Berner Fachhochschule
Haute école spécialisée bernoise
Bern University of Applied Sciences

Introduction to Computer Vision:

Point Operations

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Image Processing: Point Operations

Output / Input	Image	Description
Image	Image Processing	Image Analysis
Description	Image Synthesis (Computer Graphics)	All other IT

Image Processing vs. Image Analysis

Image Processing

- Contrast & brightness manipulation
- Color space manipulation
- Gray level reduction
- Sharpening
- Noise reduction
- Edge extraction
- Image algebra
- Geometric operations

Image Analysis

- Segmentation
- Region Representation
- Feature Extraction
- Classification
- Tracking

Image Operators

Point Operators

- Binarisation
- Gray level reduction
- Contrast & Brightness manipulations
- Histogram Equalization
- Arithmetic Operations
- Logic Operations

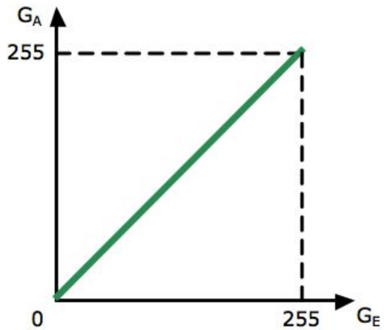
Global Operators

- Discrete Fourier Transform
- Wavelet Transform
- Hough Transform
- Principal Component Analysis

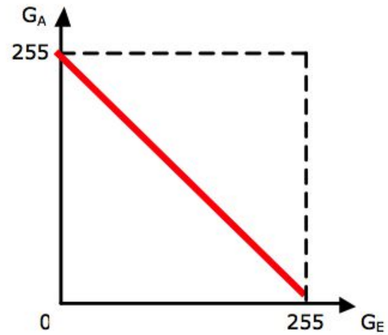
Local Operators

- Filters
  - Low Pass Filter
    - Gauss & Box Filter
  - High Pass Filter
    - Sobel Filter
    - Laplace Filter
- Morphological Operators
  - Erosion & Dilation
  - Opening & Closing
- Rank Order Operators
  - Min. & Max. Filter
  - Median Filter

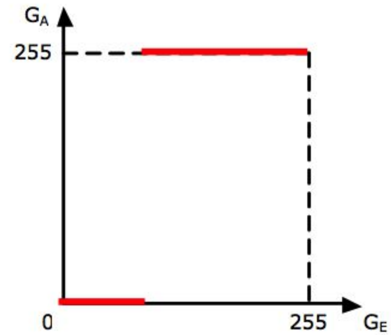
Point Operation: Mapping Function



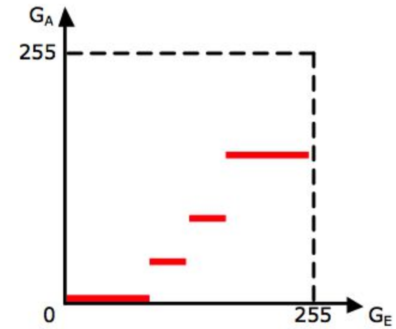
Identität



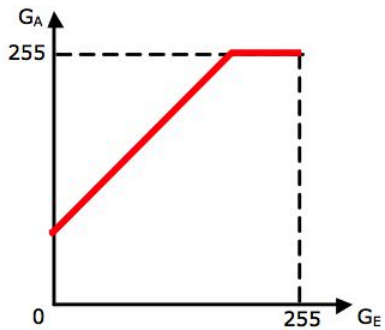
Invertierung



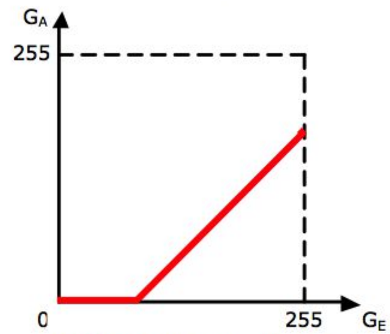
Binärisierung



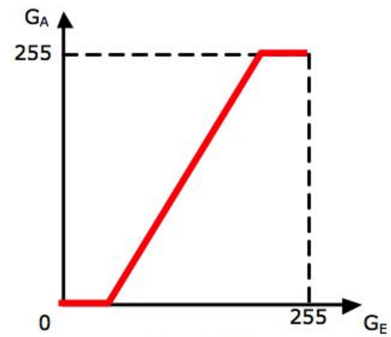
Grauwertreduktion



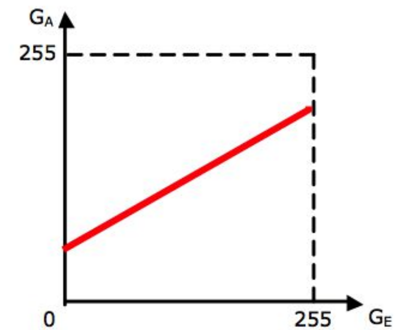
Helligkeit erhöhen



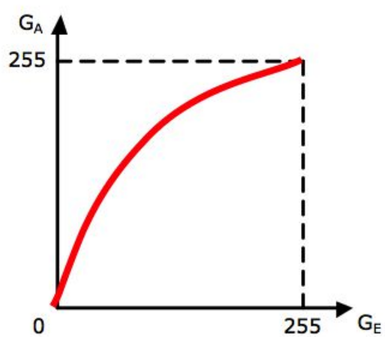
Helligkeit reduzieren



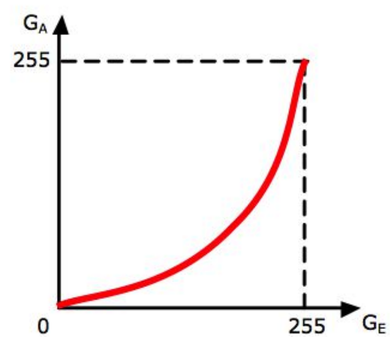
Kontrast erhöhen
Histogrammstreckung



Kontrast reduzieren
Histogrammstauchung

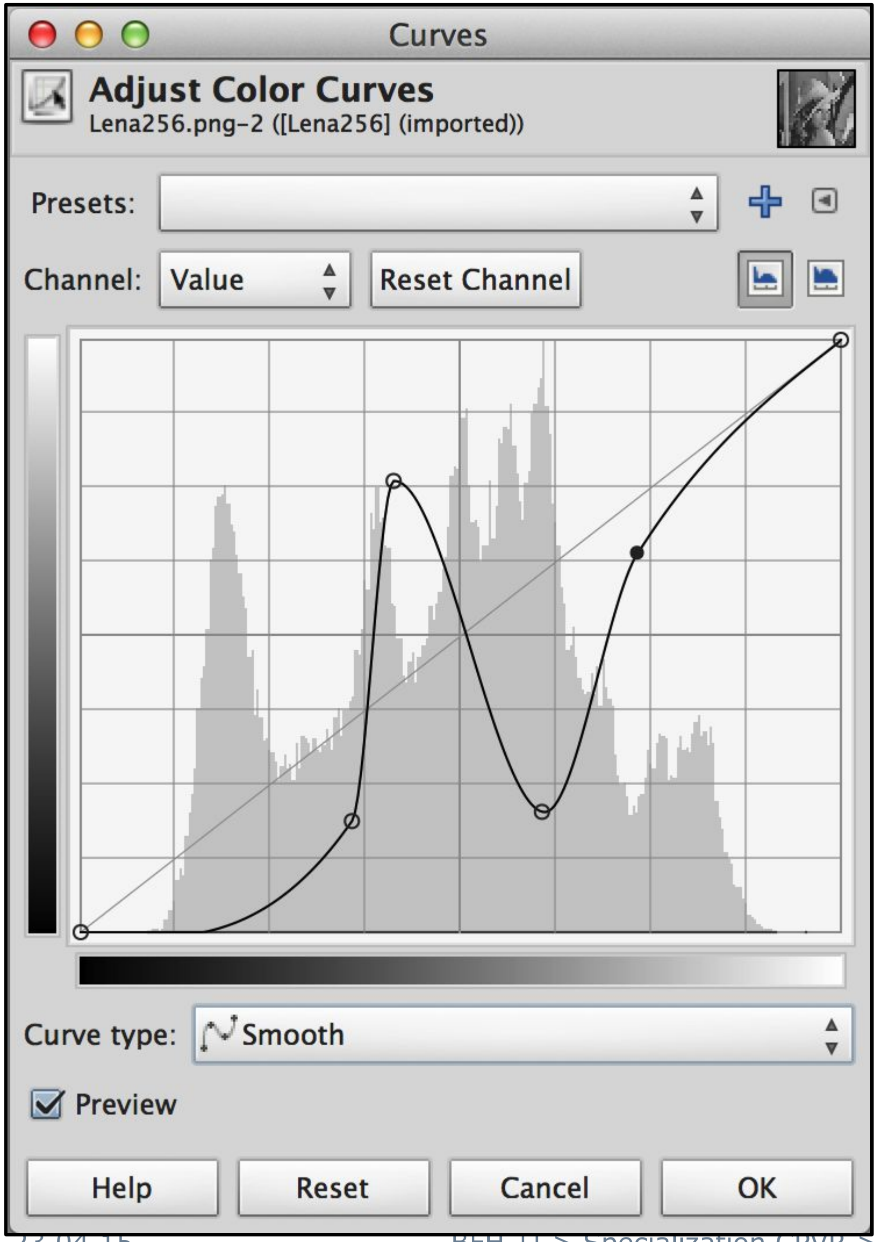


Helligkeit erhöhen
(Gammakorrektur)



Helligkeit reduzieren
(Gammakorrektur)

