

# Using a scanner for photographing small items

By Richard K. George

After seeing yet another set of wonderful items on a website being poorly represented by scans, I have decided to write a brief article on how to use a scanner to photograph small items.

## What is all this scanner stuff anyway?

Or, more than you ever wanted to know about scanners....

Basically a scanner is a device which utilizes a small array of photocells to capture an image by compiling a composite of samples taken by the photocell array as it is moved across a region being scanned.

The device typically used to capture an image of small items is a flatbed scanner. These devices also incorporate a light source and a linear motion stage of some kind to move the photocell array/light along a document (or in our case an item) sampling reflected light from the item being imaged. The resulting sensor data is arranged in an array using position information from the stage to form an image. Depending on the type of scanner there is also sometimes what appears to be a Rube Goldberg array of mirrors to focus the light onto the item being scanned as well as focus the resulting image onto the array.

There are basically two major types of flat bed scanners. Those that utilize a CCD (Charge coupled device) photosensor array and those that use a CIS (Contact Image Sensor).

The CCD units typically utilize a cold cathode fluorescent light source for illumination, and the CIS units are typically illuminated with an LED array. While the CIS scanners are typically smaller and much less expensive, they suffer from several issues that make them a poor choice for imaging small items. First, they in general have much less depth of field. Second, because the light source is relatively weak, they are affected by external lights to a much greater degree than those that use fluorescent illumination. And third, they typically have lower native resolution.

So what should one look for in a flatbed scanner for imaging small items?

First of all, one must consider the resolution and the resulting usage of the image. The first parameter of interest is the maximum **non-interpolated** resolution of the scanner. What the scanner software does to get to higher resolutions is "manufacture" pixels

between each of the actual sampled pixels based on information from the surrounding sampled pixels. This works, sort of, but you usually get better images by choosing a unit whose native scan resolution is within the range of what is needed for the end result.

Which brings up the interesting question of what resolution is actually needed in various applications. The resolution needed basically comes down to the number of pixels/inch needed on the resulting output image. And this depends on the contrast of the image (in general you need lower resolution on lower contrast image), the resolution of the output device, and the required size/distance the resulting image is to be viewed at.

For printing, typically the resolution is characterized by what is needed to make an image not look “jaggy” when viewed at roughly arm’s length. There are several research papers that indicate the “magic number” for this is about 215 PPI (pixels per inch), which is why you’ll find that many digital camera manufacturers set the native “resolution” on their images to ~ 240 PPI. There are a couple of problems with this. First and most importantly, is that while this number is OK for “typical” images, the human eye can resolve much more if the image has very high contrast (like say, at the edge between brightly illuminated metal vs. a black background), there are several papers that indicate this “ultimate” resolution can be as much as 530PPI. The second issue is that images are often viewed much closer than this, as is evidenced by the number of nose prints I have to clean off the glass of my images after they’ve been on public display. While both of these items can require a different printing strategy, a good rule of thumb to start out with is to scan the image so when displayed at the size desired it can be printed at ~ 300 pixels/inch (PPI). Note that Pixels Per Inch is different from a printer’s Dots per Inch – printers usually use a number of ink dot locations to create a resulting pixel. If the resulting image isn’t going to be manipulated/you are only displaying it with a monitor, you can get away with a much smaller image, as the typical monitor has a resolution of ~96 PPI.

The next thing to worry about is the number of bits of color information per pixel. Again, going back to the human eye, it can resolve about 200 distinct tones before a color wedge appears as a continuous variation from light to dark. This is how we ended up with 24 bit color – you can represent 256 steps in 8 bits of data X 3 for the three primary colors = 24 bits of color information per pixel. While this is great for display, it’s a big problem if the image is being manipulated – as you push/pull/truncate the tonal range of the resulting image during post processing, you can end up with “lines” appearing in areas of continuous tonal variation (posterization), digital noise becoming visible, etc.,. For this reason, it’s usually a good idea to find a scanner that has more bits of native color resolution than this – most modern ones can do 16 bit color, and I personally advise capturing the images this way if your workflow can deal with this – If you are only working with 24 bit files (READ: jpegs), just be aware of these tonal range issues and try to “fix” them with your scanner’s control software if you can. Note that native

color resolution of the scanner itself can possibly come into play here as well – sometimes colors are interpolated as well if the scanner doesn't have sufficient resolution to actually measure the colors to the accuracy requested.

