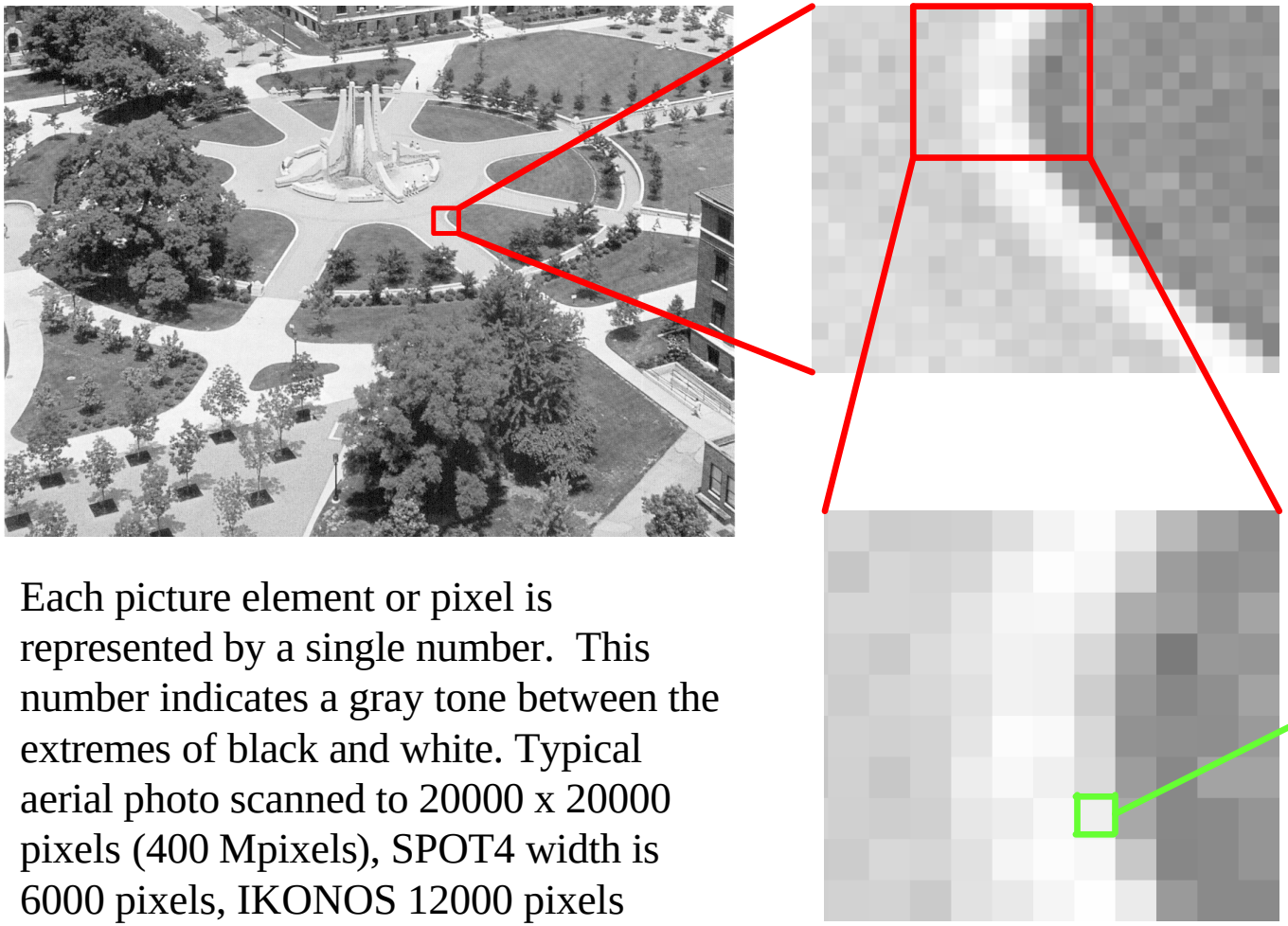
Digital Image – Monochrome or Gray Tone



Each picture element or pixel is represented by a single number. This number indicates a gray tone between the extremes of black and white. Typical aerial photo scanned to 20000 x 20000 pixels (400 Mpixels), SPOT4 width is 6000 pixels, IKONOS 12000 pixels