Point Operation: Mapping Function in Gimp



Point Operation: Mapping Function

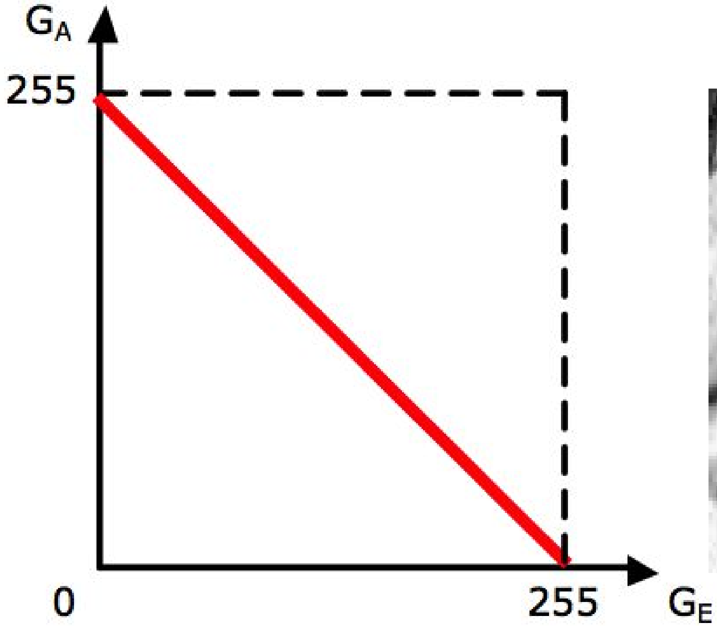
- Mapping functions are first applied to a **lookup table**:

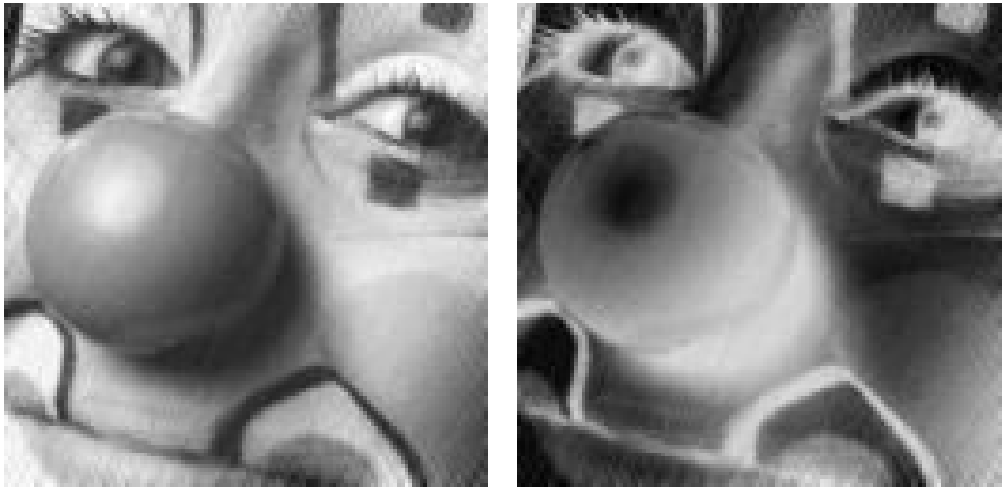
Input	0	1	2	3	4	5	6	7	...	250	251	252	253	254	255
Output	255	254	253	252	251	250	249	248	...	5	4	3	2	1	0

- The point operation is then a **simple and fast lookup operation**.

Point Operation: Invert

- Invert all gray values: $g_A(x,y) = 255 - g_E(x,y)$

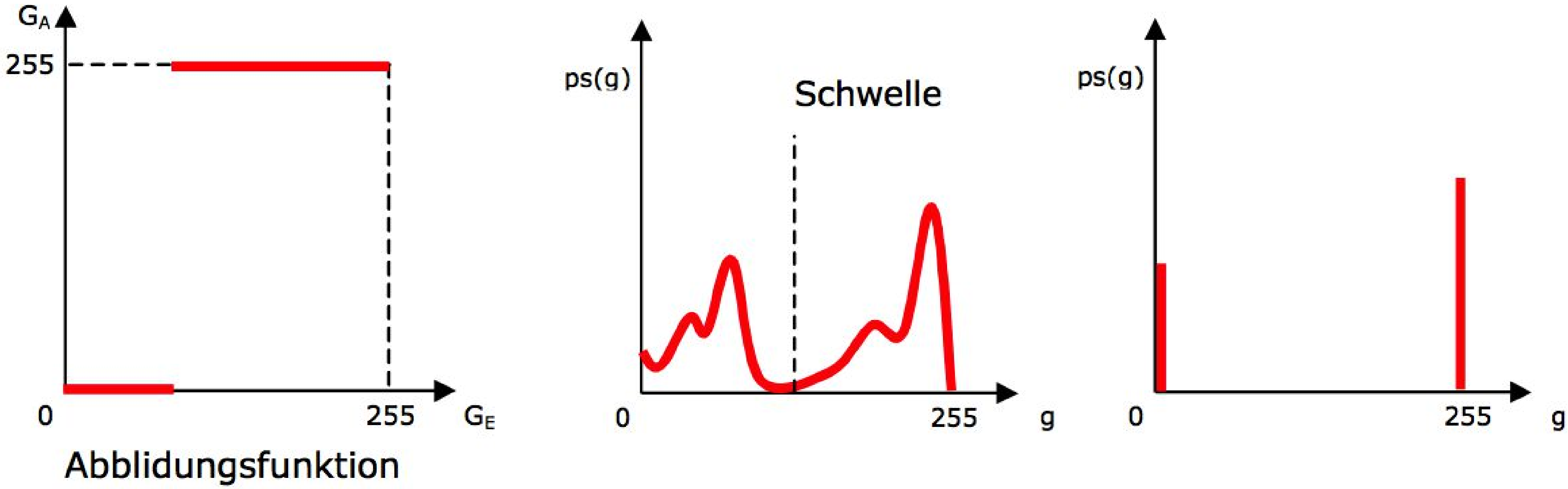




Point Operation: Binarisation

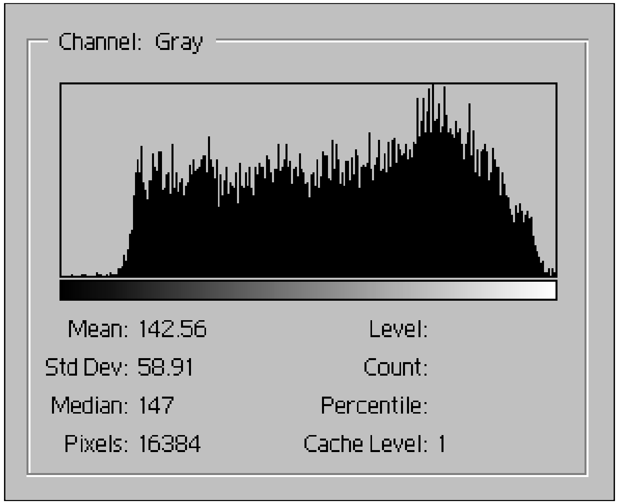
- All gray values below **threshold *t*** become black and all other become white:

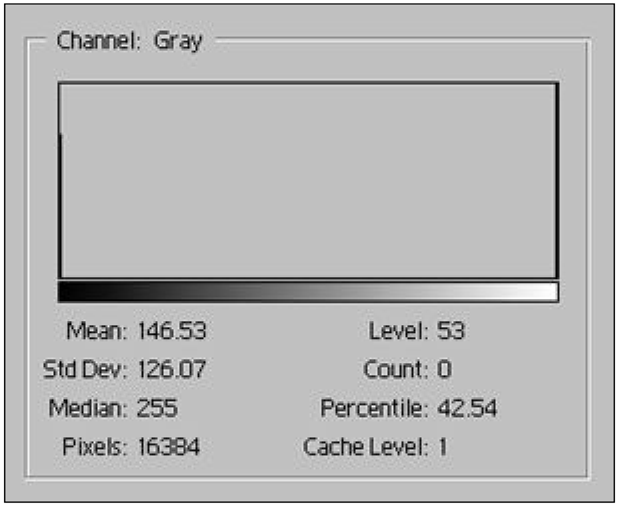
$$g_A(x,y)=\begin{cases} g_1 : g_E(x,y)<t \\ g_2 : g_E(x,y)\geq t \end{cases}$$



- Calculating the **threshold *t* automatically** is not allways possible.
- Sometimes there is **no global threshold** and an **adaptive threshold** must be calculated.

