GRAPHICS GROUP

IVS Intelligent Vision Systems New Zealand

Computer Graphics and Image Processing

Part 3: Image Processing

2 – Contrast Stretching

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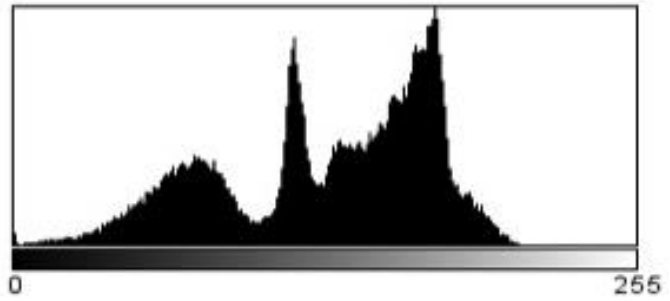
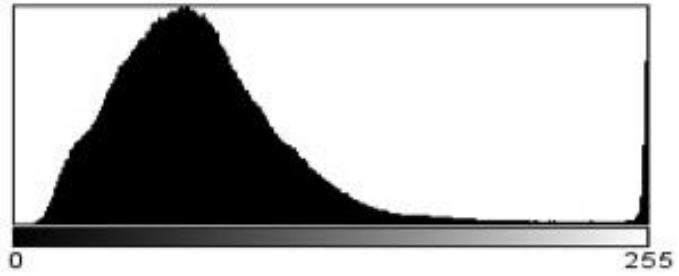
We know how to compute histogram

1. The image is scanned in a single pass
2. A running count of the number of pixels at each intensity is kept
3. These values are graphed to visualize the histogram



Count: 97200
Mean: 128.070
StdDev: 43.573

Min: 0
Max: 254
Mode: 173 (1634)

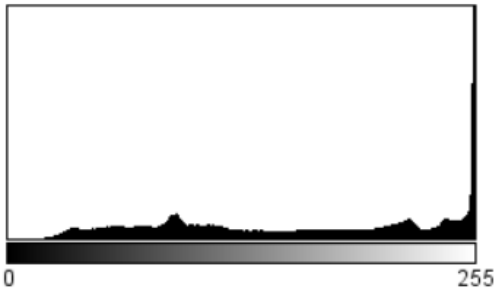


Count: 1080000
Mean: 77.690
StdDev: 42.251

Min: 2
Max: 255
Mode: 70 (14263)

Histograms of Under-/Over-Exposed Photos

Underexposed

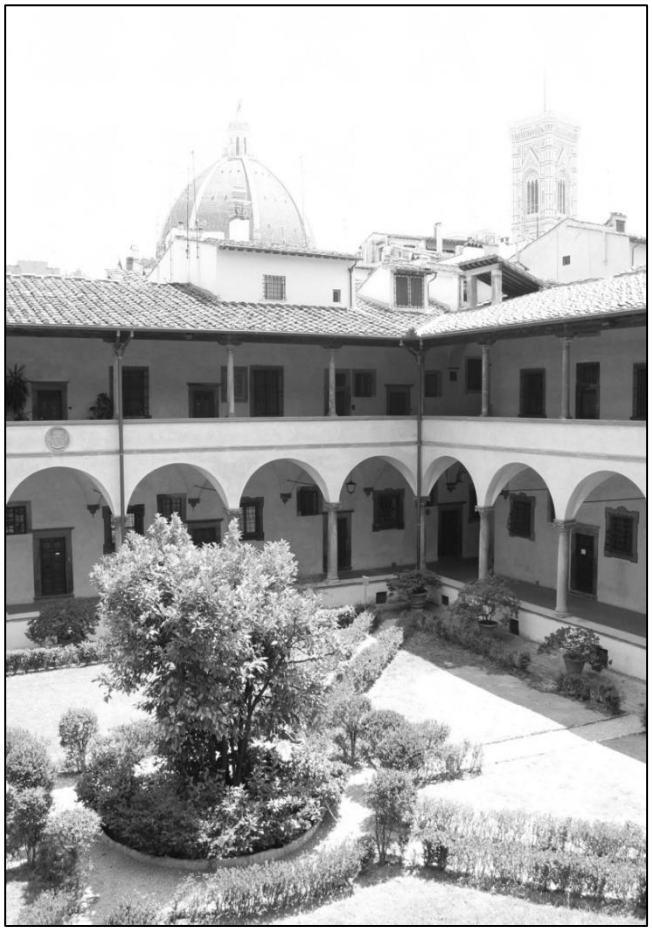


Count: 918400
Mean: 172.751
StdDev: 76.924

Min: 10
Max: 255
Mode: 255 (200682)