INTEL-1034
9,641,841

Gray Tone Quantization or Radiometric Resolution

8-bit quantization means we have $2^8 = 256$ different gray tones

00000000 (binary) = 0 (decimal)

11111111 (binary) = 255 (decimal)

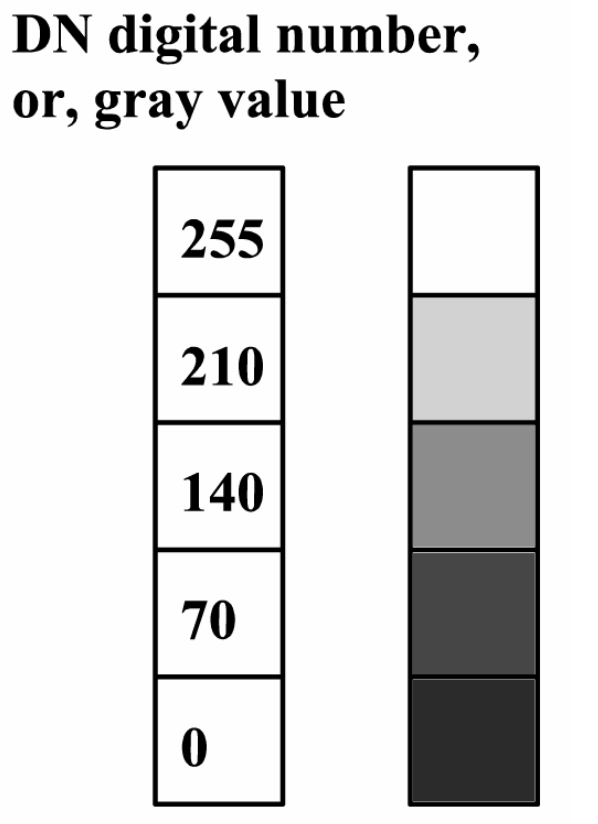
8-bit data value fits exactly into one "byte" of computer memory

12-bit quantization means we have $2^{12} = 4096$ different gray tones

Need 2 bytes per pixel

Human eye can discriminate approximately 64 gray shades

IKONOS supplies 11-bit imagery. The sensor's dynamic range must support a given quantization level or it is not "real"



