Digital Image Resolution - the basic concepts

There are two basic ways in which the resolution of digital images is specified - the colour resolution, or bit depth, and the spatial resolution.

Bit Depth

The bit depth of an image is concerned with the number of possible colour or tonal values for each pixel. Digital data is made up of a series of 0's and 1's (or "on-off" switches - in fact, many switches on electrical devices have the symbols 0 and 1 to indicate off and on). In computing, one bit is the smallest amount of data that can be processed by a computer. A single bit can either be on or off, 0 or 1, or black or white in imaging terms. 1 bit images are those composed either of black or white tones (line art). Photographers use special high contrast line or lith film to achieve this effect.

If two bits are allocated to each pixel, four combinations of 0's and 1's are possible:

i.e. 00, 01, 11, 10 (black, white and two shades of grey).

Similarly, 3 bits gives 8 combinations, 4 bits gives 16 combinations, 8 bits gives 256 combinations and so on.

In mathematical terms the numbers are derived from a power of two:

e.g. $2^2 = 4$

$2^3 = 8$

$2^8 = 256$

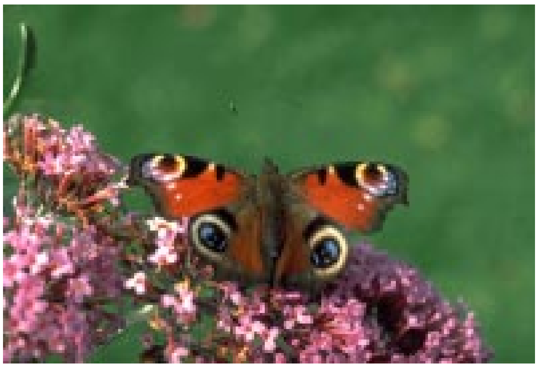
For black and white imaging, 256 grey levels (8 bits) are necessary for the eye to see a continuous range of grey tones without any noticeable banding.

A 2 bit greyscale image, with a black, white and two shades of grey

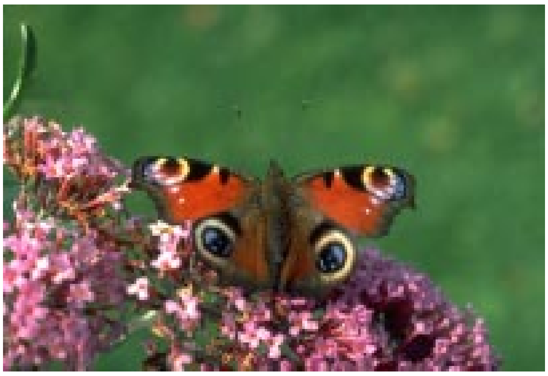
An 8 bit greyscale image, with a black, white and 254 shades of grey

Colour images

With colour images the situation is slightly more complicated. Digital colour images, rather like colour film, are composed (usually) of three primary colours, red, green and blue (they may be converted afterwards to four: cyan, magenta, yellow and black, but for display on a monitor they are three coloured). 8 bits per pixel are required for each of the three colours in order to display a continuous tone, or "photo-realistic" image, so a single pixel can have a possible 8 bits or



An 8 bit colour image, containing 256 colours



A 24 bit colour image, containing a possible 16 million colours!

256 values for the red component, 256 values for the green and 256 values for the blue. Therefore, any pixel can have 24 bits associated with it: 256 x 256 x 256 (2^{24}) giving 16 777 216 possible values! A 24 bit colour image therefore requires three times as much storage space as an 8 bit image. One very important thing to remember when scanning for example, is that if your original is monochrome, then do NOT scan it in colour mode. The resulting image will be three times larger than it needs to be!

Spatial Resolution

Digital images are composed of picture elements, or "pixels", and the resolution, or quality of a digital image will be largely, but not totally, dependent upon the total number of pixels which make up the image.

The total number of pixels in an image is derived by multiplying the number of pixels horizontally by the number of pixels vertically in the image sensor. An image composed of 640 x 480

A relatively low resolution image, containing just a few thousand pixels

A relatively high resolution image, containing several hundred thousand pixels

pixels has a total of 307,200 pixels. An image with 1024 x 680 pixels has a total of 696,320 pixels, more than twice as many. If the two images are viewed at a small size, then they may well appear to be the same quality, but if they are enlarged, then the one with more pixels will appear to have higher resolution. This is rather like film, where a 20 x 16" print will, in general, be better from a 5 x 4" negative rather than 35mm.

In the case of a flatbed scanner, if the linear CCD sensor is 8.5" wide, and contains 2540 elements, then the maximum resolution possible is 2540 divided by 8.5, giving approximately 300 pixels per inch (sometimes referred to as “samples per inch”).

Other Terminology
The terminology associated with resolution can be confusing, and many of the terms are often used interchangeably in error, even though they have very specific definitions. It is well worth acquainting yourself with the various terms.

Pixels per inch
This is the resolution of the digital image in pixels. A scanning device may have a resolution of 300ppi for example (this may be referred to sometimes as “samples per inch”). Unfortunately, many people mistakenly use the term dots per inch when referring to scan resolution. Input devices such as scanners produce pixels. Output devices such as ink jet printers use dots of ink or dye to print their images!

Dots per inch
This is the resolution of the output device, such as a printer. It refers to how many dots can be placed on a page by the printing device.

Lines per inch
This is the scale used to define the screen ruling used by printers when using half tone screens for reproducing continuous tone photographs in publications like books and magazines. It refers to the number of lines [of dots] per inch used in the screen - typical figures are 85lpi (newspapers), 133 - 150 lpi (typical books).

Practical resolution
For most beginners to digital imaging, the obvious question is how large a print can be produced from a certain size of digital file? There are several answers to this. Firstly, the size of final print that is acceptable will depend on you the viewer, and your criteria for a “good” print. Different people will have different views as what constitutes an acceptable print.
Nonetheless, some guidelines can be given, which should lead to good results. As discussed in the “printers” article, the quoted resolution for an ink jet printer for example, is not the resolution of the actual image. A pixel in the original image is represented by a group of dots on the printed page. This process means that the “effective resolution” of the printed image is lower than the value quoted for graphic or text output. Theoretically, for photographic quality colour printing on an ink jet printer, each pixel in the image needs to be represented by four dots of ink, so the effective resolution of a 720 dpi printer is 720/4 = 180dpi. In reality, a setting of 200 or 220 dpi will yield excellent results, depending on the type and quality of paper used. As an example, you might have a digital camera with a 2 megapixel chip, which has dimensions of 1728 x 1152 pixels. When printed at 200 ppi on a 720 dpi ink jet printer, this will yield a print of 8.6 x 5.7" (21.9 x 14.6cm).

If this image is to be printed in a book or magazine, a useful rule of thumb is to divide the largest dimension by 300. In the case above this would be 1728/300 = 5.76" (14.63 cm).

Whilst these figures are fine in theory, it is well worth experimenting. Different paper surfaces will affect the final quality of the output, and, in the end, it is all down to what you think is an acceptable print.