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1. What is a digital Image?

I'll skip explaining what a picture is and begin defining a digital image. Digital images are made of picture elements called pixels. Typically, pixels are organized in an ordered rectangular array. The size of an image is determined by the dimensions of this pixel array. The image width is the number of columns, and the image height is the number of rows in the array. Thus the pixel array is a matrix of M columns x N rows. To refer to a specific pixel within the image matrix, we define its coordinate at x and y. The coordinate system of image matrices defines x as increasing from left to right and y as increasing from top to bottom. Compared to normal mathematic convention, the origin is in the top left corner and the y coordinate is flipped. Why is the coordinate system flipped vertically? Originally, digital images were defined in terms of the electron beam scanning pattern of televisions. The beam scanned from left to right and top to bottom. Other than this historical reason, there is no purpose served by this inversion of the y coordinate.

Image size is not to be confused with the size of the real world representation of an image. Image size specifically describes the number of pixels within a digital image. The real world representation of a digital image requires one additional factor called resolution. Resolution is the spatial scale of the image pixels. For example, an image of 3300x2550 pixels with a resolution of 300 pixels per inch (ppi) would be a real world image size of 11" x 8.5". To clarify resolution terms, ppi is **p**ixels **p**er **i**nch and dpi is **d**ots **p**er **i**nch. Ppi refers to pixel arrays, while dpi refers to printer resolution. In reality these two resolution terms are used interchangeably. Another resolution term you may encounter is lpi, for **l**ines **p**er **i**nch, which describes halftone resolution and is used in magazine and newspaper printing. Many image editing applications default the resolution to 72 ppi. This is true for saving JPG images in ImageJ as well.

Having defined the number of pixels, MxN, only provides a rectangular shape for our image. One more parameter, intensity, is needed to truly define an image. Each pixel has its own intensity value, or brightness. If all the pixels have the same value, the image will be a uniform shade; all black, white, gray, or some other shade. It is in the type

of intensity used for each pixel that image types vary. Black and white images only have intensity from the darkest gray (black) to lightest gray (white). Color images, on the other hand, have intensity from the darkest and lightest of three different colors, **R**ed, **G**reen, and **B**lue. The various mixtures of these color intensities produces a color image. Thus the two most basic types of digital images, B&W and Color, are known as grayscale and RGB images. In addition to the intensity type of each pixel, the range of intensity values also varies.

Intensity values in digital images are defined by bits. A bit is binary and only has two possible values, 0 or 1. An 8-bit intensity range has 256 possible values, 0 to 255. This can be seen mathematically by $2^{(\#\ of\ bits)}$. For a 1-bit, or binary, image, $2^1 = 2$ possible values and for an 8-bit image, $2^8 = 256$ possible values. The standard digital photo uses an 8-bit range of values; RGB images use 8-bit intensity ranges for each color and B&W images have a single 8-bit intensity range. Since RGB images contain 3 x 8-bit intensities they are also referred to as 24-bit color images. So far we have only discussed the range of possible values and not the interval between values. Theoretically, an 8-bit range could occupy values from 0 to 1 using $^1/_{256^{th}}$ increments, but in reality, 8-bit images are defined to use only integer (whole number) values from 0 to 255.

التعليقات

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