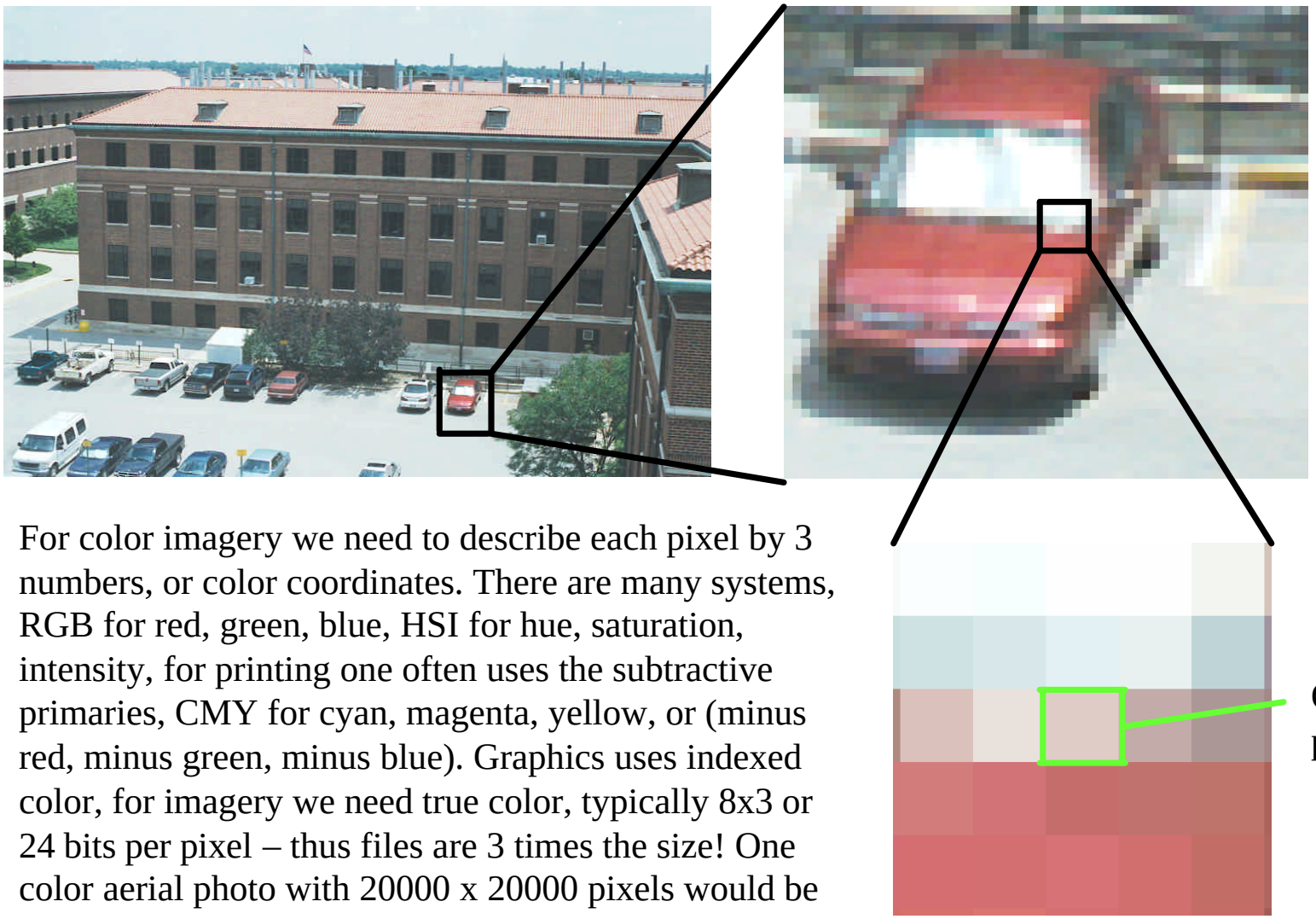
C language has *unsigned char* data type which is 8-bits, MATLAB has *uint8*, unsigned integer, also 8-bits

Image Files

214	204	206	208	223	243	252	232	186	158	143
198	214	211	216	240	253	248	212	157	142	147
214	214	213	228	245	246	233	173	162	146	146
208	202	219	230	242	240	217	160	123	152	150
204	212	216	225	242	240	206	152	135	143	163
								143	142	154
									163	163
										149

There are many image file formats. ".raw" just stores binary values by rows, top to bottom. ".tif", ".bmp" include header data about image pixel dimensions, physical size (pixels per inch), mode, bits per pixel, etc. "indexed color" is just for graphics, imagery potentially needs all possible values. To save space, some people use image compression. JPEG, joint photographic experts group, is best for imagery (although lossy – depending on quality level chosen), MPEG is equivalent for motion picture ….

Color Digital Imagery

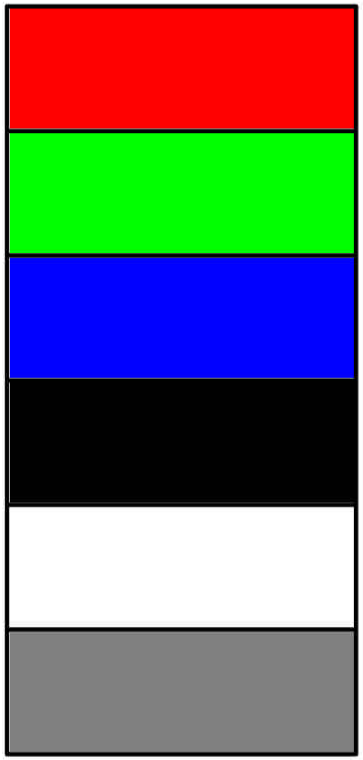


For color imagery we need to describe each pixel by 3 numbers, or color coordinates. There are many systems, RGB for red, green, blue, HSI for hue, saturation, intensity, for printing one often uses the subtractive primaries, CMY for cyan, magenta, yellow, or (minus red, minus green, minus blue). Graphics uses indexed color, for imagery we need true color, typically 8x3 or 24 bits per pixel – thus files are 3 times the size! One color aerial photo with 20000 x 20000 pixels would be 1.2Gb.