Count: 918400
Mean: 63.235
StdDev: 66.709

Min: 0
Max: 251
Mode: 2 (40205)

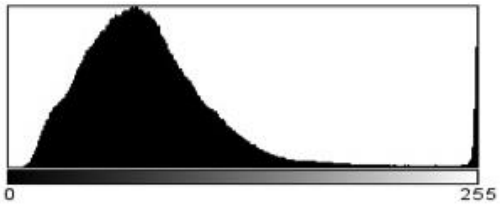


Overexposed

https://www.easyhdr.com/examples

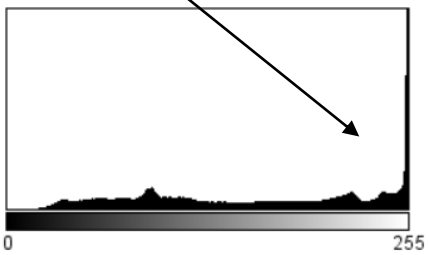
Using histograms

- An image histogram is a useful tool for assessing brightness and contrast of an image



Majority of intensities in dark image distributed to the left

Majority of intensities in bright image distributed to the right



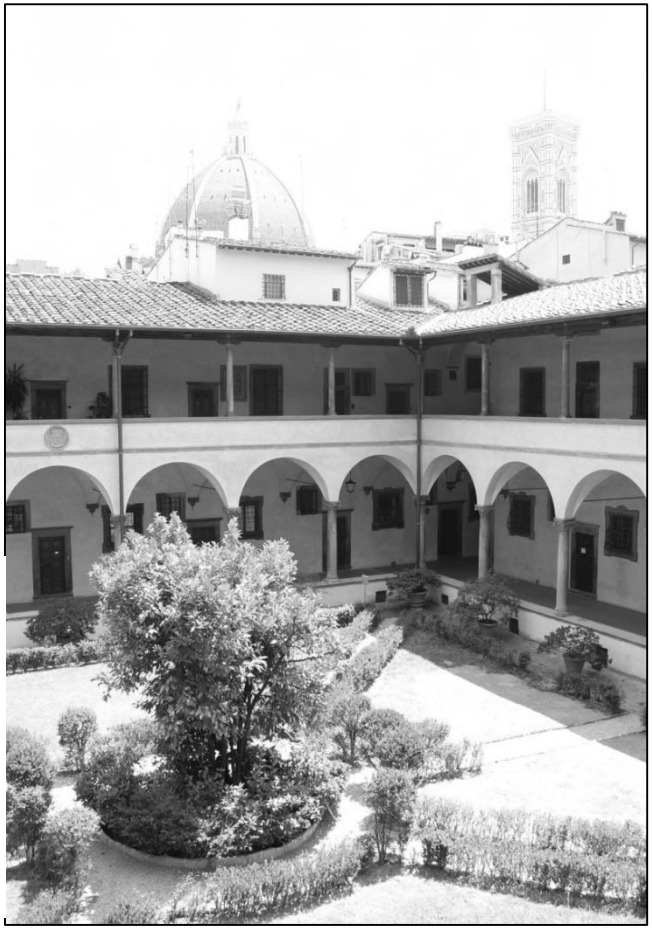
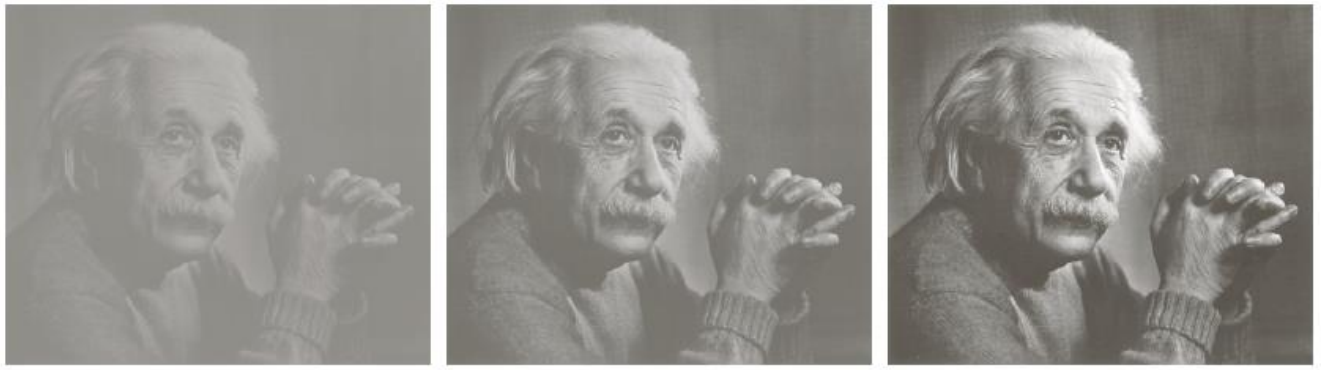