The next concern is the depth of field of the scanner. Other than the previously observed generalization that CCD scanners have more depth of field than CIS scanners, this has to be checked out on a scanner by scanner basis to see if the unit is suitable for the items you want to scan.

And the final “big” thing to worry about is the dynamic range of the scanner. A lot of scanners report the dynamic range of a scanners in terms of Dmax or density range. This goofy number can basically be related to bits of resolution by the following equation:

$$D_{max} = \log_{10}(2^{\text{bits of resolution}})$$

Where Dmax is the magic number given by the manufacturer and Bits of resolution is the number of bits of effective resolution being sampled). Note that these numbers seem to in general be pretty aggressive on the part of the manufacturers. In general, the bigger the Dmax, the bigger a dynamic range you can capture with the scanner. So what number do you need? If you are just scanning documents/photos, etc., (where the resulting data isn't being manipulated much) probably an honest 8 bits of resolution (which works out to a Dmax of 2.4 or so) is enough. If you are working on physical items with a lot of variation between the brightest color and the darkest color and are capable of working with 48 bit data, the larger the Dmax the better.

Another way to think of it is in photographic terms of “stops” – with slide film you can get up to about 5 stops (some say 6 stops) of tonal variation, which is a fair proxy for real things on the scanner. This works out to a needed effective Dmax of 3 to 3.6 or so. But again, with the typically extremely optimistic Dmax numbers the manufacturers provide, you'd probably want to go for a stated Dmax of 3.9 or more if possible.

## **How do I get the color right?**

**Or, how come my whites are so red?...**

The human brain/eye connection is an amazing thing – it can adjust dynamic range so that the whitest thing in an image becomes the white, the darkest thing become the black, and overlook all kinds of issues with color – particularly when the original isn't available to compare the image to. Its also helpful that most people are very good at not “seeing” problems with color, etc., unless the error is very large (particularly if a reference of some sort isn't available).

But if you are doing a lot of imaging, sooner or later you are going to run into looking at a resulting scan or print versus the original and seeing that it looks visibly different. You have just experienced why most imaging professionals spend a lot of effort on something called 'color management'. The whole purpose of all this effort is to be able to deliver an image that looks (more or less) like the original object subject to various constraints (the colors and luminosity the output device (printer, monitor, etc.,) is capable of showing, lighting under which the object or output is viewed, etc.,).

The process of color management involves calibrating your input/output devices to a "known" standard and keeping track of which color space an image is recorded/manipulated in. This in theory allows another person with similarly calibrated equipment to "see what you see" in your image.

Color management can be a fairly arcane process, as is evidenced by the large number of books in print on the subject. Also, as its fairly easy to find texts and articles on "how to do it" (and to prevent the reader from falling asleep), I'll present only a (very) brief summary here.

The theory is that you always work in a "common" color space, which some call the "profile Connection Space" or PCS. As few input devices perfectly measure or re-create all colors, a mapping file typically called a "profile" is created for each device. The purpose of this profile is to allow the software to adjust input or output data so it matches the "perfect" associated color value in the PCS. This profile is usually created by running some kind of calibration software utilizing a known reference of some kind.

It is very easy and not terribly expensive to do for monitors – there are now a number of mass-market photospectrometers (ColorMunki, Colorvision Spyder, etc.,) at very reasonable prices. And the process is pretty straightforward – you periodically stick the "puck" over a square created on your screen by the calibration software and it does the rest – the software ends up putting the created profile in the appropriate place and even Windows knows what to do with it with no prompting. I would recommend at least considering calibrating your monitor if you plan to do any manipulation on your images, particularly if you are using them on the web, where the data is "assumed" to be matched up to this perfect color space.