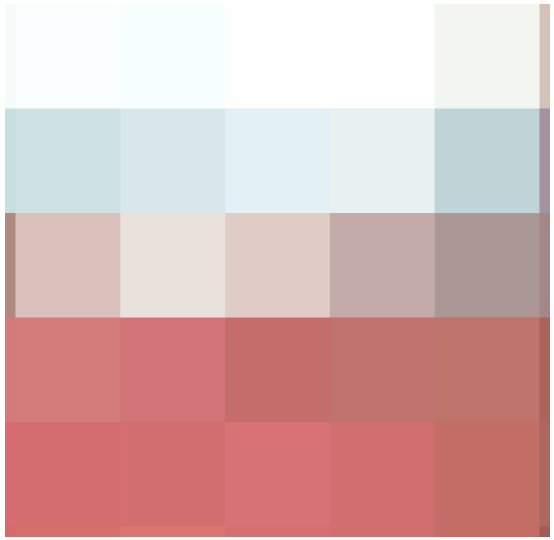
Image Fusion - Different Geometries, Scales, and Spectral Bands

Red/Green/Blue Additive Primaries for Digital Image

R / G / B
255/0/0
0/255/0
0/0/255
0/0/0
255/255/255
128/128/128



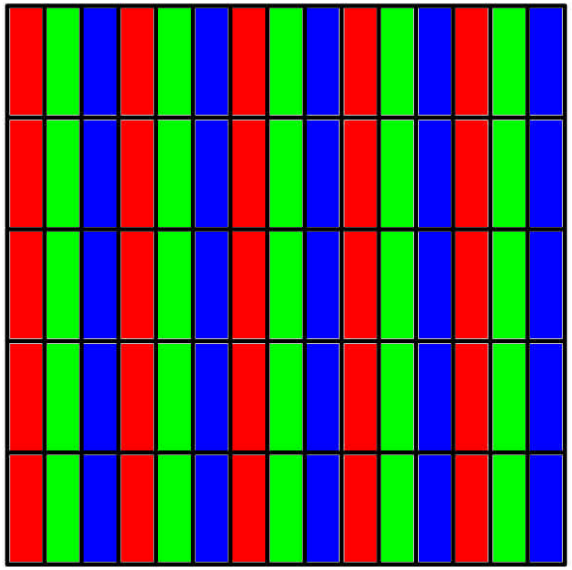
For 8-bit quantization, we need three bytes per pixel. So we have potentially 2^{24} = 16,777,216 different colors that can be represented. For 12-bit quantization, there are *many* colors that can be represented. Good question to ask: are the low order bits in a 12-bit image significant or are they noise? As before, it depends on whether the sensor dynamic range is sufficient, and whether the analog to digital conversion is done well. Even in 8-bit images people encode “digital watermarks” and other “messages” (steganography) by fiddling with the low order bits and nobody can see the difference.



RGB color components for the 5x5 image region extracted from the previously shown image. Note that we rarely get “saturated” colors in imagery. Even the saturated red from the automobile paint becomes 210/110/110 in the image. i.e. the red component (210) dominates, but green (110) and blue (110) components are present as well.