Image contrast

Informally, the **contrast** of an image $\mathbf{g} = (g(x, y) : (x, y) \in \mathbf{R})$ is the difference in visual properties (e.g. brightness or colour) that makes a depicted object distinguishable in the image.



a b c

FIGURE 2.41 Images exhibiting (a) low contrast, (b) medium contrast, and (c) high contrast.

Taken from: Gonzalez & Woods, Digital Image Processing, 3rd ed.

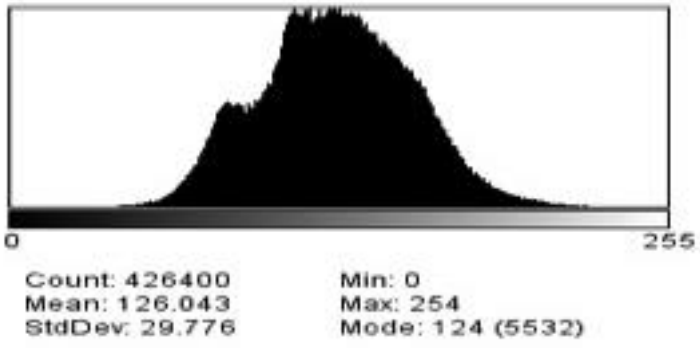
High contrast means the object of interest is darker or brighter than its background

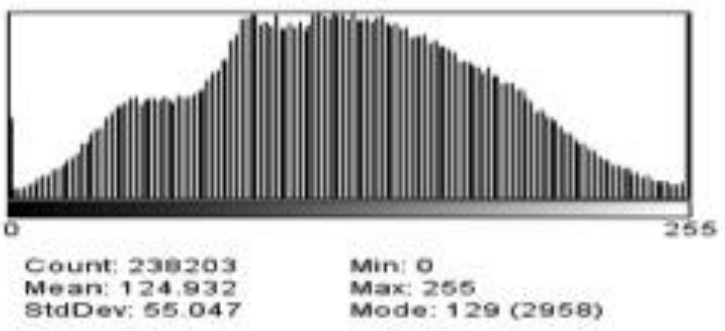
Image contrast

Informally, the **contrast** of an image $\mathbf{g} = (g(x, y) : (x, y) \in \mathbf{R})$ is the difference in visual properties (e.g. brightness or colour) that makes a depicted object distinguishable in the image.

- Formalization attempts:
  - Michelson contrast $\frac{g_{max} - g_{min}}{g_{max} + g_{min}}$ — Minimum/maximum greyvalues in image
  - Weber contrast $\frac{g_{fg} - g_{bg}}{g_{bg}}$ — Greyvalues of foreground & background objects
  - Use pixel value's standard deviation $\frac{\sigma_g}{Q - 1}$ — Standard deviation relative to total number of representable greyvalues Q (e.g. 256)

