Digital Image Basics

Written by Jonathan Sachs

Introduction

When using digital equipment to capture, store, modify and view photographic images, they must first be converted to a set of numbers in a process called digitization or scanning. Computers are very good at storing and manipulating numbers, so once your image has been digitized you can use your computer to archive, examine, alter, display, transmit, or print your photographs in an incredible variety of ways.

Pixels and Bitmaps

Digital images are composed of *pixels* (short for picture elements). Each pixel represents the color (or gray level for black and white photos) at a single point in the image, so a pixel is like a tiny dot of a particular color. By measuring the color of an image at a large number of points, we can create a digital approximation of the image from which a copy of the original can be reconstructed. Pixels are a little like grain particles in a conventional photographic image, but arranged in a regular pattern of rows and columns and store information somewhat differently. A digital image is a rectangular array of pixels sometimes called a *bitmap*.

Types of Digital Images

For photographic purposes, there are two important types of digital images—color and black and white. Color images are made up of colored pixels while black and white images are made of pixels in different shades of gray.

Black and White Images

A black and white image is made up of pixels each of which holds a single number corresponding to the gray level of the image at a particular location. These gray levels span the full range from black to white in a series of very fine steps, normally 256 different grays. Since the eye can barely distinguish about 200 different gray levels, this is enough to give the illusion of a stepless tonal scale as illustrated below:

Assuming 256 gray levels, each black and white pixel can be stored in a single byte (8 bits) of memory.

Color Images

A color image is made up of pixels each of which holds three numbers corresponding to the red, green, and blue levels of the image at a particular location. Red, green, and blue (sometimes referred to as RGB) are the primary colors for mixing light—these so-called additive primary colors are different from the subtractive primary colors used for mixing paints (cyan, magenta, and yellow). Any color can be created by mixing the correct amounts of red, green, and blue light. Assuming 256 levels for each primary, each color pixel can be stored in three bytes (24 bits) of memory. This corresponds to roughly 16.7 million different possible colors.

Note that for images of the same size, a black and white version will use three times less memory than a color version.

Binary or Bilevel Images

Binary images use only a single bit to represent each pixel. Since a bit can only exist in two states—on or off, every pixel in a binary image must be one of two colors, usually black or white. This inability to represent intermediate shades of gray is what limits their usefulness in dealing with photographic images.

Indexed Color Images

Some color images are created using a limited palette of colors, typically 256 different colors. These images are referred to as indexed color images because the data for each pixel consists of a palette index indicating which of the colors in the palette applies to that pixel. There are several problems with using indexed color to represent photographic images. First, if the image contains more different colors than are in the palette, techniques such as dithering must be applied to represent the missing colors and this degrades the image. Second, combining two indexed color images that use different palettes or even retouching part of a single indexed color image creates problems because of the limited number of available colors.

Resolution

The more points at which we sample the image by measuring its color, the more detail we can capture. The density of pixels in an image is referred to as its *resolution*. The higher the resolution, the more information the image contains. If we keep the image size the same and increase the resolution, the image gets sharper and more detailed. Alternatively, with a higher resolution image, we can produce a larger image with the same amount of detail.

For example, the following images illustrate what happens as we reduce the resolution of an image while keeping its size the same—the pixels get larger and larger and there is less and less detail in the image:

Original (400x262)

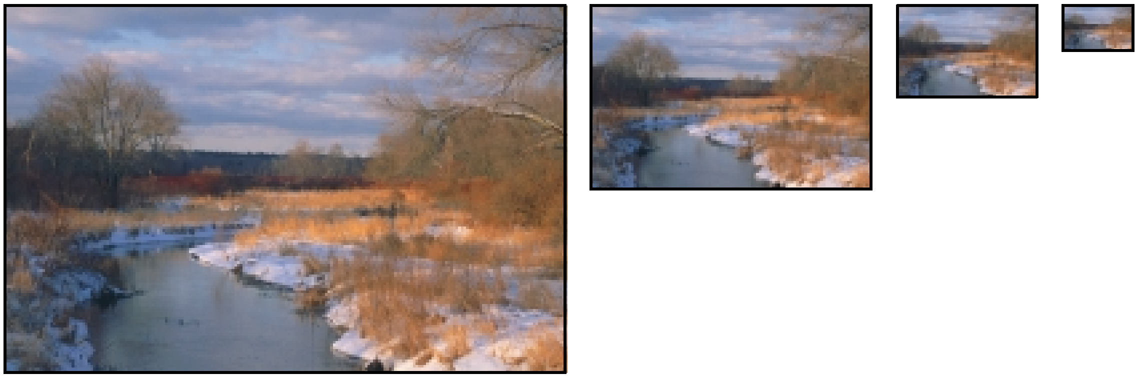
Half Size (200x131)

Quarter Size (100x65)

Eighth Size (50x32)

Legend3D, Inc. Ex. 2006-0004
PRIME FOCUS V. LEGEND3D
IPR2016-01243

As we reduce the resolution of an image while keeping its pixels the same size—the image gets smaller and smaller while the amount of detail (per square inch) stays the same:



Color Terminology

While pixels are normally stored within the computer according to their red, green, and blue levels, this method of specifying colors (sometimes called the RGB *color space*) does not correspond to the way we normally perceive and categorize colors. There are many different ways to specify colors, but the most useful ones work by separating out the hue, saturation, and brightness components of a color.

Primary and Secondary Colors and Additive and Subtractive Color Mixing

Primary colors are those that cannot be created by mixing other colors. Because of the way we perceive colors using three different sets of wavelengths, there are three primary colors. Any color can be represented as some mixture of these three primary colors.

There are two different ways to combine colors—*additive* and *subtractive* color mixing.

Subtractive color mixing is the one most of us learned in school, and it describes how two colored paints or inks combine on a piece of paper. The three subtractive

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