Pixels revisited.

We received the following questions from a reader:

Question: I use Ulead Photo Impact software for editing photos. I have read your article "Understanding Pixels". I have a query about how pixels are related with to the size of a photo. If they are related, then how many pixels are in one inch?

In your article, pixels are explained as a parameter of quality of a photo, i.e. more pixels gives a clearer photo, but in photo editing software there are some standard sizes in pixels for photos like 4 x 6" where the equivalent size in pixels is 384 x 576 pixels. Please explain this.

Answer: Indeed, the more pixels (picture elements) that are captured when a digital image is created - in the case of a digital camera, the photo is taken - the higher the quality of the resulting image. Older digital cameras typically captured only 640 x 480 pixels (0.307 megapixels). Today, consumer cameras that capture 8 megapixels (3264 x 2448 pixels) are available - that's 26 times more pixels than the early cameras could capture. Think of the old cameras as shooting a very coarse grained "film" and the new cameras shooting a very fine grained "film". Notice when discussing the cameras, we didn't mention the term pixels per inch (ppi) - sometimes called dots per inch (dpi). Digital cameras really don't have a "ppi" – just total pixels.

The pixel per inch (ppi) value starts to become important when we are talking about outputting digital images to make prints.

To keep things easy for photographers to understand, photofinishing labs that make prints from digital images on traditional photographic color paper don't talk about ppi. They specify the required number of pixels in terms of minimum suggested values. An on-line service that I use in the United States that has a Fujifilm Frontier Digital Minilab suggests the following:

Minimum Resolution (pixels)	Print Size (inches)
640x480	2.5x3.5
1024x768	4x6
1152x864	5x7
1536x1024	8x10

If you divide the number of pixels by the image size you get a recom-

mended MINIMUM pixel per inch value in the range of 150 to 200 ppi for this digital minilab. MORE pixels per inch will give a better print. But notice again, that the lab carefully doesn't mention ppi or dpi – just total pixels.

Going back to the analogy of coarse grained "film" (few pixels) and fine grained "film" (lots of pixels), the images made from fine grained "film" will look better when made into large prints. Large prints from the new high pixel count cameras will look much better than prints from the old low pixel count cameras.

Things can get confusing when you want to make digital prints at home using an inkjet printer. My two-year-old Epson C-80 is a 4 ink, 2880 x 720 dpi printer while the new Epson R-200, for example, is a 6 ink, 5760 x 1440 dpi printer.

 The first thing to remember is that the quoted printer dpi value is NOT directly comparable to a ppi value. In the case of inkjet printers, the dots are just that – dots of ink – which are NOT pixels. This is why I prefer to use the term "ppi" instead of "dpi" when talking about digital images. Digital images have pixels; digital inkjet (and laser) printers have dots. Digital printers use these dots to reproduce the pixels in a digital image through a pro-

cess called dithering. Dithering fools the eye into thinking it sees a pixel with one color and density by using a varying pattern of many small dots of different colors. Thus, it takes many small dots to create one pixel with an inkjet print.

The exact placement of the small dots that make up a pixel is critical to maintaining image sharpness and avoiding a blotchy image appearance. There are many different mathematical techniques that are used to create the dot pattern used to "dither" an image – one common technique is called error diffusion. Several books have been written about the dithering techniques used in printing.

Notice that most inkjet printers, like the mentioned Epson printers, have two dpi values. The first value is the number of small dots per inch across a line in the print and the second value is the number of lines per inch in the page direction.

Unfortunately, inkjet printer manufacturers don't give specific recommendations as to how the ppi of an image relates to the printer's dpi. I recommend you do a printing photographic quality image experiment with your inkjet printer system – that means the printer, paper, and ink – to find out how you can make

good looking prints

In conducting your experiment, remember that printer drivers for different printers, as well as different computer operating system versions, use different terms to describe the quality options that are available. Typically they will have some settings that are low quality (often called draft), some that fall in the "medium" quality range, and some that are "high quality".