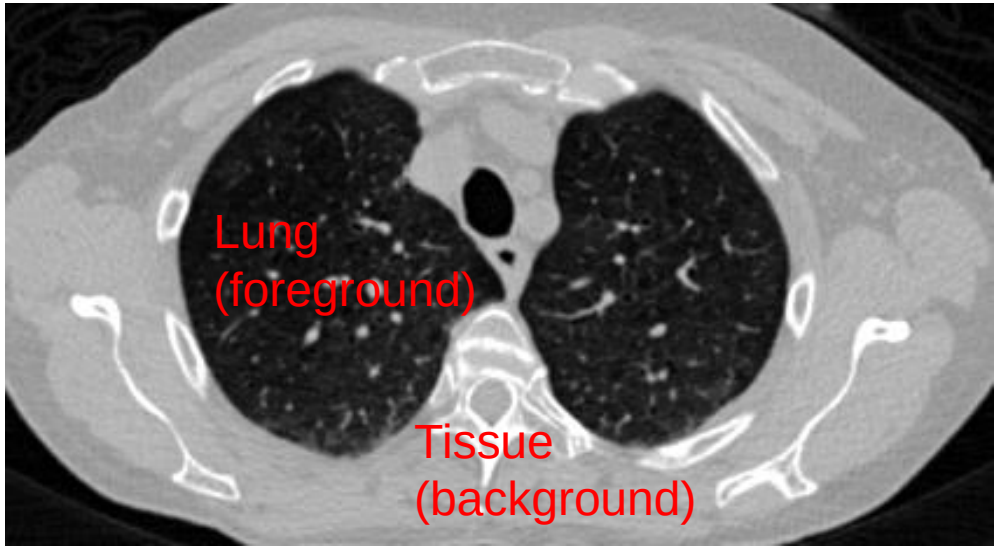
Image Contrast Examples



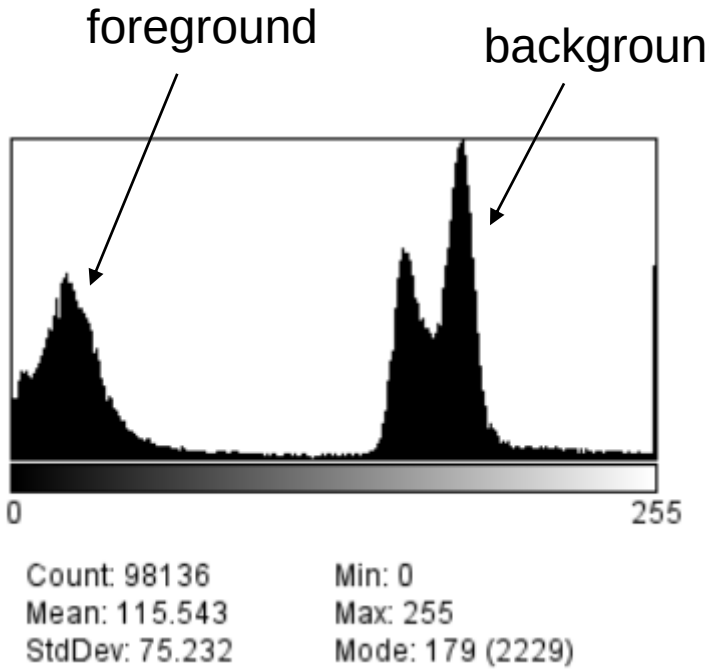


Standard deviation based measure good for contrast computation!