One observation: the "free" tool shipped with windows for monitor calibration (adobe gamma) is pretty much useless – don't waste your time with it. While it had some value in the era of CRT displays whose colors were often WAY off and varied a LOT with monitor age, temperature, etc., unless you've dealt with color issues before you'll often make the color fidelity of a modern LCD display worse.

Calibrating scanners is a bit more difficult, usually involving scanning a known color chart and then using the associated software to create the profile. You can then either

use this profile in your photo editing tool or (typically) you tell the scanner's control software where the profile is and it manipulates the file automatically.

Calibrating and using gamut limited devices like printers is much more complicated in that it usually involves the creation of a profile as well as subsequent manipulation of the file to be printed to get the colors "in gamut" (you can let the printer do this, but you often end up with pretty funky looking images if the colors are very far of the color gamut that the printer is capable of printing).

And what about the term "color space"? There are many (Adobe RGB, SRGB, etc.,), and again there are many books written on the topic, so I won't bore you even more with the details here other than to note that for ANYTHING going on the web, the data should be converted to the SRGB color space – while there are supposedly more programs out there that are color space aware, most of the common applications will merrily strip/ignore your color space information and just assume the data is supposed to be SRGB, which again will result in different colors than you intended being displayed.

I have included several links in the bibliography to web sides with reasonable introductory discussions of color management.

## **OK, stop with all that longhaired rambling-How do I scan stuff?**

OK, enough of that – how do you actually scan stuff? The first thing to try is scanning something to test what your scanner is capable of. The first thing to try is the ol' banana test – this will give you some idea of the dynamic range and depth of field of your scanner – here's an example from an Epson perfection 4870:

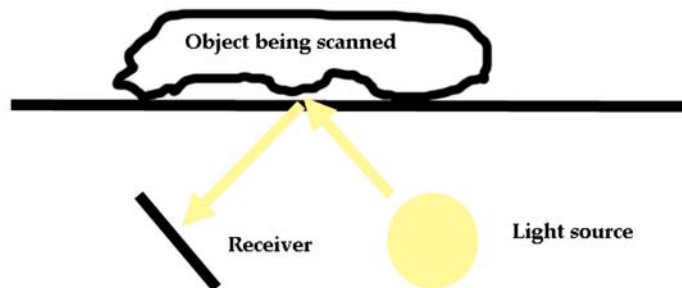


And here's a larger crop of the stem that shows the depth of field:



As can be seen, there's only a few tenths of an inch of depth that is in focus – and this is with a CCD scanner. It should be noted that other scanners do have more depth of field than this, as this unit was optimized for the scanning of photos, negatives, etc.

There are some more interesting things that can be seen in this image. The first is that the light is fairly directional, coming from the "bottom" of the banana in this case. Most if not all scanners will show this effect due to the placement of the lighting:



Because of the lighting geometry, you are pretty much always going to end up with fairly hard shadows in uneven areas of the object being scanned. For those wanting a solid white background, be prepared to spend some time in photoshop cutting these shadows out, and using clever selections for masking.

Because of this issue, users often prefer to go with a simple black background. This is most easily produced by simply leaving the scanner lid open (as long as your ceiling doesn't have mirrors on it, that is). Leaving the lid open on the banana gives the following result:



It is interesting to note that the dark background makes the image appear brighter. Another benefit of using a dark background is that on some scanners a dark background will “fool” the scanner’s control software into thinking the item is darker and will compensate by lightening the image slightly.

This image also reveals another issue with using a scanner for imaging. Because of the close proximity of the light to the object being scanned, there is a very rapid falloff in illumination versus the height of the object above the scanning surface. While this is usually ok on flat objects, it can end up being a problem on any object with a fair amount of depth to it.



Here is another example of an item scanned with different backgrounds:



The scanner light was coming from the bottom of these two images, so some fairly harsh and distracting shadows are visible in the cutouts of the item with the white background. Also note that the background is not perfectly white, so if this is desired, the background must be worked on in post-process to remove the shadows and make the background white.

In addition, this example illustrates the basic visual design principle of a light background making an item of interest appear darker (both images had the same post-process and the intensities across the image are essentially identical).

Another thing to note is that because the object being imaged is relatively flat, the illumination is fairly even across the piece.