As a starting point for your experiment, select a high resolution (lots of pixels) digital image that has good sharpness, lots of colors, and a good tonal range from shadows to highlights. Create an image that is sized at 200 ppi for the print size you are making (a 4 x 6 inch print would require 800 x 1200 pixels). You will have to use your image enhancement software resize feature to do this. Starting from the same high resolution image, create a second image that is sized at 300 ppi for the print size you are making (a 4 x 6 inch print would require 1200 x 1800 pixels).

Make a print of the 200 ppi image with the printer set to print at a medium quality level. Make a second print of the 200 ppi image with the printer set to a high quality level. Make a third print with the 300 ppi image and the printer

set to the same medium quality level as before. Make a forth print with the 300 ppi image and the printer set to the same high quality level as before. Look at the prints. What combination looks best to you? Write it down the values you used so you don't forget them, and use them as a starting point when working with digital images in the future.

See the sidebar for my test results.

In regard the question about "...4 x 6 inch where the equivalent size in pixels is 384 x 576 pixels....". If you divide 384 by 4 (or 576 by 6) you get 96 ppi, but why does the software suggest 96 ppi? One of the things Ulead's Photo Impact software is designed to do, is work with images destined for use on the Internet where they will be viewed on computer monitors. Most new computer monitors have a resolution of about 96 ppi (some older monitors have a resolution of 72 ppi). By the way, you'll usually see monitor resolution given in terms of "dpi". Thus their recommended 384 x 576 pixel size is designed to reproduce a 4 x 6 inch image on a computer monitor. It's not a particularly good value to use if you intend to make prints of your images.

The term ppi is also important to understand when using a scanner.

Before you set out to scan an item – be it a document or a photo – it is important to know what you intend to do with the scanned digital image. Remember you can always use a digital image with lots of pixels to make a small print but you can't use a digital image with just a few pixels to make a large print. Remember also that big images require more storage space on your hard drive.

Let's say that we have a traditional 3R print – 3.5 x 5 inches – that we want to scan so we can make a 5 x7 inch print on our inkjet printer. Assuming that we want to send our printer a 200 ppi file, we will need at least 1000 x1400 pixels. We will have to scan the 3R print using at least 285 ppi to get the required number of pixels. 285 ppi isn't offered by most scanner software so we will probably have to use 300 ppi. This will produce a 1050 x 1500 pixel image and that will be fine.

So to answer your question "… how many pixels are in one inch?", you can see the answer is it depends on what you want to do with the image. To view an image on a computer monitor, 96 ppi is fine, but to make a photographic quality print of that image, AT THE SAME SIZE as it is on the monitor, would require about 200 ppi.

Thus, a 4 x 6 inch image on the 96 dpi monitor requires 384 x 576 pixels, but making a photographic quality 4 x 6 inch print at 200 ppi would require 800 x 1200 pixels.

Understanding the concept and use of the terms ppi and dpi is probably one of the most important issues in digital imaging. I hope this has helped.

The following table does the math for you and shows you how many pixels you need in an image to make a print at different pixel resolutions in ppi:

Print size	100 ppi	150 ppi	200 ppi	300 ppi
2.5x3.5	250x350	375x525	500x700	750x1050
4x6	400x600	600x900	800x1200	1200x1800
5x7	500x700	750x1050	1000x1400	1500x2100
8x10	800x1000	1200x1500	1600x2000	2400x3000

I encourage readers to submit questions about my articles and digital imaging in general to this magazine. Such feedback helps me understand your interests and gives me ideas for future articles.

[Sidebar]

My printer test setup.

Starting from the same high resolution image file, I prepared three test images: the first at 100 ppi, the

second at 200 ppi, and the third at 300 ppi. I then printed these file using my 4-ink Epson C-80 printer and Epson Heavyweight Matte Paper. The Epson printer driver features vary with the computer operating system. I'm running Mac OS 10.3.3 and the printer driver offers 18 different choices of output quality. I made prints of each test image file with the 720 DPI High Quality setting (sort of a medium quality level in the list) and 1440 x 1440 DPI Highest Quality setting (almost the highest quality setting in the list).