Image Contrast Examples



CT image slice of the thorax



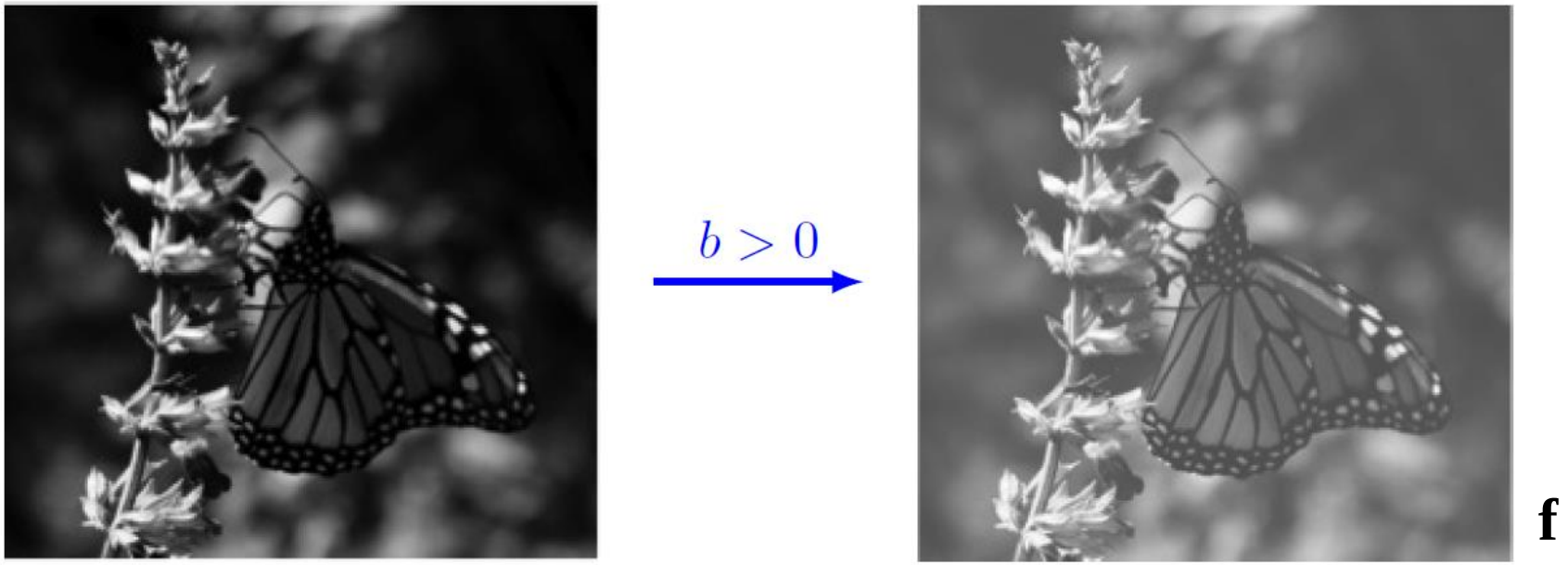
Weber based measure good for contrast computation! $\frac{g_{fg} - g_{bg}}{g_{bg}}$

Brightness and contrast adjustment

- We can perform adjustments by applying a linear transformation to each greyvalue:

$$f(x,y) = ag(x,y) + b$$

- Acting globally on the image g!



The brightness increases if $b > 0$ and decreases if $b < 0$.

Brightness and contrast adjustment

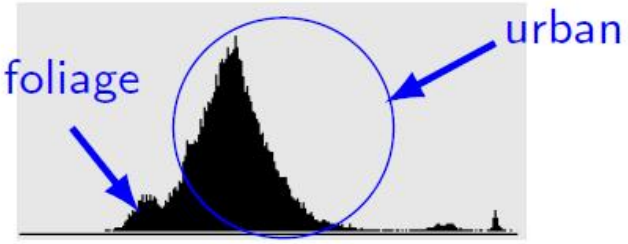
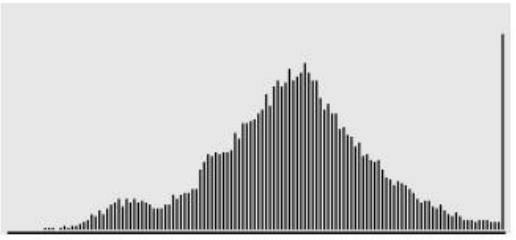
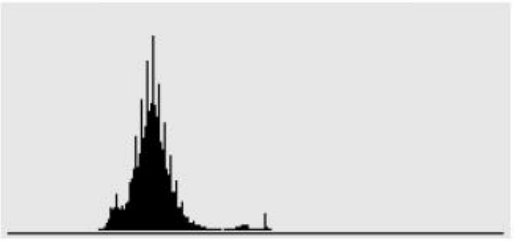
- We can perform adjustments by applying a linear transformation to each greyvalue:

$$f(x,y) = ag(x,y) + b$$

- Acting globally on the image g!

Contrast increases (a>1) and decreases (a<1)

Brightness and contrast adjustment

Parameters	Image	Histogram
$a = 1;\ b = 0$		Pixel value range: $[48, 248]$ 
$a > 1;\ b > 0$		
$a < 1;\ b < 0$		

Contrast adjustment

Contrast adjustment (also called normalisation) increases the dynamic range of intensities in low-contrast images.

Main reasons for acquiring low-contrast images:

- Poor illumination conditions.
- Poor image sensor dynamics.
- Incorrect setting of the lens aperture.

