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The following terms are used in this article*:

Bit

The smallest unit of computerized data. A single digit number in base-2, either 1 or 0.

Color Channel

Stores information about color elements in the image. For example, a RGB image contains 3 color channels: red, blue, and green.

File Compression

Encoding repeatable patterns of binary 0's and 1's, to reduce the file size for processing, storage, transmission, and display.

ICC Color Profile

A file that defines the relationship between the color data your device receives or transmits and a standard color space defined by ICC and based on a measurement system defined internationally by CIE.

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Improve Your IQ

Image Quality (IQ)

What determines image quality? Of course, there are the image's aesthetic qualities.

Does it meet the customer's expectations? Is the composition pleasing? Is the lighting balanced? Does the image communicate the intended marketing message to the targeted audience? These factors are subjective and not easily measured.

On the other hand, several technical characteristics of a digital image are objective and scientifically measurable, using widely accepted principles. Although a detailed explanation of these is more than most people need to know, a basic understanding makes it easier to produce higher-quality digital images.

The technical quality of a digital image starts with the quality of the capture device – the camera body, image sensor, lenses, and software. The capture device initially determines pixel count, detail, noise, bit depth, file format, file compression, and color accuracy.

Let's briefly examine these elements of quality:

Pixel Count

Pixel count is the most common measure of image quality. Pixel count is expressed as the total number of pixels a digital image contains, in width and in height, for example, 2,400 x 3,000 pixels.

Since a pixel has no exact size, pixel count is a more accurate measure of quality than an image's resolution – the measure of an image's pixel density, expressed in pixels per inch or ppi, for example, 300 ppi. To measure an image's resolution, you must know both the pixel density (ppi) and the image's dimensions.

Higher image resolution does not mean higher quality. For example, a 4 x 6-inch

image with a resolution of 300 ppi is equivalent to a 12 x 18-inch image with a resolution of 100 ppi. Both images have an identical pixel count – 1,200 x 1,800 pixels.

Most would agree, the more pixels you have, the better the image. Today, most professional digital SLR cameras can capture 8 to 12 megapixels or MP of information. Digital camera backs, for use on medium- and large-format camera bodies, start at 11 to 22 MP. Today's devices capture an incredible amount of pixels, equal to or beyond the resolving capability of traditional photographic film.

Image Sensor Resolution

Resolution, as the word is used in digital imaging, is something of a misnomer. Today it is commonplace to describe a camera's image sensor pixel count as its resolution. But for purists who know photography and optics, resolution is the measure of the ability of a device to resolve individual lines on an ISO test chart, according to ExtremeTech.com. The more lines per inch the camera can resolve (see), the higher its resolution, for example 1,200 LW/PH (Line Widths/Picture Height).

Why is it important to measure the resolution of a camera's image sensor this way rather than pixel count? Different cameras, each capable of capturing the same number of pixels, produce images of varying quality. Often the difference in resolution is due to the size and quality of the camera's image sensor.

Take, for example, the Samsung Digimax V6 digital camera, which effectively captures 6.1 MP, using an image sensor that measures 7.18 x 5.32 mm. Compare that with the Pentax *ist DS camera, which also captures 6.1 MP. However the Pentax's image sensor measures 23.7 x 15.5 mm. Both cameras capture the same

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Image Sensor

A solid-state device containing a photosite for each pixel in the image. Each photosite records the brightness of the light that strikes it during an exposure.

ISO

International Organization for Standardization.

LZW

Short for Lempel-Zif-Welch. A lossless form of file compression.

Megapixel (MP)

One million pixels.

Pixel

An abbreviation of the term 'picture element.' The smallest picture element of a digital image.

Pixels per Inch (ppi)

An indication of the quality of images, based on the number and density of the pixels.

RAW

A file containing the uninterpolated data collected directly from the image sensor before processing.

Signal-to-Noise Ratio (SNR)

The ratio of the magnitude of the desired components of a signal to the amount of noise in the signal.

**All definitions courtesy of Google Dictionary and Adobe.*

number of pixels, but the Pentax produces a higher quality image, as measured by its resolution.

Digital Noise

Digital noise is the electronic equivalent of film grain. Often overlooked, noise is as much a factor in influencing digital image quality as film grain is to film-based images. Nearly all electronic devices, including image sensors, generate a certain level of noise – the less noise, the higher the perceived visual quality of the digital image. Signal-to-Noise Ratio or SNR measures the amount of noise generated by the image sensor.

Professional-level digital cameras contain larger, higher quality image sensors, which generate less noise than consumer-level cameras. Their sensors have a greater dynamic range and maintain a cooler operating temperature. Heat increases the noise generated by an image sensor; improved temperature control reduces digital noise. This is especially apparent in the shadow detail, where noise becomes obvious.