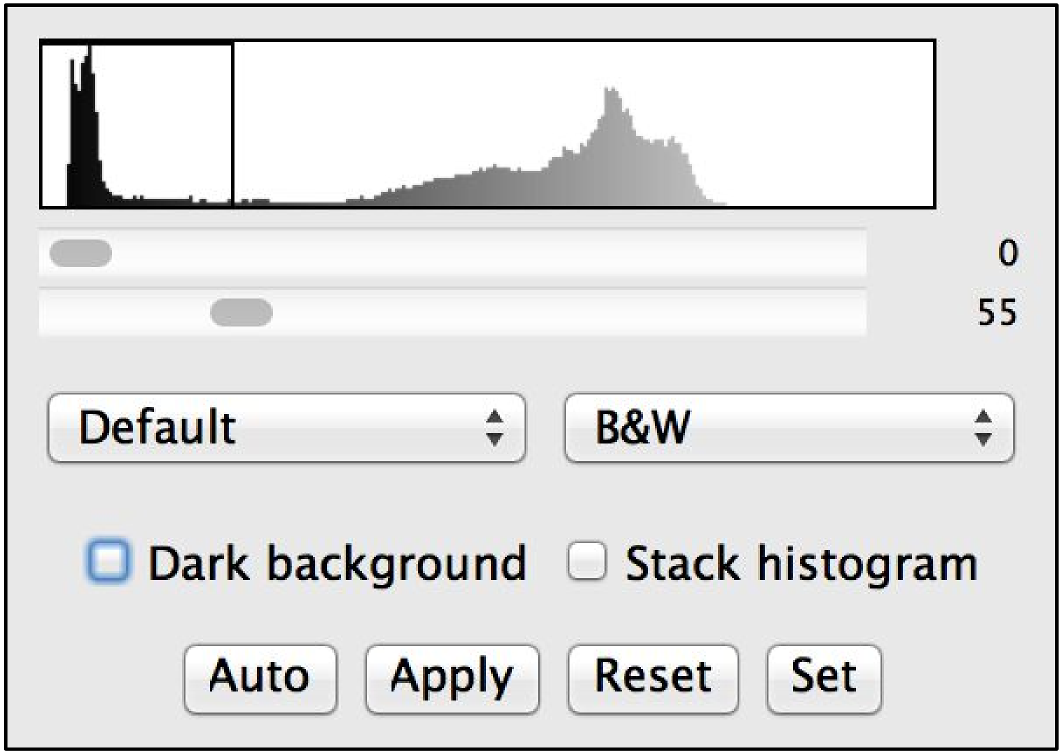
Point Operation: Binarisation





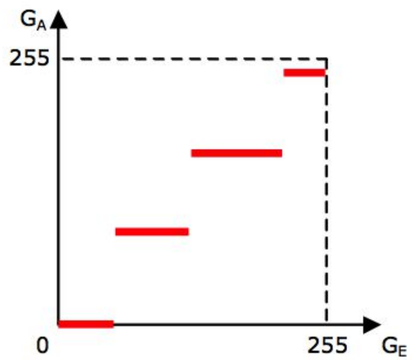
Point Operation: Binarisation

- Manual setting threshold in **ImageJ**: Image > Adjust > Threshold

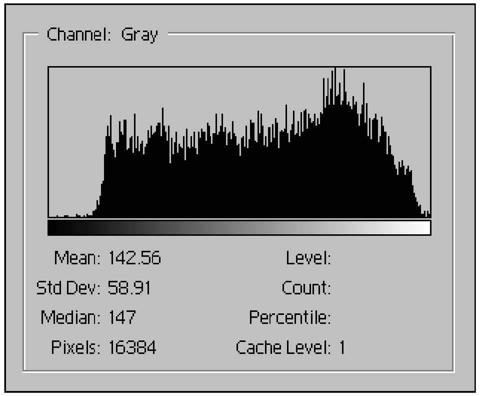


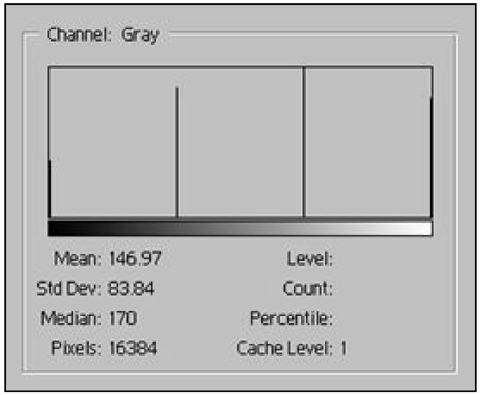
Point Operation: Gray Level Reduction

- Reducing the NO. of gray levels is also know as gray level slicing.
- It is often a prestep for edge detection.
- The Reduction is mostly done with a **lookup table**.
- Well known algorithm: **Median Cut Algorithm** from Paul Heckbert
- Used for bit depth reduction for image formats (e.g. BMP, PNG & GIF)



Abbildungsfunktion



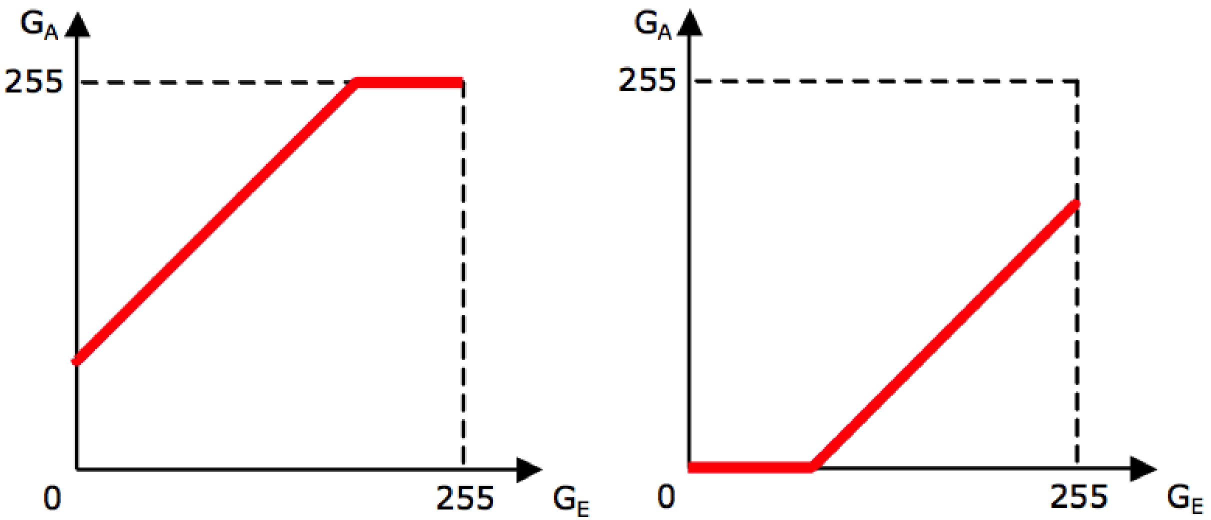


Point Operation: Linear Brightness Correction

- Linear brightness correction can be expressed in the line equation:

$$g_A(x,y) = c \cdot g_E(x,y) + b$$

where *c* changes the contrast and ***b* the brightness**.

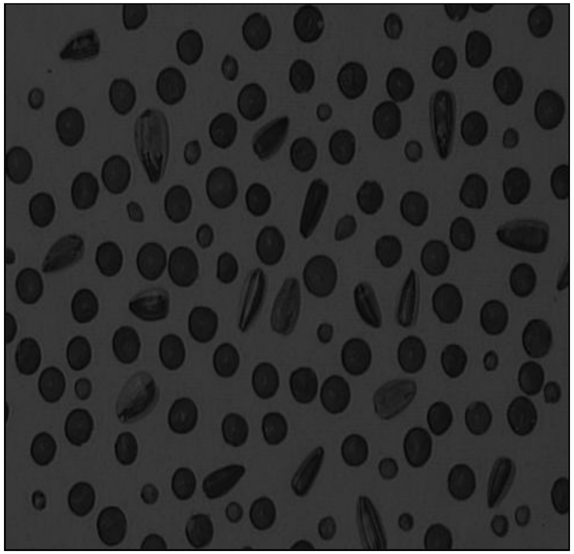


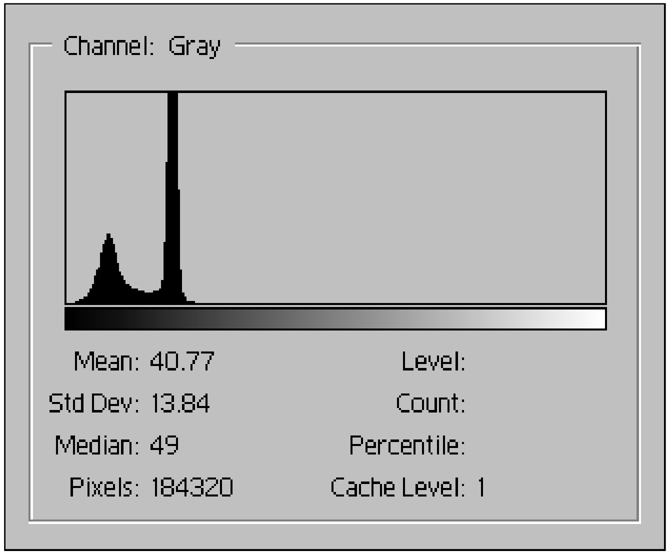
Abbildungsfunktion
Helligkeit erhöhen

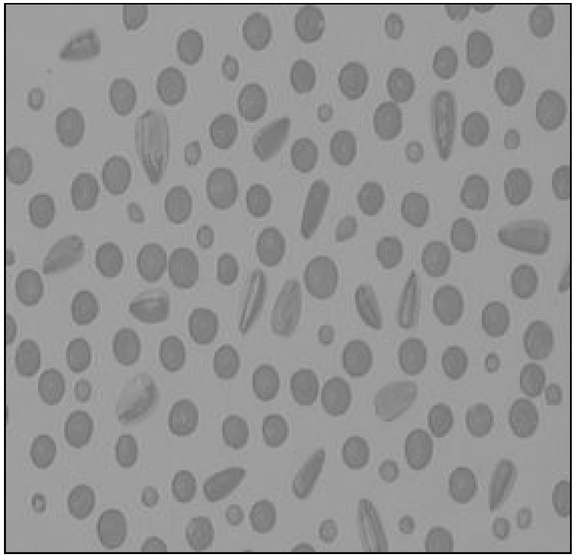
Abbildungsfunktion
Helligkeit reduzieren