To get a better look at the dots on each print, I magnified them by scanning them using my Epson Perfection 3200 flatbed scanner set to 1200 ppi. I then compared the various images on my computer monitor using Photoshop.

My test observations.

Setting the Epson C-80 printer driver to 720 dpi High Quality, the 200 ppi image was sharper than the 100 ppi image but not noticeably sharper than the 300 ppi image. All images were grainy. See Figure 1.

Setting the Epson C-80 printer driver to 1440 dpi Highest Quality, the 300 ppi image was very slightly sharper than the 200 ppi image. Both were about as smooth in tonal

gradation. See Figure 2.

Comparing the 200 ppi image printed at both 720 dpi High Quality and 1440 dpi Highest Quality, the 720 dpi image was grainer and not as smooth in tonal gradation. See Figure 3.

Looking at the actual prints themselves, my conclusion is that 200 ppi and 720 DPI High Quality are a good set of values for most of my print applications using my printer. Your results with your images and your printer may vary.
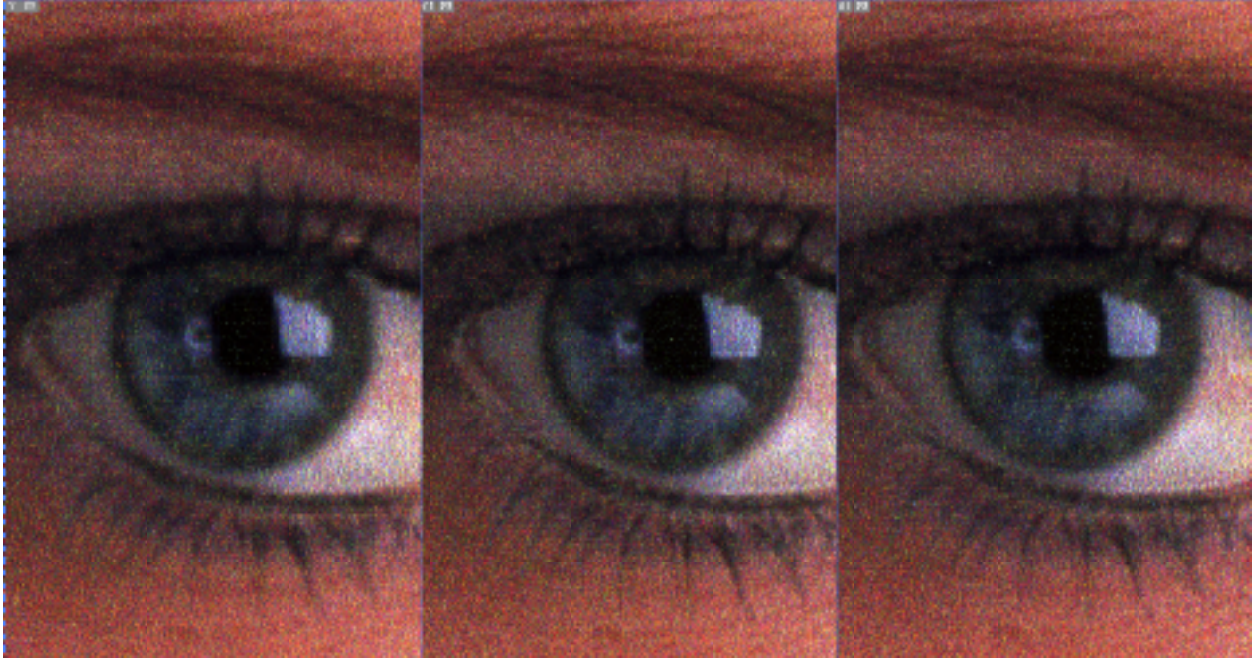
Figure 1. 100ppi (left), 200 ppi (center), and 300 ppi (right) image files printed at 720 DPI High Quality.
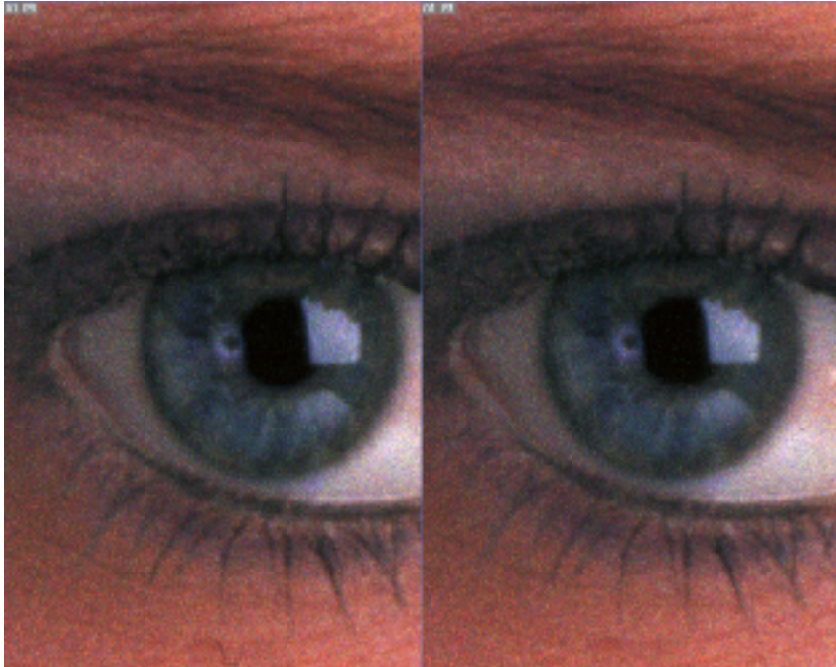
Figure 2. 200 ppi (left) and 300 ppi (right) image files printed at 1440 x 1440 DPI Highest Quality.
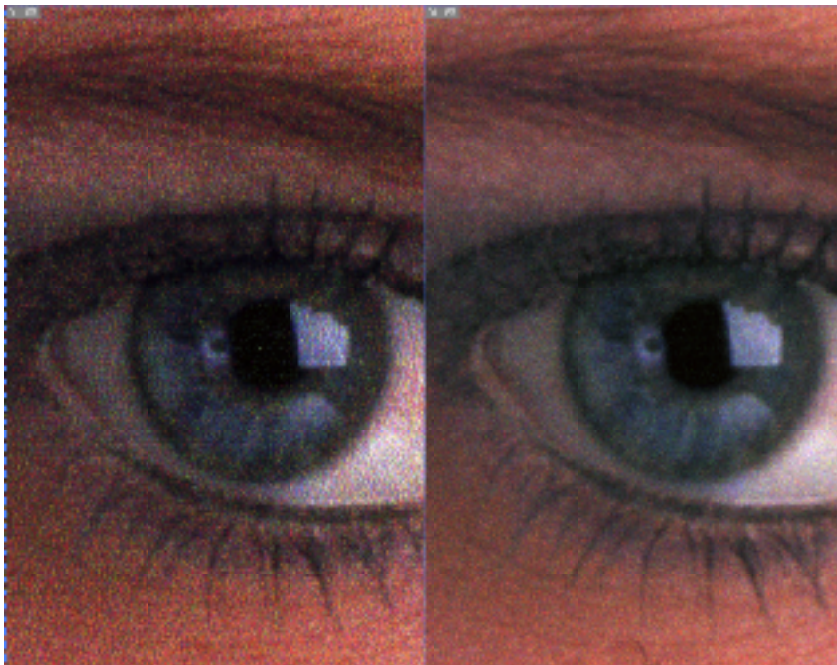

Figure 3. 200 ppi image file printed at 720 DPI High Quality (left) and 1440 x 1440 DPI Highest Quality (right).