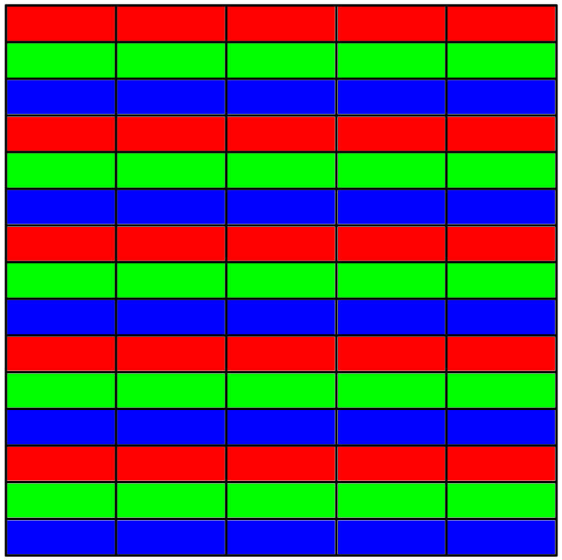
R / G / B

251/255/254	247/255/255	254/255/255	255/255/255	243/245/241
207/226/227	216/231/233	227/241/244	232/241/239	191/212/214
219/193/187	232/225/220	223/204/199	194/171/169	172/151/151
210/124/124	209/115/119	197/109/107	192/115/110	190/115/107
212/110/112	211/111/112	215/114/118	208/111/110	195/109/103

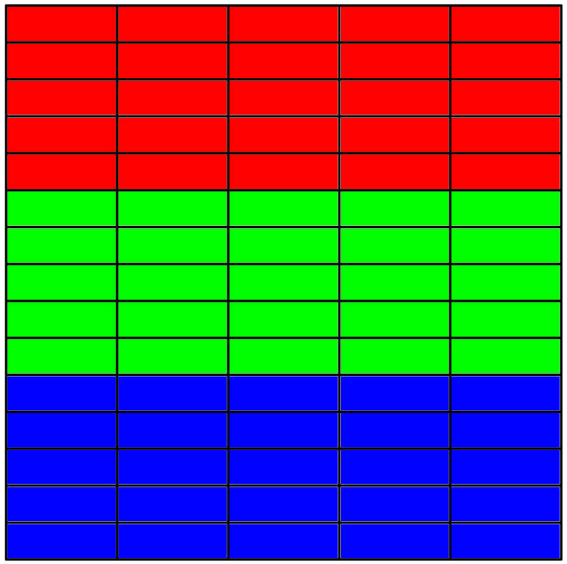


Band sequential by pixel, BSP. Most common for color photographs.