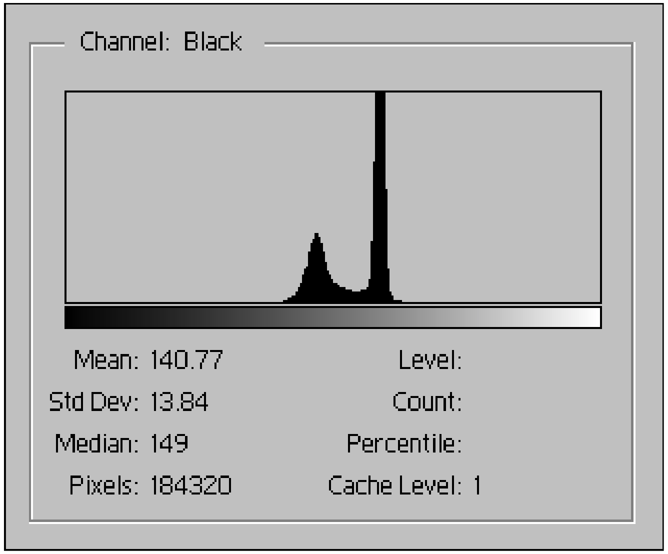
Point Operation: Linear Brightness Correction

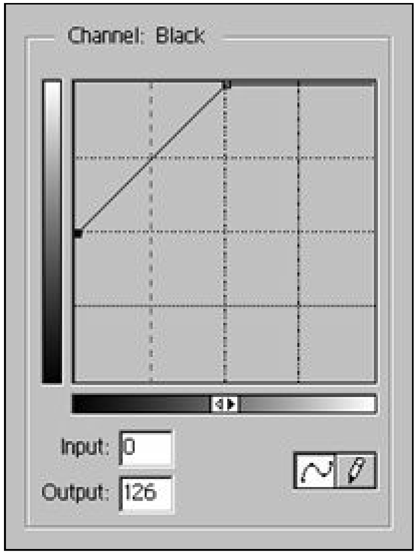
- The histogram is shifted:









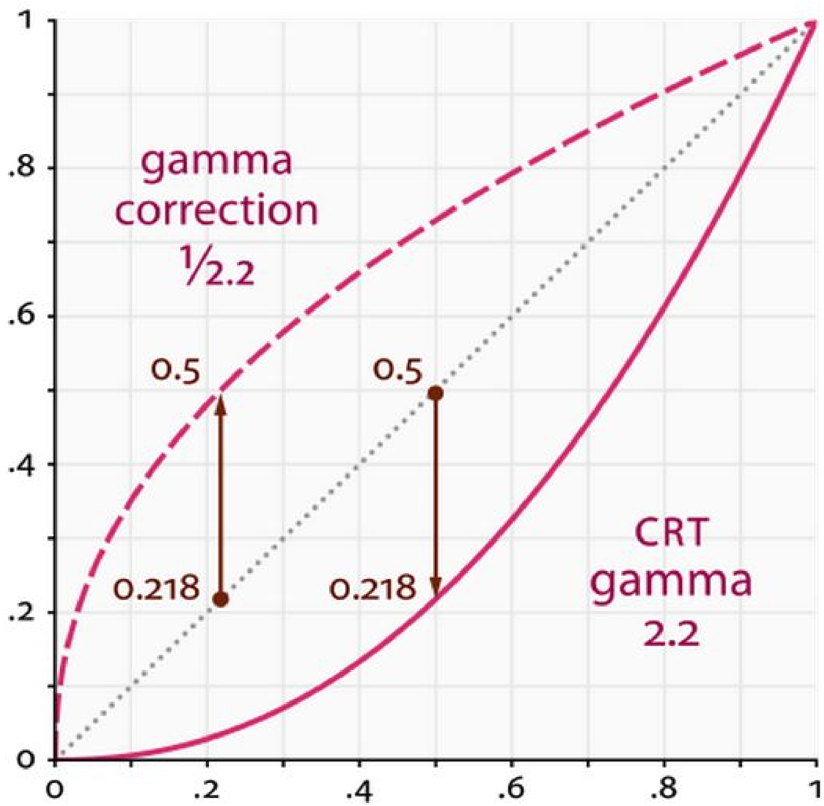


Point Operation: Gamma Correction

- The **gamma correction** is a **non linear** brightness correction:

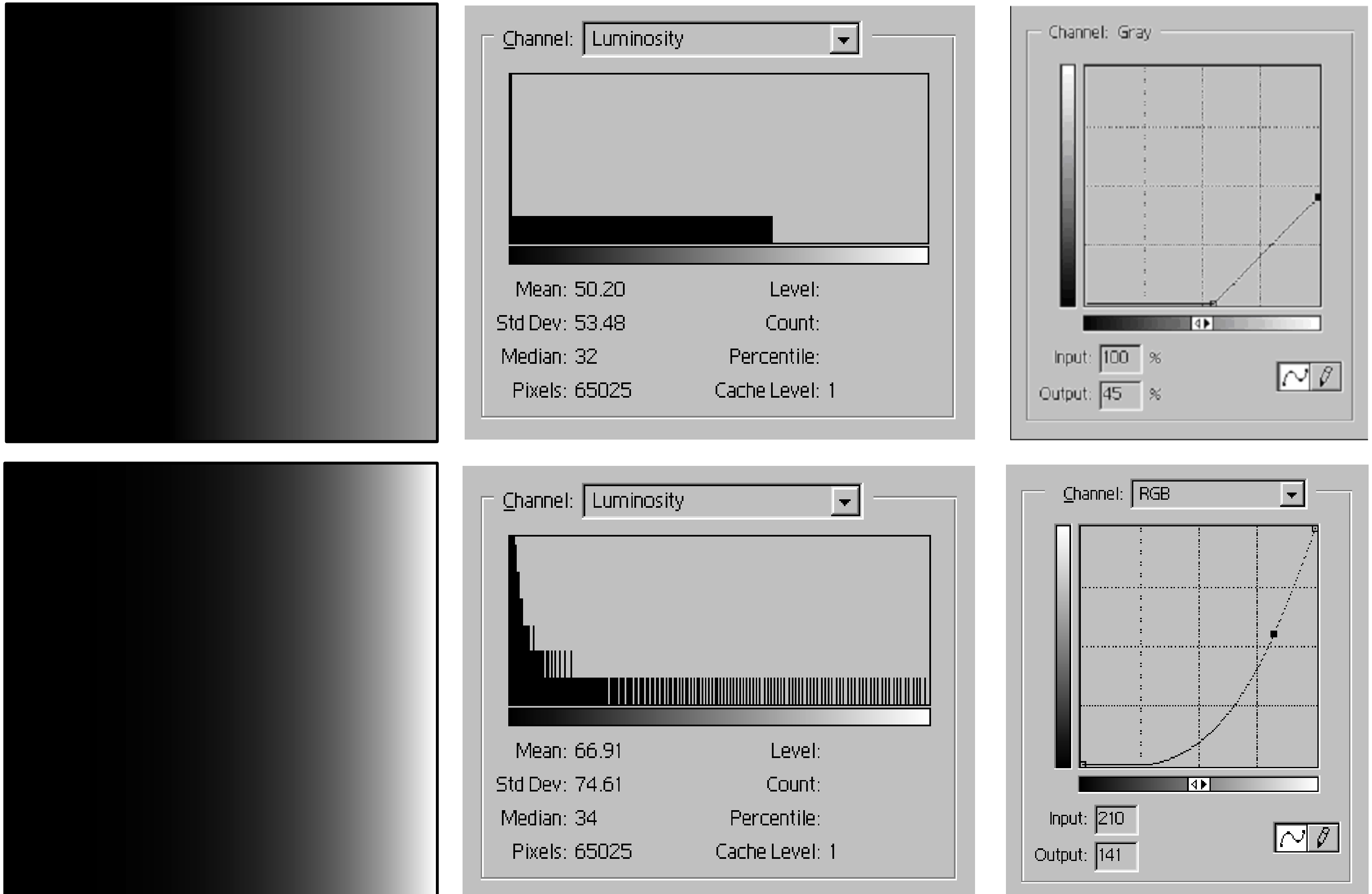
$$g_A(x,y) = 255 \cdot \left(\frac{g_E(x,y)}{255} \right)^{\gamma}$$

where **γ < 1 increases** and **γ > 1 decreases** the brightness:



Point Operation: Gamma Correction

- The gamma correction **preserves information** in the dark & bright areas.