Another issue is that with the extremely directional light, often details simply vanish. This can be seen in the following examples. First, here is a “normal” image of an item:



When this item is scanned, it can appear very different. This next image is of the same item being scanned so the light is coming from the right hand side:



The big problem here is that the gold trim on the bolster is not very visible because it is fairly flat in the direction of the scan, and not much light is reflected from it into the sensor. In addition, the shape of the blade is somewhat lost. In this case, an image that shows the bolster better as well as giving definition to the blade can be obtained by rotating the piece by roughly 45 degrees on the scanner bed:



From these images, you can also see that the sensor is “viewing” at what amounts to a slight angle. This is useful because you can show a little bit of edge detail if desired. I believe this effect is less visible with a CCI scanner, but the depth of field is also in general smaller, so it’s a tradeoff.

If the un-natural look of the reflective surfaces is an issue, it might have to be addressed in post-process, experimentation with the orientation of the object on the scanner bed, lifting the object slightly to make the offending surface not parallel to the surface of the scanner bed, or possibly looking at the use of a different imaging method.

Another visual difference is the checkerboard pattern on the bolster. This pattern has been created by starting with a shiny surface and then etching the checkerboard pattern onto it. In the photograph, the reflective squares of this checkerboard appear light colored because they are reflecting a white surface. This was a decision on the part of the photographer for aesthetic reasons. In the scan, these appear darker than the etched areas. This is because the highly reflective areas reflect very little light toward the sensor (just like the gold colored outline on the bolster).

Here is another scan of an item with gold decoration. In this first image, the piece has been scanned so the light is coming from the right hand side of the image:

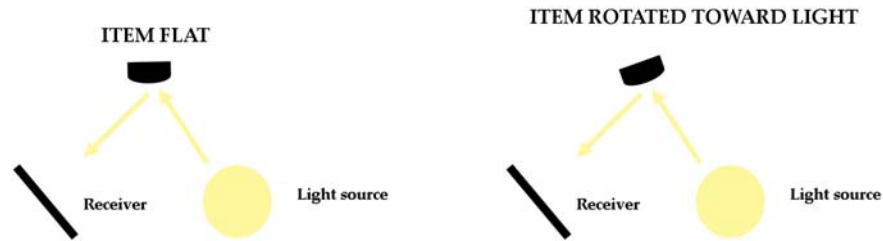


If the piece is rotated 90 degrees so the light is coming from the top of the image, the following scan is obtained:



By changing the direction of the light, the depth of the carving is now much more visible. Unfortunately, the image also shows better the rapid light falloff problem that one has to deal with when imaging with scanners. This image will probably need to either need to have some post process done in a photo editing tool to accentuate the edges, or be re-scanned after adjusting the scanner's imaging controls.

The second image can be improved by rotating the item so that the incoming light is striking at a different angle:



Doing this gives the following result:



This makes the carving look even better by reducing the shadows.

The catch is that the item has been rotated so much that the top edge is right at the edge of the depth of field provided by this particular scanner. However, this is only going to be visible if the image is viewed at a significantly larger size than is shown above, so this may be a non-issue for your purposes. It would also be a non-issue on scanners with a greater depth of field.

If you like the image as-is, you can try and define the edges by using a light background:



In this case, you can see where the edges of the piece are more easily - but as mentioned earlier, post process might be required to obtain a pure white background, remove the distracting shadows, etc.

It should be noted that the previous scans have had several adjustments done to them using photoshop. They all have had their contrast increased, as well as having the darker regions of the images lightened using the “curves” command in that tool (called “opening the shadows” in the vernacular). A number of these adjustments can also be done within the scanner’s software.

Usually a scanner is fairly good at adjusting its scan to maximize what is called the dynamic range of the image (the lightest colors approach the maximum intensity that can be displayed, and the darkest colors approach black). However, it’s not so good at adjusting the contrast, and is really not good at displaying darker colors so they can be seen in other medium.

To illustrate this, here is a scan of the kogai shown in the earlier images with no image adjustments.



If you were to look at the full size image, you could just barely make out the edges of the piece, but when reduced in size as shown above, the piece “vanishes” into the background.