Band sequential by line, BSL



Band Sequential, BS

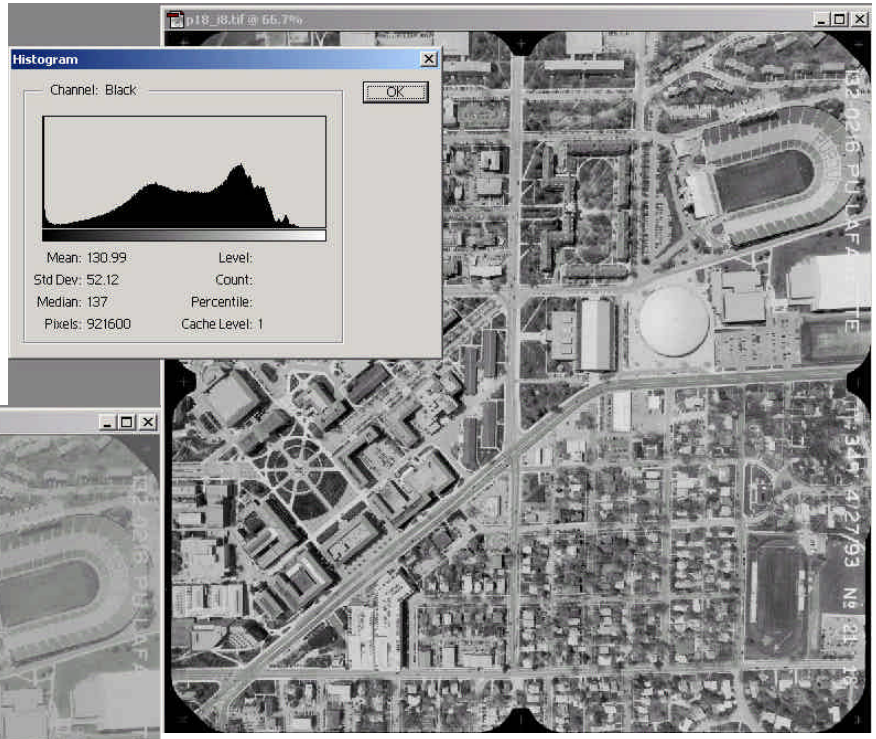


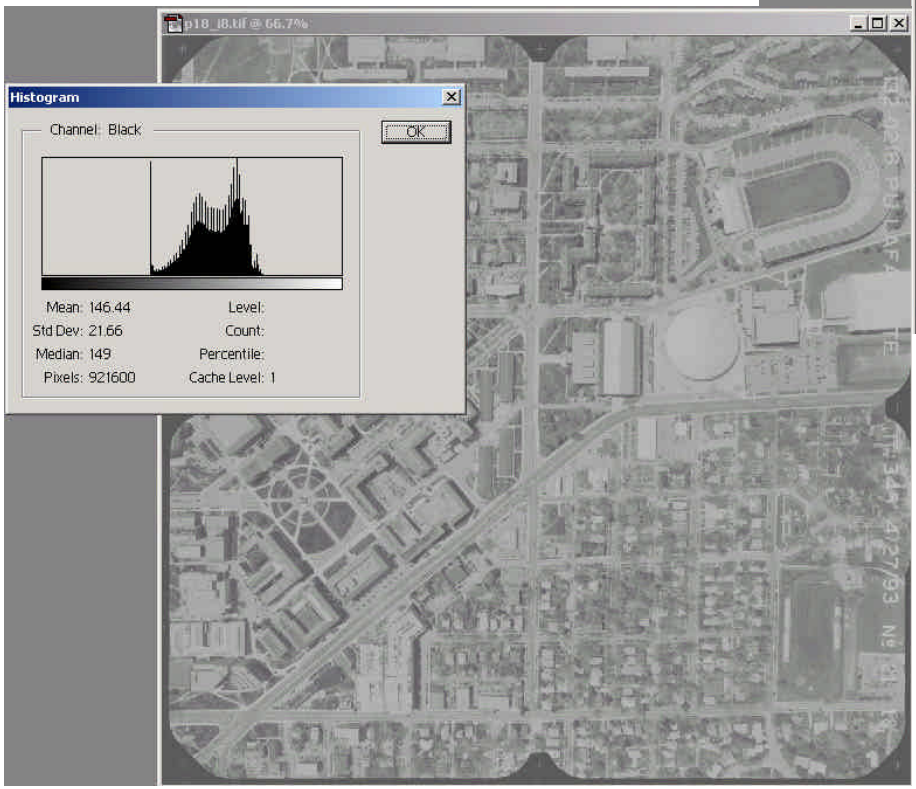
Encoding the Color Components

Ideally, a header file, or file header structure will specify how the color components are stored – however sometimes the structure (metadata) gets separated from the image file and you have to “reverse engineer” the file structure. Same options apply to MSI / HSI.