Point Operation: Gamma Correction

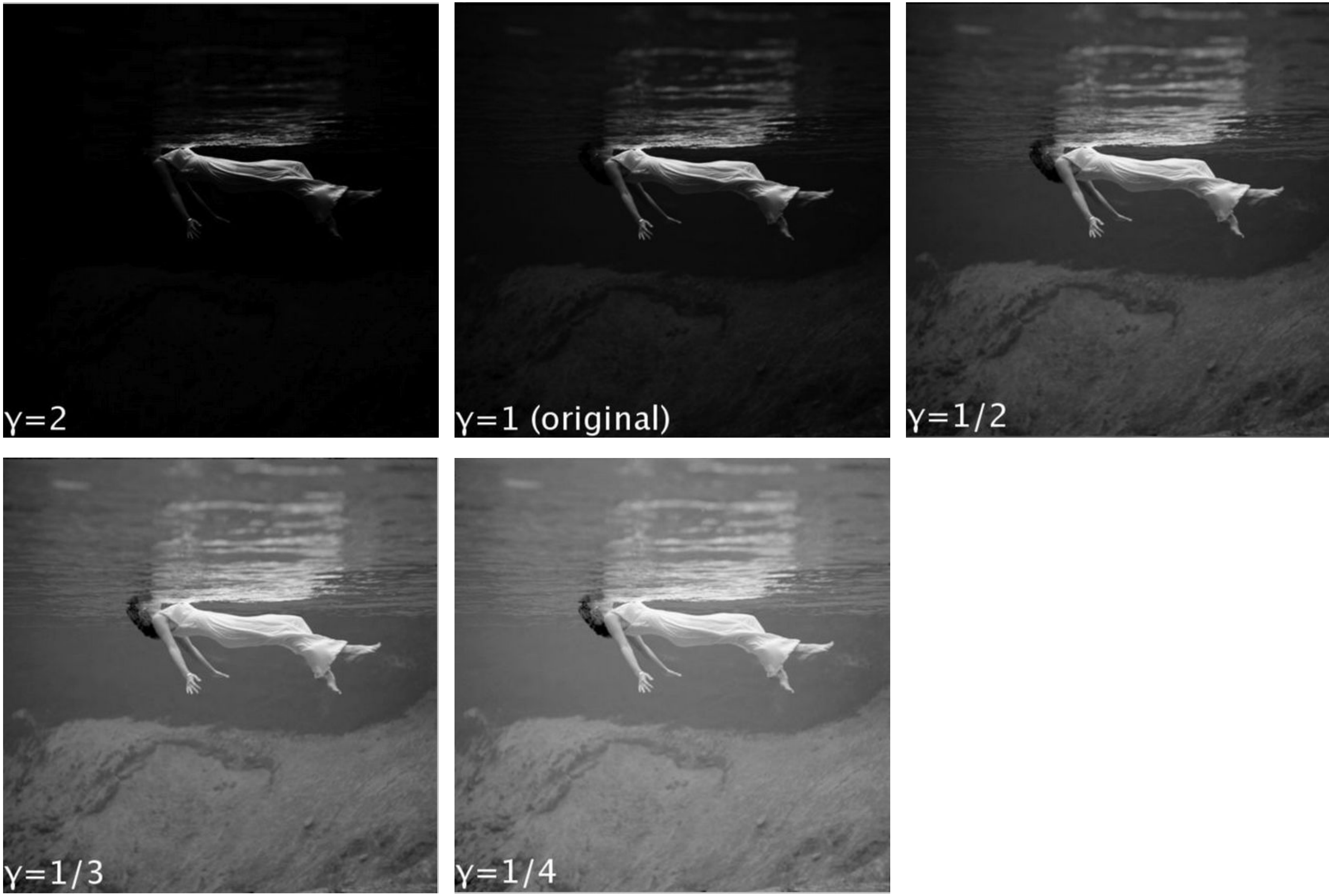


Image: en.wikipedia.org/wiki/Gamma_correction

Point Operation: Gamma Correction

- Gamma correction is important because **analog devices have non linear sensitivity**.
- E.g. analog **film material** has a **non linear sensitivity**:

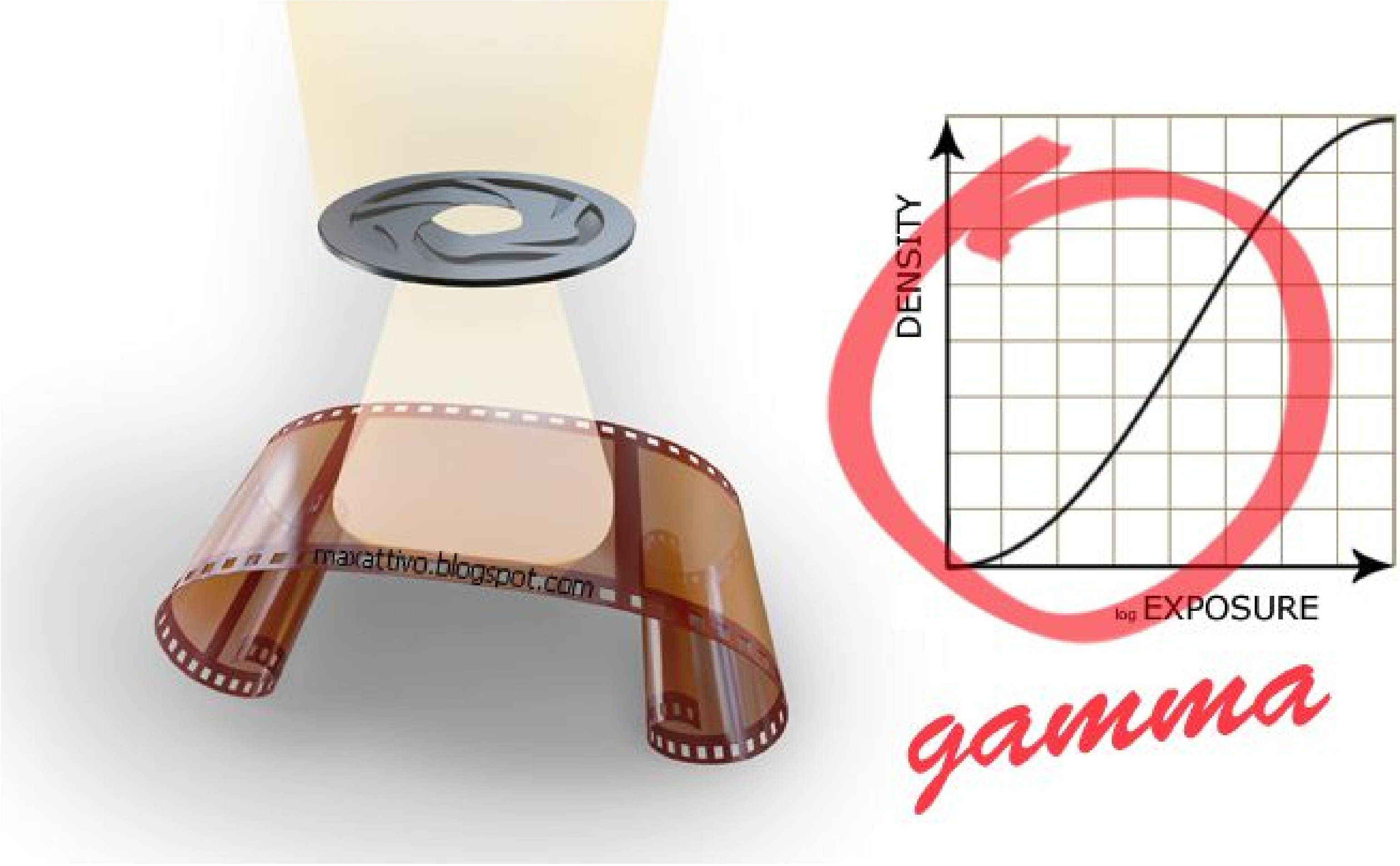


Image: maxattivo.blogspot.ch

Point Operation: Gamma Correction

- **CRT Monitors** display power is **not linear:**

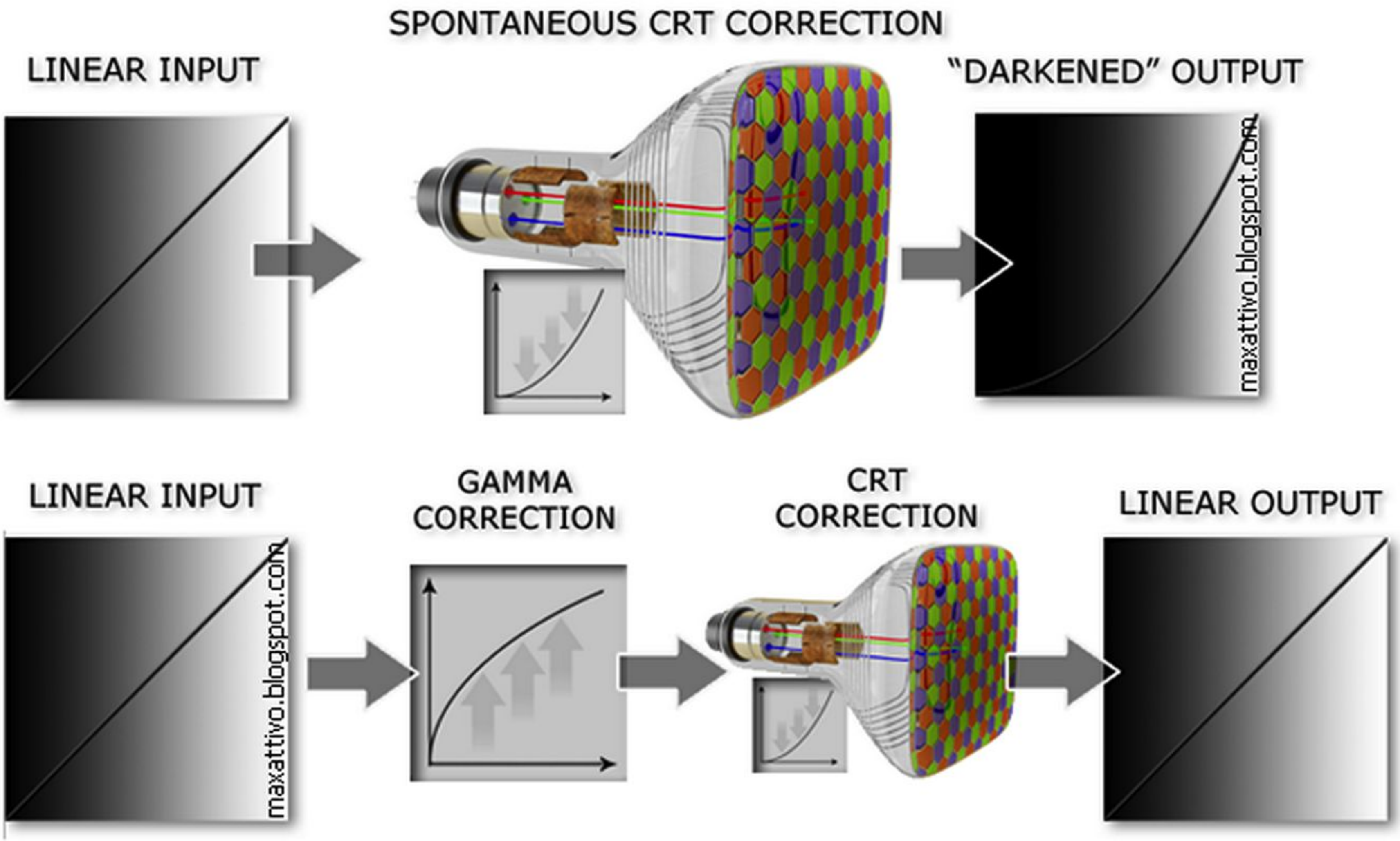


Image: maxattivo.blogspot.ch

Point Operation: Gamma Correction

- The **human light perception** is also **not linear:**

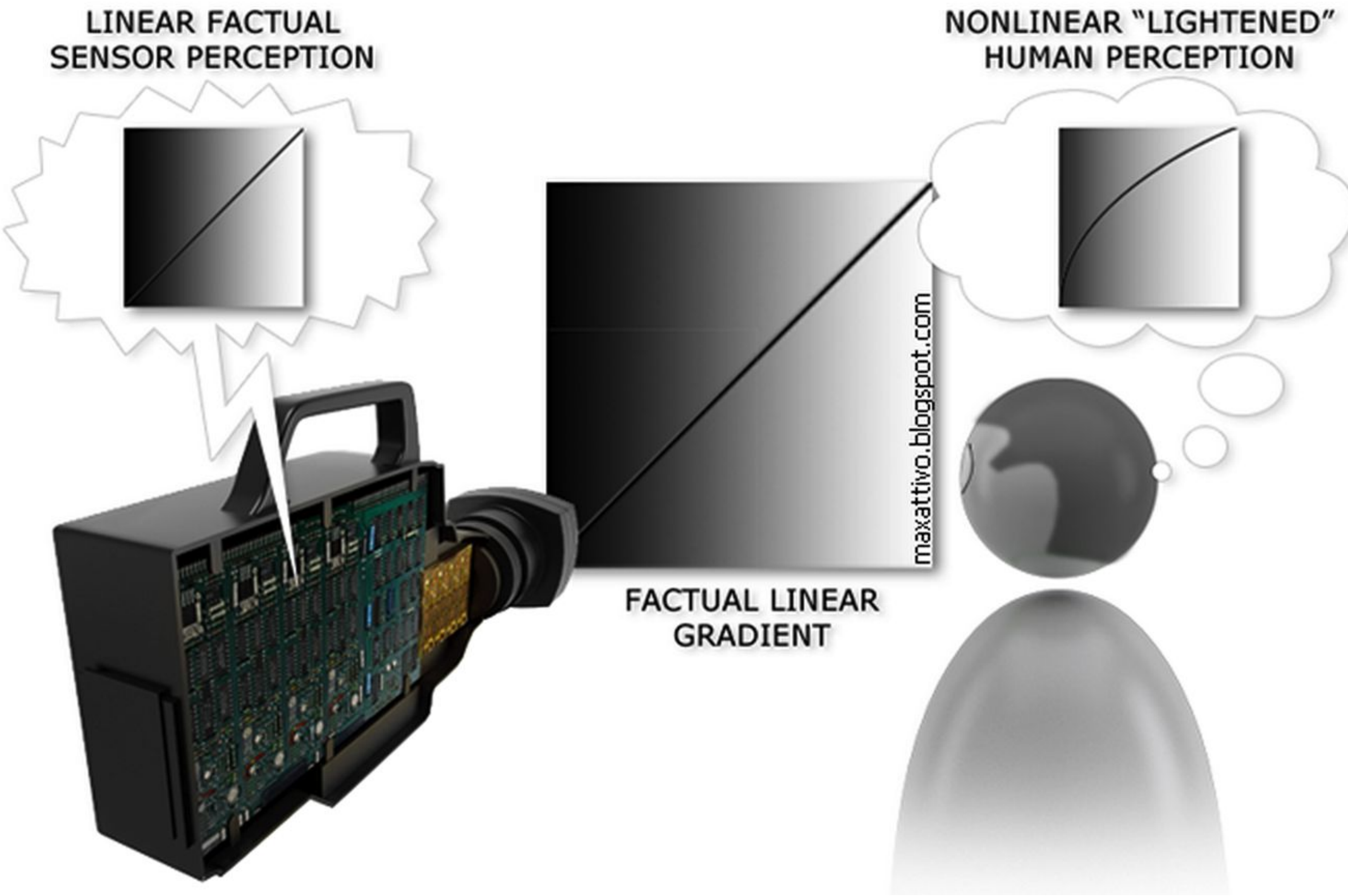


Image: maxattivo.blogspot.ch

Point Operation: Gamma Correction

- Gamma Correction is important in the **digital workflow:**

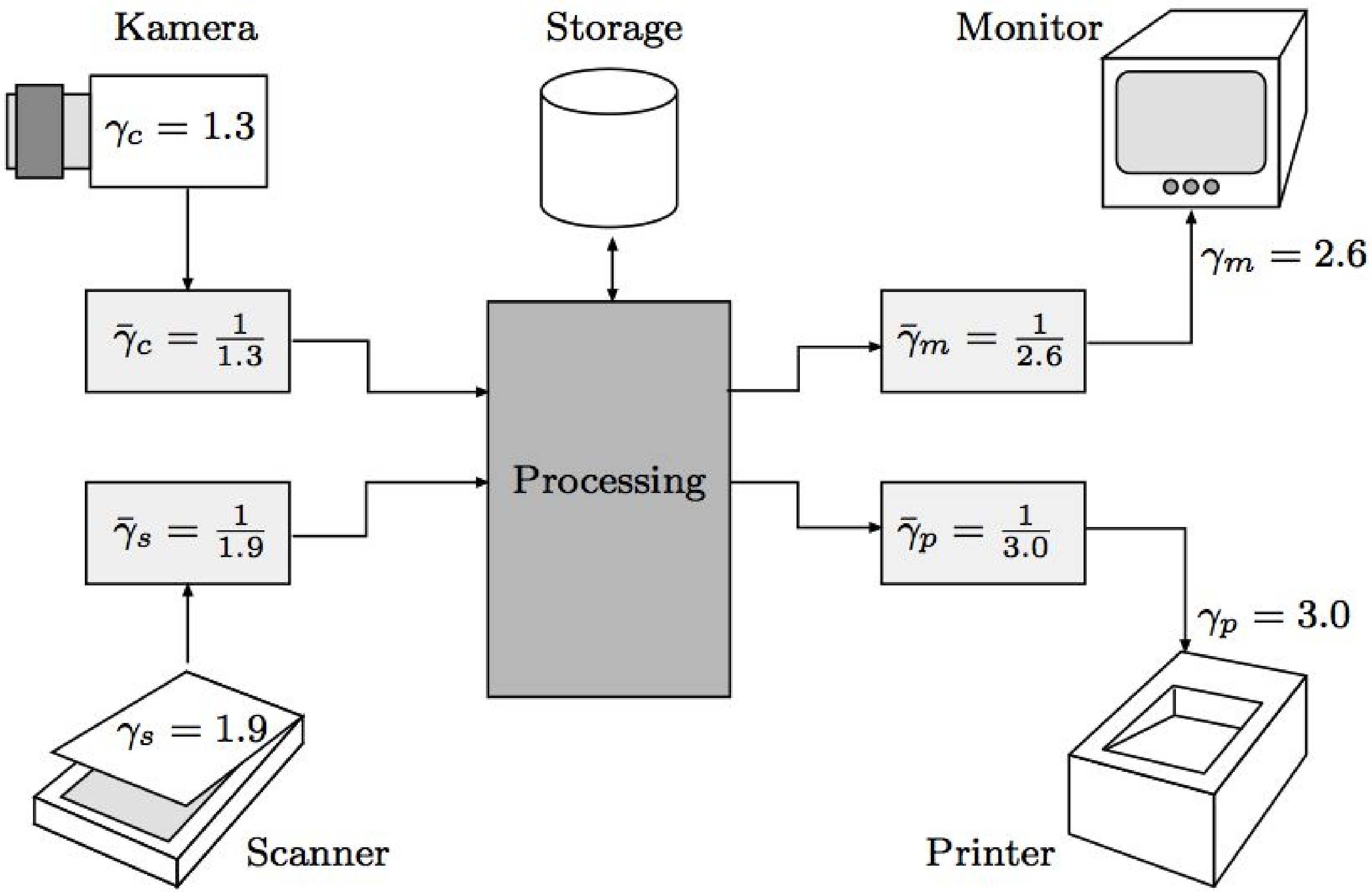


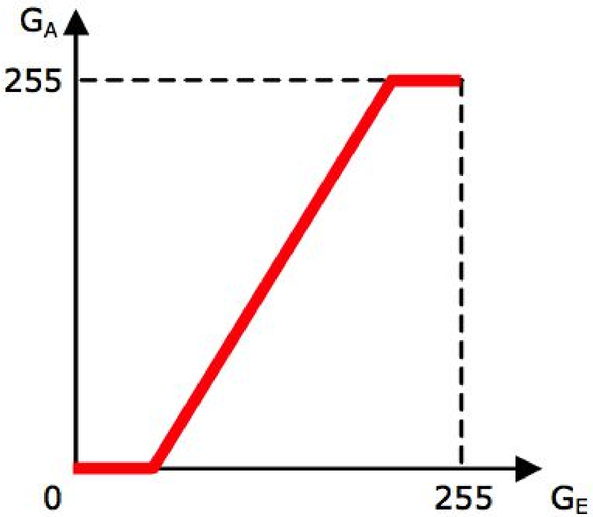
Image: W. Burger: imagingbook.com

Point Operation: Linear Contrast Correction

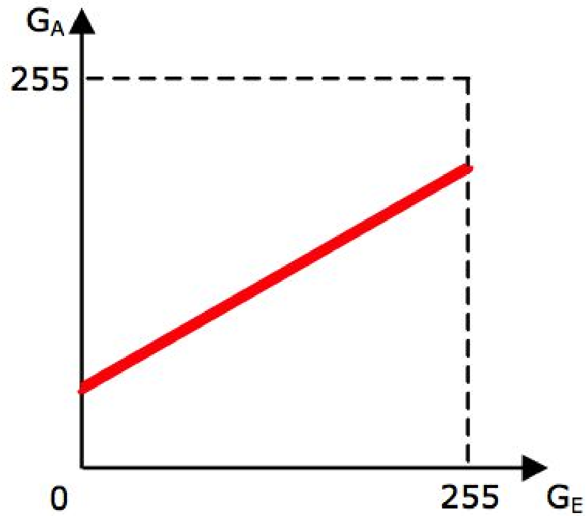
- Linear contrast correction can be expressed in the line equation:

$$g_A(x,y) = c \cdot g_E(x,y) + b$$

where ***c* changes the contrast** and *b* the brightness.