Contrast adjustment: "stretching" pixel-wise grey values (intensities) to span a larger range of values.

- Typically, the full range of grey values, e.g. 0 to 255 in an 8-bit greyscale image.
- Improving visual contrast of an image.

Contrast adjustment

- An original image $\mathbf{f}$: the lowest, f_{low}, and highest, f_{high}, pixel values considered for stretching.
  - f_{low} and f_{high} are not necessarily the min and max pixel values.
- The **new** lower, g_{min}, and upper, g_{max}, pixel values.
- Stretching (adjusting, or normalising) $\mathbf{f}$ into the image $\mathbf{g}$:

$$s_{\text{out}} = (f(x,y) - f_{\text{low}}) \left(\frac{g_{\text{max}} - g_{\text{min}}}{f_{\text{high}} - f_{\text{low}}} \right) + g_{\text{min}}$$

$$g(x,y) = \begin{cases} g_{\text{min}} & \text{if } s_{\text{out}} < g_{\text{min}} \\ s_{\text{out}} & \text{if } g_{\text{min}} \leq s_{\text{out}} \leq g_{\text{max}} \\ g_{\text{max}} & \text{if } s_{\text{out}} > g_{\text{max}} \end{cases}$$

- Simply selecting f_{low} and f_{high} as the max and min values in the image $\mathbf{f}$ can cause unrepresentative scaling due to outliers.
- More robust: the 5^{th} and 95^{th} percentiles of the histogram for $\mathbf{f}$.

Contrast stretching example

$f_{\text{low}} = 55;\ f_{\text{high}} = 205;\ g_{\text{min}} = 0;\ g_{\text{max}} = 255:$

55	105	125	125
175	75	105	125
155	205	75	85
155	155	175	55

$f(x,y)$	$g(x,y)$
55	0
75	34
85	51
105	85
125	119
155	170
175	204
205	255

0	85	119	119
204	34	85	119
170	255	34	51
170	170	204	0

$$g(x,y) = \begin{cases} 0 & \text{if} \quad s_{\text{out}} < 0 \\ s_{\text{out}} & \text{if} \quad 0 \le s_{\text{out}} \le 255 \\ 255 & \text{if} \quad s_{\text{out}} > 255 \end{cases}$$

$$s_{\text{out}} = (f(x,y) - 55)\left(\tfrac{255-0}{205-55}\right) + 0 = 1.7\,(f(x,y) - 55)$$

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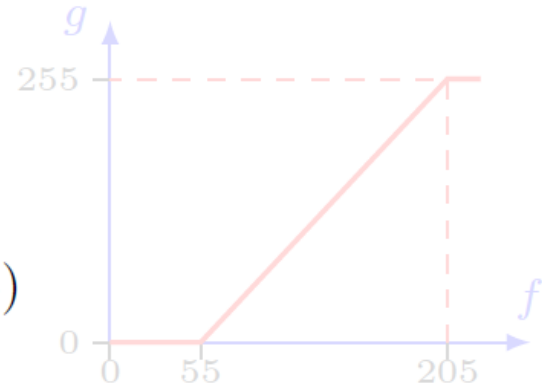

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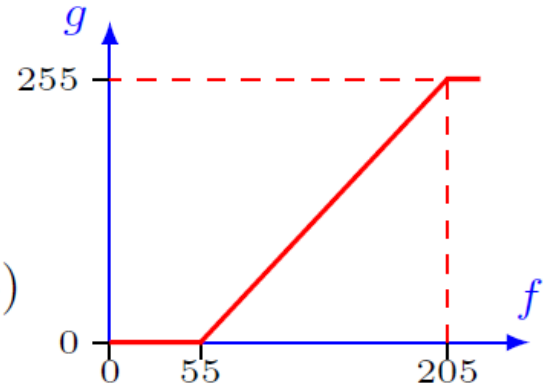