Image Histogram

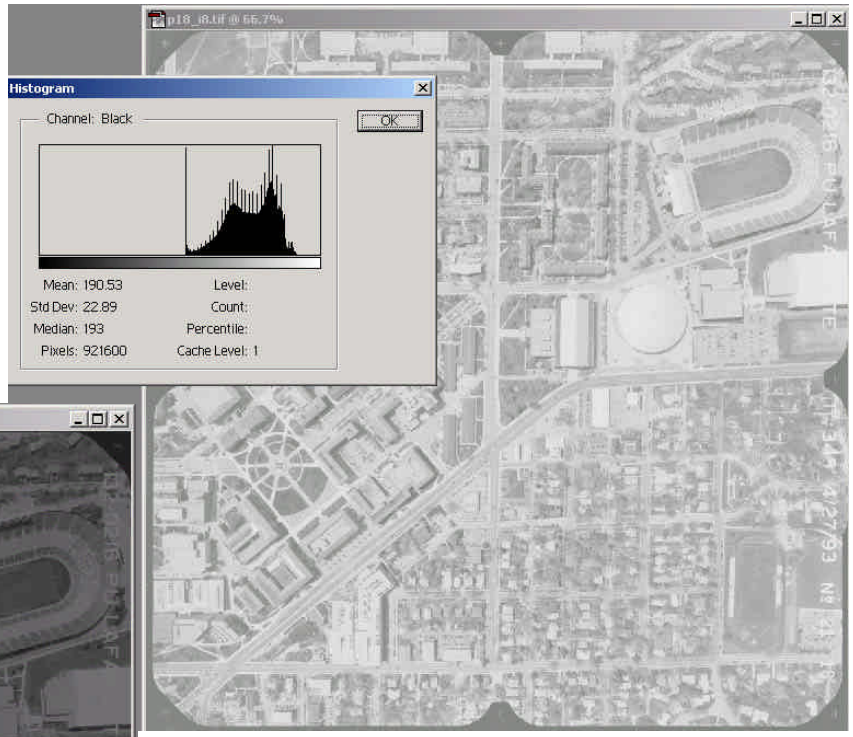
Image histogram shows distribution of gray values (or color components in 3 separate histograms). It is like a probability density function for a particular image, if normalized