The Bit Depth

Bit depth, also called color depth or pixel depth is a measure of how much color data an image contains. Images commonly contain 8 bits of data per color channel (red, blue, and green). Eight bits of data result in 256 possible tonal variations per channel (2^8). An RGB image with 8 bits/channel is called a 24-bit RGB image (8 bits/channel by 3 color channels = 24 bits/pixel). A 24-bit RGB image may contain up to 16.8 million color combinations (256^3).

Advances in imaging technology allow cameras to capture ever-increasing bit depth. Higher-end digital cameras now capture 12 and 16 bits/channel. At 12 bits/channel (36-bit RGB), an image can contain 4,096 different tonal values per color channel (2^{12}), or 68.7 billion total possible color combinations ($4,096^3$).

Higher bit depth images present challenges; the first is software. Adobe Photoshop was one of the first software programs to process images greater than 8 bits/channel. File storage and computer processing requirements also present a challenge with

How Big is That Image?

Ever wonder how to calculate the file size of a digital image? It's relatively easy to do. Take total number of pixels and multiply by bit depth. This will give you the image's approximate uncompressed file size in bits.

To calculate the images size in megabytes, divide your answer in bits by 8 (8 bits/byte). Then divide it again by 1,024 (1,024 bytes/kilobyte), and again by 1,024 (1,024 kilobytes/megabyte).

Let's try an example of an 8 x 10-inch, 24-bit RGB image, at a resolution of 300 ppi:

1. $(8 \text{ in.} * 300 \text{ ppi}) * (10 \text{ in.} * 300 \text{ ppi}) = 2,400 \text{ pixels} * 3,000 \text{ pixels.}$
2. $2,400 \text{ pixels} * 3,000 \text{ pixels} = \underline{7,200,000 \text{ pixels.}}$
3. $7,200,000 \text{ pixels} * 24\text{-bits/pixel} = \underline{172,800,000 \text{ bits.}}$
4. $172,800,000 \text{ bits} / 8 \text{ bits/byte} = \underline{21,600,000 \text{ bytes.}}$
5. $21,600,000 \text{ bytes} / 1,024 \text{ bytes/kilobyte} = \underline{21,094 \text{ kilobytes.}}$
6. $21,094 \text{ kilobytes} / 1,024 \text{ kilobytes/megabyte} = \underline{20.6 \text{ megabytes.}}$

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Adobe Digital Negative (DNG)

www.adobe.com/products/dng

Anatomy of a Digital Camera: Image Sensors

www.extremetech.com/article/2/0,1558,1157577,00.asp

Cornell University Digital Imaging Tutorial

www.library.cornell.edu/preservation/tutorial

Digital Camera Corner Topics

www.dpcorner.com/topics

Digital Photography Review Glossary

www.dpreview.com/learn/?/Glossary/Digital_Imaging

Luminous Landscape Tutorials

www.luminous-landscape.com/tutorials

Measure Your Camera's Performance

www.imatest.com

higher bit depth images. The physical file size of a 48-bit RGB digital image is twice that of an identical 24-bit RGB file with the same resolution.

Higher bit depth provides a higher level of color accuracy and smoother transitions between colors, without harsh breaks. Higher bit depth also provides greater dynamic range, with better shadow and highlight detail. Lastly, higher bit depth provides more data for complex computer functions, including scaling and color correction.

Color Management

Color management allows photographers to capture exceedingly color-accurate images by calibrating and profiling their cameras. Profiling measures the way the capture device sees and records known colors from a target. An ICC color profile is a file that contains the numeric color measurements obtained during profiling, and is embedded in the digital image file.

The embedded profile allows graphic arts experts to process, or transform the digital image from one color space to another (RGB to CMYK), while maintaining a high level of color fidelity.

File Format and Compression

Digital cameras and image-editing software offer a variety of file formats and compression methods for saving images. The most common file formats for high-quality digital image storage are RAW, TIFF, JPEG, Photoshop, and EPS. These formats retain all image data, bit depth, ICC color profiles, and other useful metadata.

Most formats also offer a choice of file compression methods, either lossy or lossless. Lossy compression methods, such as JPEG, average together adjacent pixels of similar colors, producing smaller files at the cost of image quality. Lossless compression methods, on the other hand,

such as LZW and ZIP, only compress adjacent pixels of identical color, resulting in less compression and larger files – without loss of image quality.

Conclusion

Pixel count, image sensor resolution, digital noise, bit depth, file format, compression method, and color management all affect image quality. Understanding and controlling each of these variables will help you achieve optimal results. Capturing and preserving the highest-quality digital image possible will allow you to reproduce that image faithfully in a variety of mediums. Does the image look good? Beauty is in the eye of the beholder. Is it a good quality image, technically? That can be measured and controlled.



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