Fortunately, we all don’t have to be photoshop gurus to figure out what to do with the scanner to get something done. In the case of the Epson 4870, they have some reasonably simple controls. The scanner’s software presents several adjustments. The first is to select automatic adjustment, which produces the image shown above. The next box is called a “histogram adjustment”, which is analogous to the “levels” command in photoshop. Usually the scanner does a fair job of adjusting the dynamic range, so its uses won’t be discussed here, though as with photoshop, adjusting the histogram can be used to accomplish many of the adjustments can be done with other tools in the software. The next box over is the one of interest in this case, and is marked “tone correction”, which is the same as the “curves” command in photoshop, elements, etc.

Going into this menu, there is a simple correction marked “open shadows” – just using this setting produces the following result:



The last control is “image adjustment”, and allows you to tweak the colors, contrast, brightness, etc. of the image to your heart’s content. Again, if you have profiled your unit, you should not have to mess with the colors, and you will get unpredictable results on other people’s displays, prints, etc., if you are tweaking these parameters without at least calibrating your monitor.

A bit more tweaking of these curves yields the following result:



While this more or less allows the outline to be visible, the main part of the image has lost contrast, etc. This is one of the reasons that most imaging professionals use photoshop – it allows the user to selectively apply various adjustments areas of interest. Here is an example of using photoshop on the image directly from the scanner without changing its controls as shown above:



As there are many, many books in print on photoshop usage (as well as pretty much every scanner having its own unique user interface), figuring out what all these various parameters is left as an exercise for the reader.

As can be seen, a scanner can be used to make fairly good images of small objects, provided the user can live with the lighting, depth of field, and perspective constraints. In general, scanners that utilize a CCD for imaging work better for this task than CIS scanners. The direction of the light is important – lighting direction can be changed by rotating the object to be photographed on the scanner bed. If the end use of the image is reproduction in print or for digital distribution, the user should be careful of making modifications to the color without taking steps to insure that the resulting image will appear as desired when printed or displayed. This is typically insured by the use of color management techniques. And if one does not have access to or wishes to figure out how to use all the features of their photo editor, many of the necessary tonal and contrast adjustments can be executed using the scanner's control software.

## **Bibliography**

Web Links:

Scanners in general:

[http://en.wikipedia.org/wiki/Image\\_scanner](http://en.wikipedia.org/wiki/Image_scanner)  
<http://computer.howstuffworks.com/scanner.htm>  
<http://www.xbitlabs.com/articles/other/display/scanner-an.html>  
<http://www.scantips.com/>

Using a scanner as a camera:

<http://www.photogalaxy.com/articles/scanner.php>  
<http://www.scanner-magic.com/index.html>

Color management:

[http://en.wikipedia.org/wiki/Color\\_management](http://en.wikipedia.org/wiki/Color_management)  
<http://www.cambridgeincolour.com/tutorials/color-management1.htm>

Other more esoteric issues (human eye resolution, etc.)

<http://www.clarkvision.com/imagedetail/eye-resolution.html>  
<http://photo.net/learn/drangle/>

Next, here are some books I have found useful in the areas of imaging:

Macro Photography:

Constant, Alan R. Close Up Photography. Boston. Focal Press, 2000

Lighting:

Hunter, Fil and Fuqua, Paul. Light Science & Magic

An Introduction to Photographic Lighting. Boston. Focal Press, 1997

Resolution:

Williams, John B. Image Clarity

High Resolution Photography. Boston. Focal Press, 1990

Photography stuff in general:

Freeman, Michael. Image

Designing effective pictures. New York. Amphoto, 1988

Shaw, John. John Shaw's Nature Photography Field Guide. New York. Amphoto, 2000

Photoshop:

Blatner, David and Frasier Bruce. Real World Photoshop CS. Berkeley, California. Peachpit press, 2004

Color management:

Frasier, Bruce, Murphy, Chris, and Bunting, Fred. Real World Color management, Second Edition. Berkeley, California. Peachpit press, 2005

Additional recommended books can be found at my website:

<http://www.rkgphotos.com/links.htm>

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