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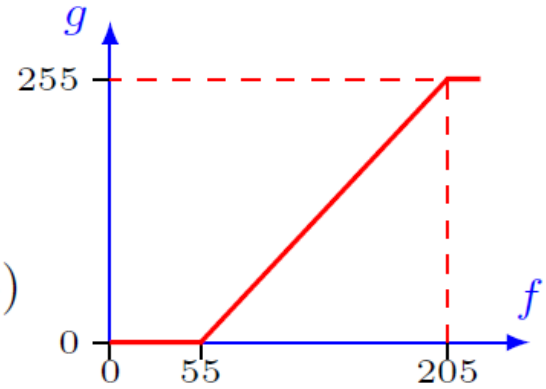
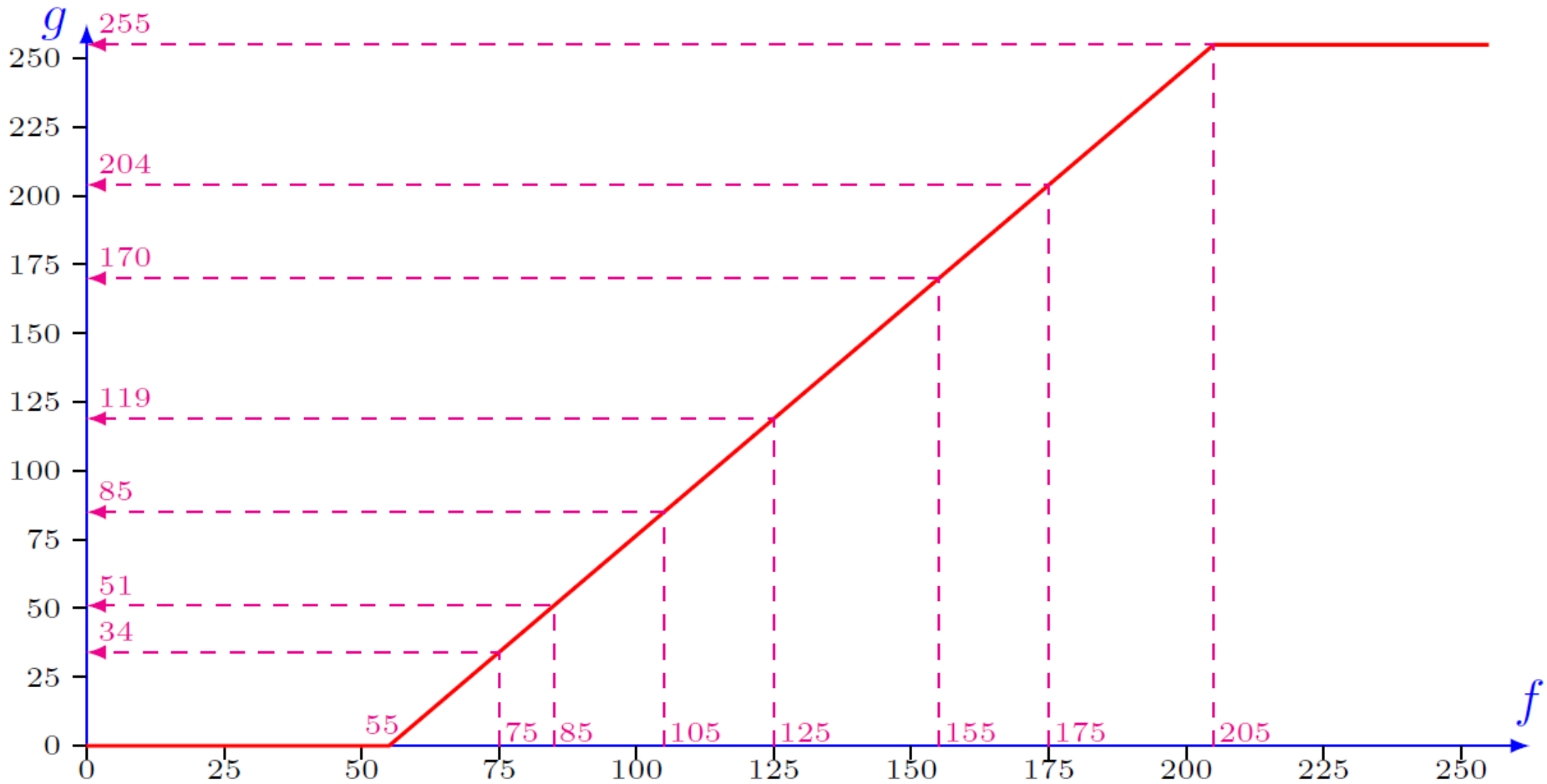
$$s_{\text{out}} = (f(x,y) - 55)\left(\frac{255-0}{205-55}\right) + 0 = 1.7\,(f(x,y) - 55)$$