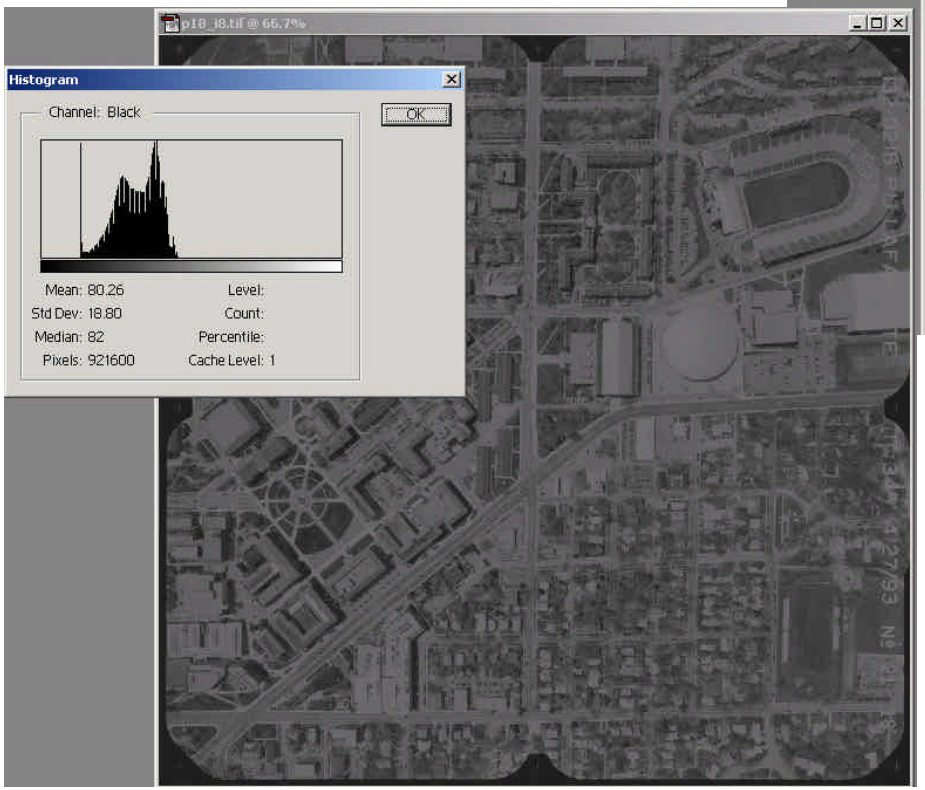




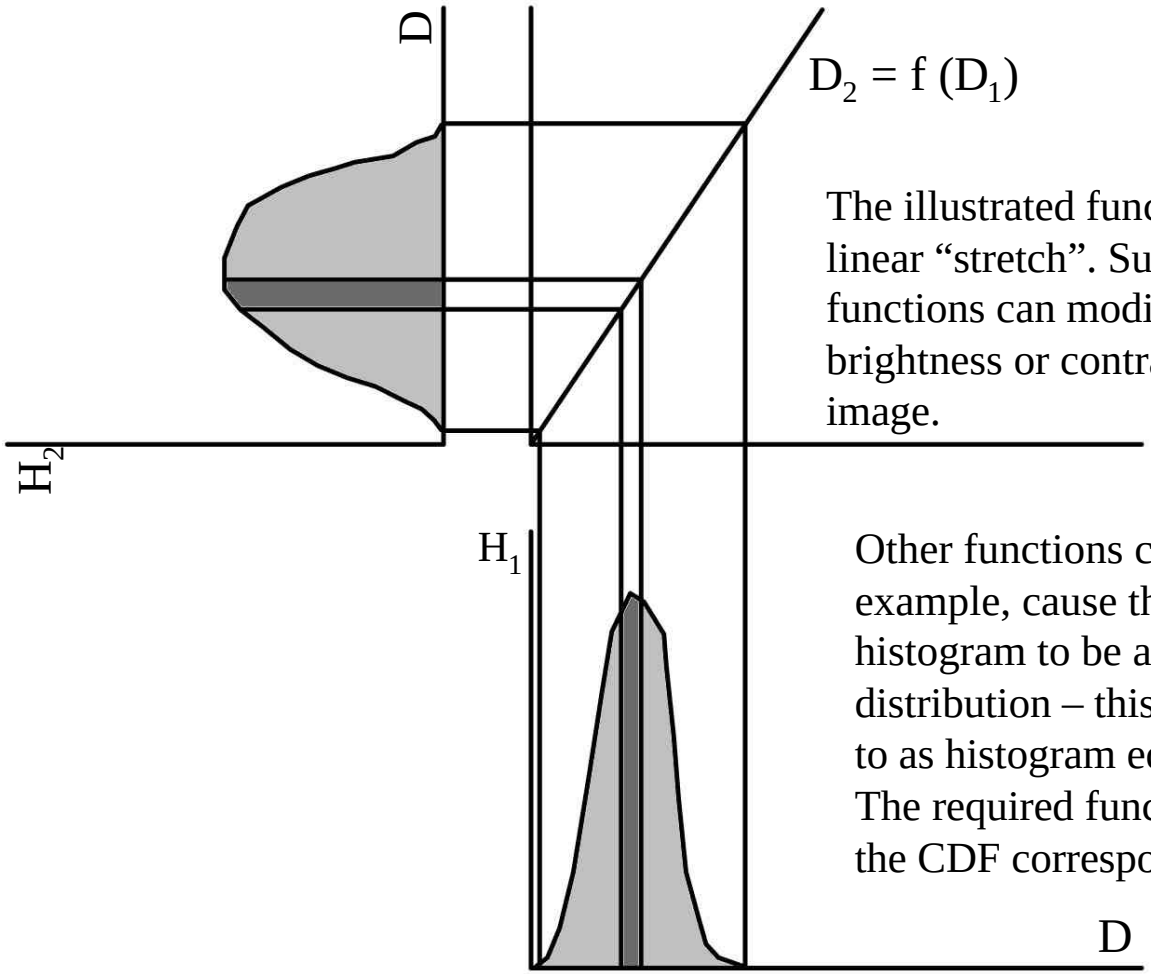
Width of the histogram is related to *contrast*

Position of the histogram is related to *brightness*. In the signal processing world, contrast and brightness are referred to as *gain* and *offset*.





Histogram Modification



The illustrated function is a linear "stretch". Such linear functions can modify the brightness or contrast of an image.

Other functions can, for example, cause the output histogram to be a "uniform" distribution – this is referred to as histogram equalization. The required function is just the CDF corresponding to H_1

Gradient Operators for Edge Enhancement - Sobel

-1	0	1
-2	0	2
-1	0	1

-1	-2	-1
0	0	0
1	2	1

Vertical Edge Image by Sobel Operator