattern, which is further smoothed by the scanning software.

One of the primary differences between digital cameras and flatbed scanners is that digital cameras use a light-sensitive photo receptor that is overlaid by a Color Filter Array, which contains a series of red, green, and blue filters arranged in a pattern commonly referred to as a Bayer pattern. Thus, the photo receptor in a digital camera collects only one value: a grayscale value that represents the density of the light striking the photo receptor that has been filtered by a red, green, or blue color filter. The color value for picture element (aka pixel) is calculated (interpolated) based on the density of the light striking the imaging receptor value together with the values of the eight surrounding neighbor sensors. (Fifty percent (50%) of the filters on the Color Filter Array are green, and 25% of the filters on the Color Filter Array are red, and the remaining 25% of the filters on the Color Filter Array are blue.) Because of the enhanced sensitivity (dynamic range) of the light values that pass through the red, green, and blue filters on the Color Filter Array, digital cameras are superior for depicting slight color variations, which can be tremendously helpful when eliminating background noise that interferes with the visualization of the impression.

More specifically, as stated earlier, flatbed scanners have a constant resolution over the entire area scanned, but the images produced using a single light density, which frequently makes it difficult to distinguish between color values that overlay darker backgrounds. In other words, the light density is the same regardless of whether the pixel value is red, black, green or blue. Because of the limited brightness values, the difference between the saturation and brightness values makes it extremely difficult, and at times impossible, to separate background colors and relevant image detail when suppressing noise or patterns. This can be especially detrimental when trying to separate ridge detail developed by certain chemical processes, such as ninhydrin prints developed on checks or money orders where there is limited contrast between the ridge detail and the dark (often black) backgrounds.

It is imperative that the ***<u>appropriate</u>*** camera settings be used to optimize the ability to suppress background noise in digital images. Using fully automatic settings on a digital camera will reduce the ability to suppress background colors, which would be like scanning the impression. It may be possible, however, to use the mode Lab color to suppress the background in a scanned image or an image that was photographed using automatic settings.

The bottom line is that there are no fixed rules about what items should be scanned or digitally photographed. It is just a matter of choosing the device that will work best for the scenario based on the type (make, model and specifications) of the scanner or camera that is available for use; the size of the area of interest; the resolution required, if any, for the image type (category); and the type of type of digital image processing techniques that will be required.

References:

General Guidelines for Capturing Latent Impressions Using a Digital Camera, Scientific Working Group on Imaging Technologies (SWGIT), Version 1.2, December 6, 2001

Document #6 Standard for Friction Ridge Digital Imaging (Latent/Tenprint), Scientific Working Group on Friction Ridge Analysis, Study and Technology (SWGFAST), Version 2.0, March 13, 2013

Electronic Biometric Transmission Specification (EBTS), Criminal Justice Information Services (CJIS), Federal Bureau of Investigation (FBI), Version 10.0, July 2, 2013

NISTIR 7839, Examination of Downsampling Strategies for Converting Fingerprint Imagery, National Institute of Standards and Technology (NIST), Version 1.0, January 2013