Contrast stretching as linear mapping

$s_{\text{out}} = 1.7f(x,y) - 93.5;\ g(x,y) = \min\{255, \max\{s_{\text{out}}, 0\}\}$:



Linear mapping: Gain a and bias b

- Mapping equation to transform an image f into the image g, given boundaries f_{low} and f_{high} of a stretching interval and the minimum, g_{min}, and maximum, g_{max}, values for the new image g:

$$g(x,y) = \begin{cases} g_{\max} & \text{if} \quad f(x,y) > f_{\text{high}} \\ af(x,y) + b & \text{if} \quad f_{\text{low}} \leq f(x,y) \leq f_{\text{high}} \\ g_{\min} & \text{if} \quad f(x,y) < f_{\text{low}} \end{cases}$$

- The mapping parameters a and b are derived by solving a system of two linear equations:

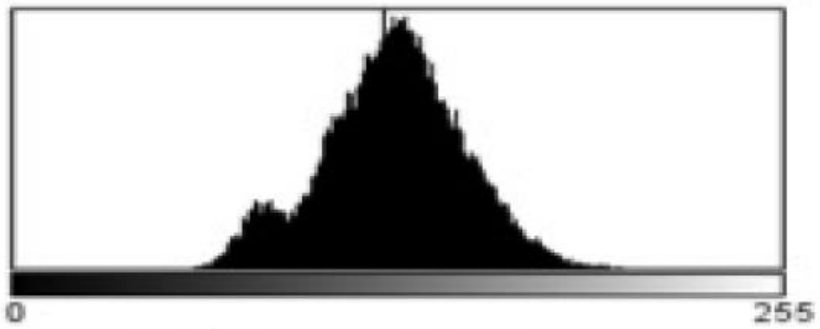
$$\begin{cases} af_{\text{low}} + b = g_{\min} \\ af_{\text{high}} + b = g_{\max} \end{cases} \Rightarrow \begin{cases} a = \frac{g_{\max} - g_{\min}}{f_{\text{high}} - f_{\text{low}}} \\ b = g_{\min} - f_{\text{low}} \frac{g_{\max} - g_{\min}}{f_{\text{high}} - f_{\text{low}}} \end{cases}$$

Example $f_{\text{low}} = 55;\ f_{\text{high}} = 205;\ g_{\min} = 0;\ g_{\max} = 255 \Rightarrow$

$a = \frac{255-0}{205-55} = \frac{255}{150} = 1.7;\ b = 0 - 55 \cdot 1.7 = -93.5$

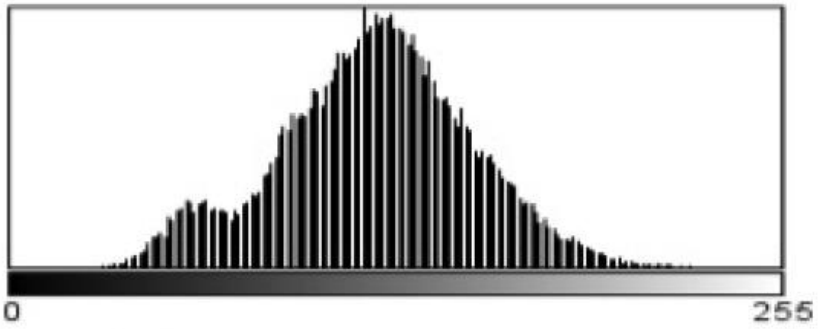
Contrast stretching example

$f_{\text{low}} = f_{\text{min}} = 38;\ f_{\text{high}} = f_{\text{max}} = 224;\ g_{\text{min}} = 0;\ g_{\text{max}} = 255:$



Count: 50499
Mean: 125.761
StdDev: 23.861

Min: 38
Max: 224
Mode: 123 (994)



Count: 50499
Mean: 120.307
StdDev: 32.711

Min: 0
Max: 255
Mode: 117 (994)

$$g(x,y) = (f(x,y) - 38)\,\frac{255-0}{224-38} = 1.37 f(x,y) - 52.1$$