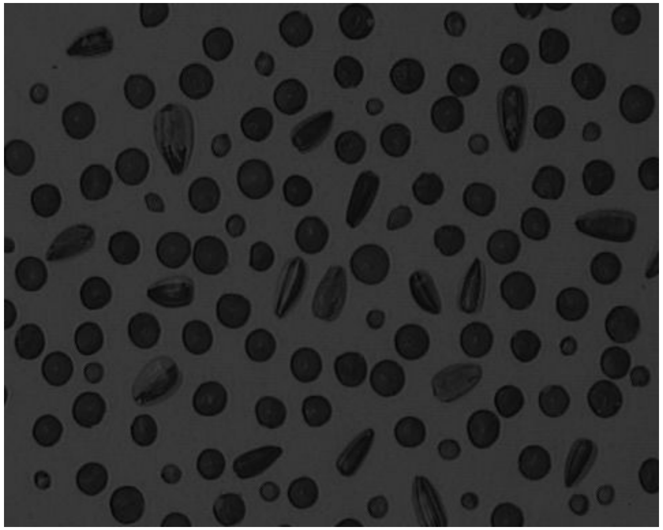
Abbildungsfunktion
Kontrasterhöhung

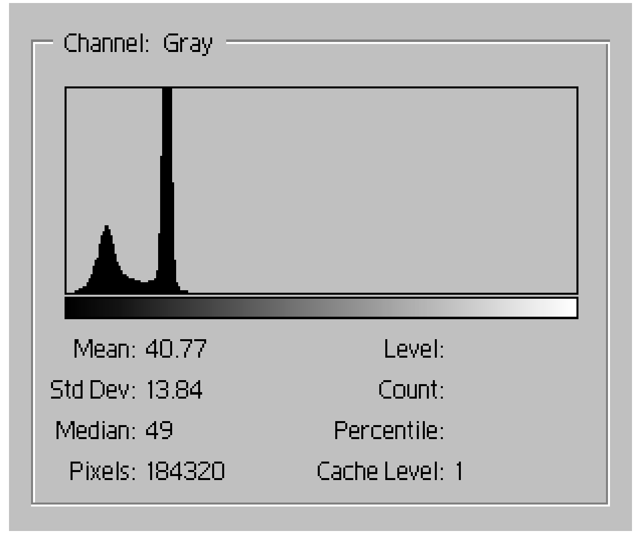


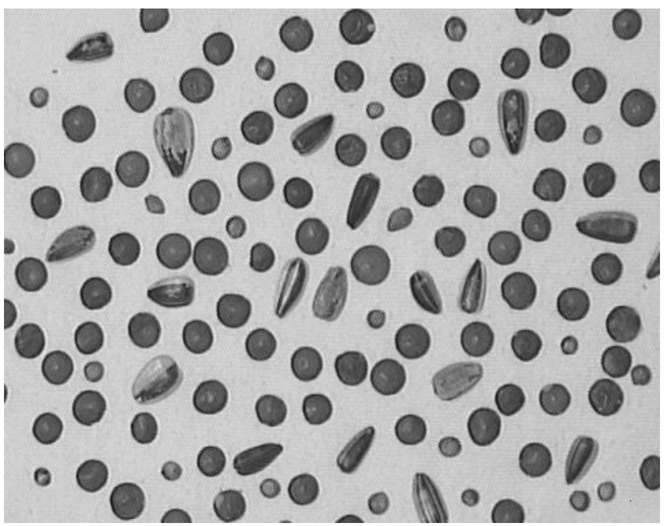
Abbildungsfunktion
Kontrastverminderung

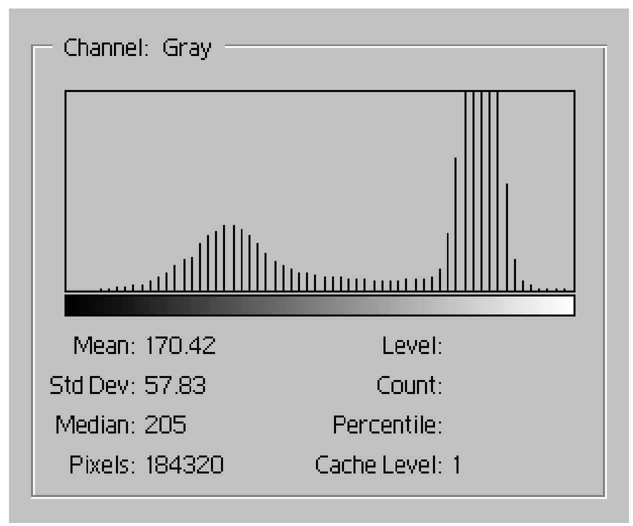
Point Operation: Linear Contrast Correction

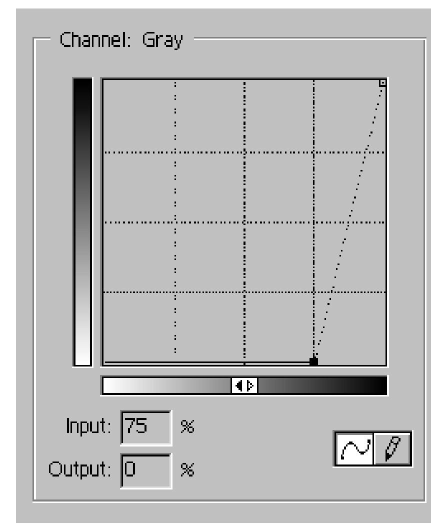
- The histogram is spread:











Point Operation: Linear Contrast Correction

- For **automatic contrast correction** the formula is:

$$g_A(x,y) = (g_E(x,y) - g_{min}) \cdot \frac{255}{g_{max} - g_{min}}$$

- If g_{min}=0 and g_{max}=255 we cut off a percentage of the brightest and darkest:

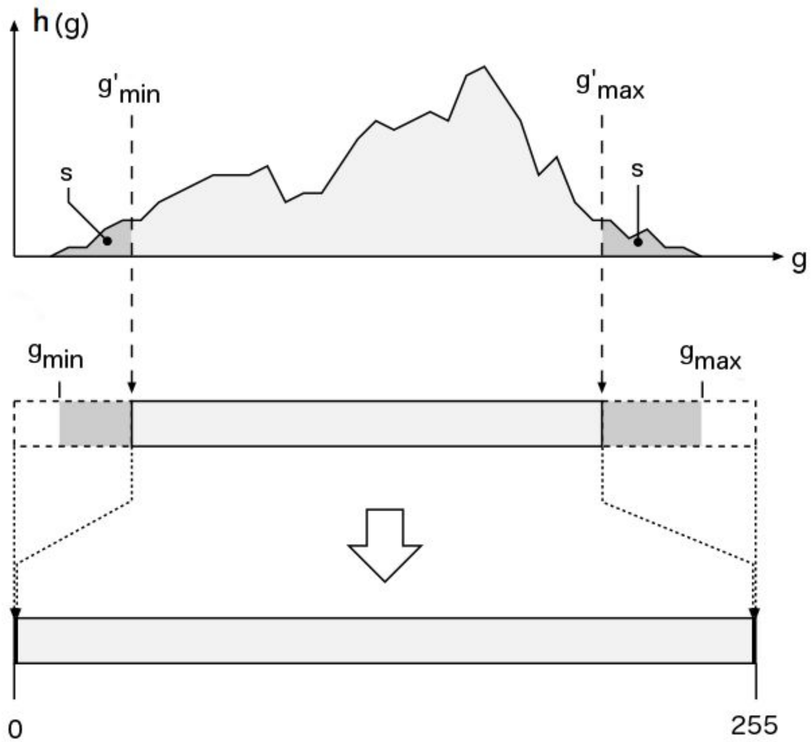


Image: W. Burger: imagingbook.com

Point Operation: Histogram Equalization

- Another automatic contrast correction is the **equalization of the histogram**.
- The algorithm uses the **cummulative histogram**:

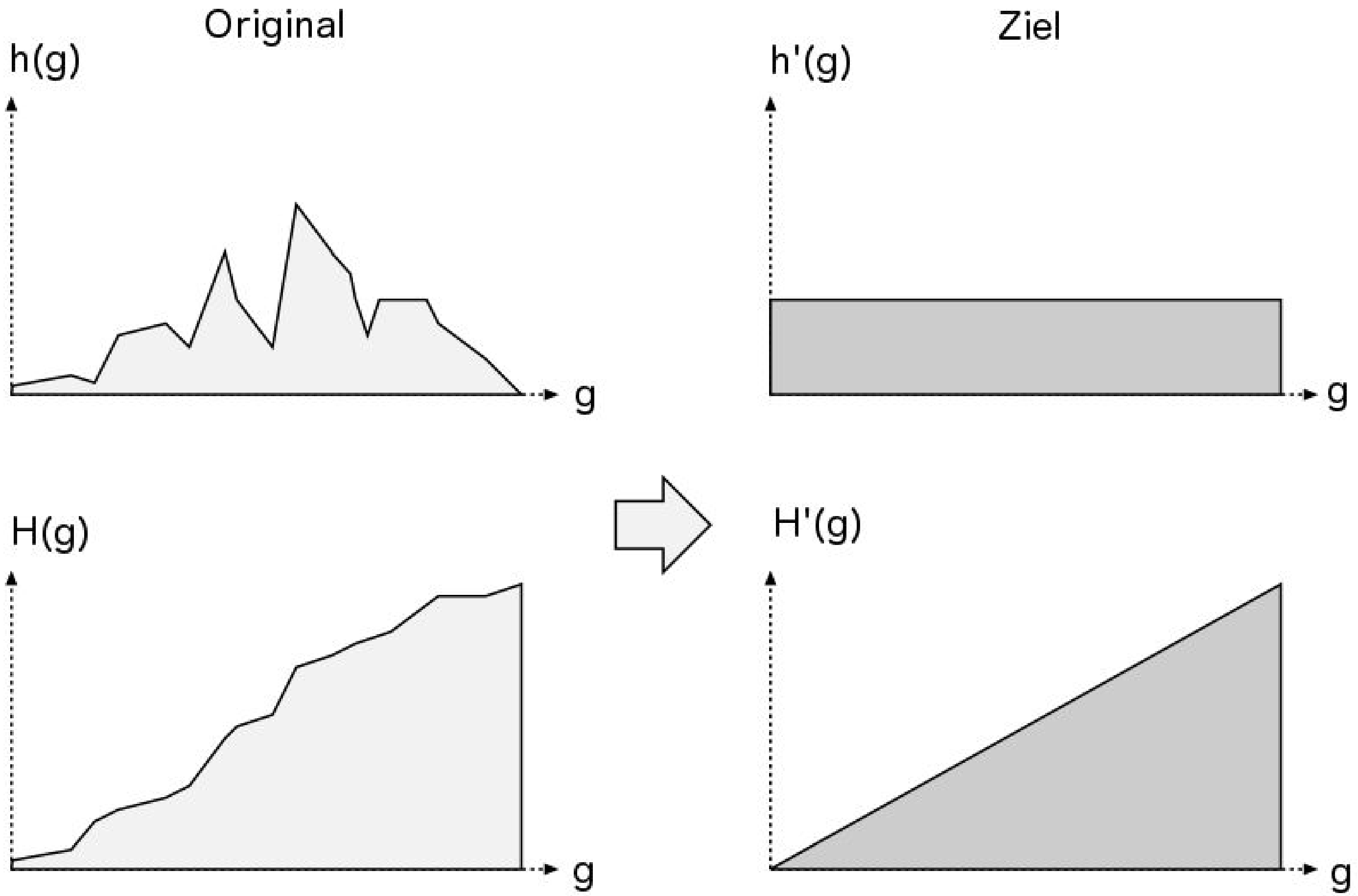
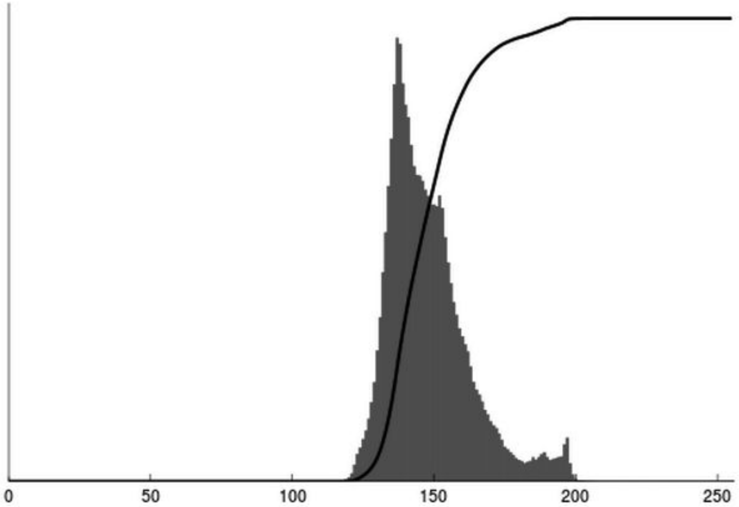


Image: W. Burger: imagingbook.com

Point Operation: Histogram Equalization

- We can use the cumulative histogram as a LUT.
- Gray levels with lots of pixels get spread apart.

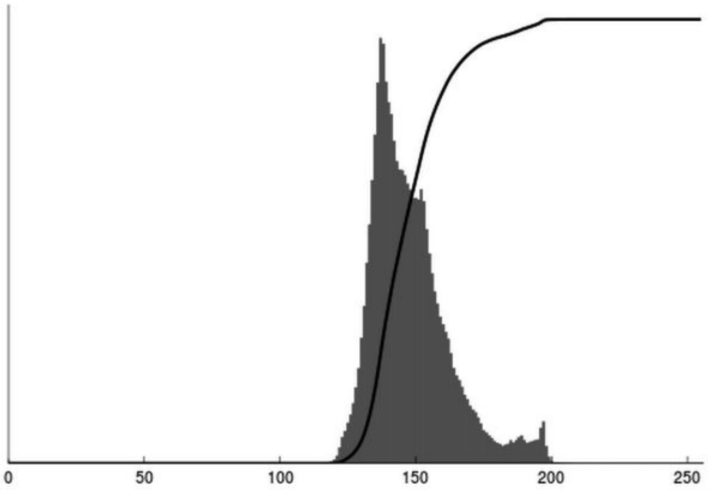


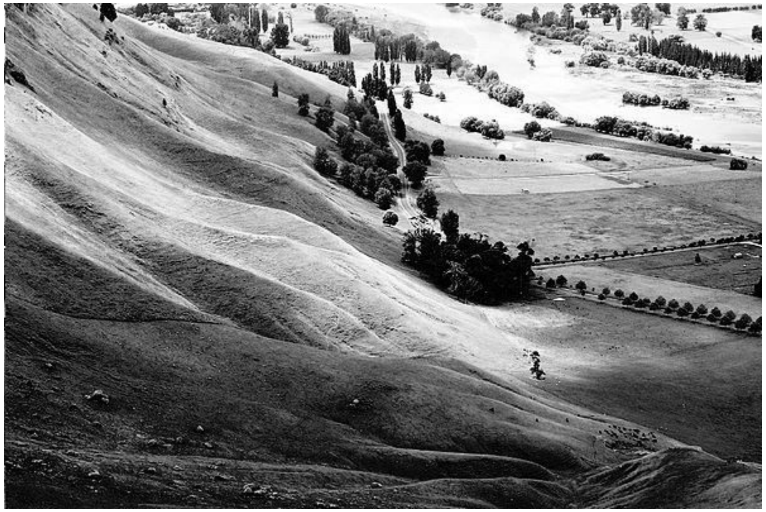
- The scaled cumulative histogram is used as mapping function:

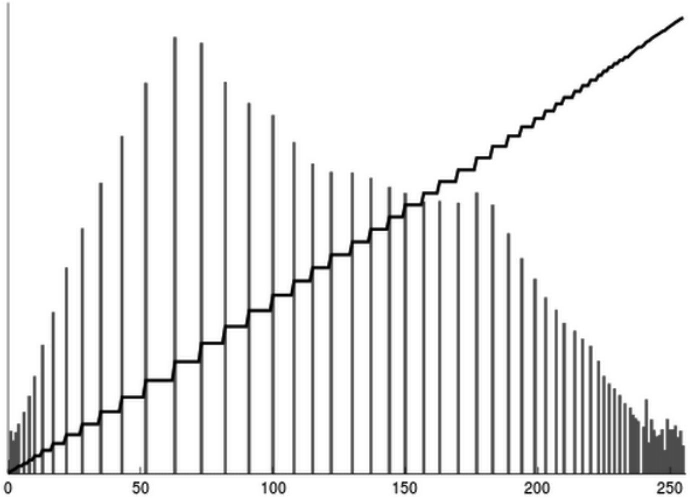
$$f_{eq}(g) = H(g) \cdot \frac{(K-1)}{N}$$

Point Operation: Histogram Equalization

- After the histogram equalization we have equal or less gray levels.
- We often loose information even that the contrast is strong.

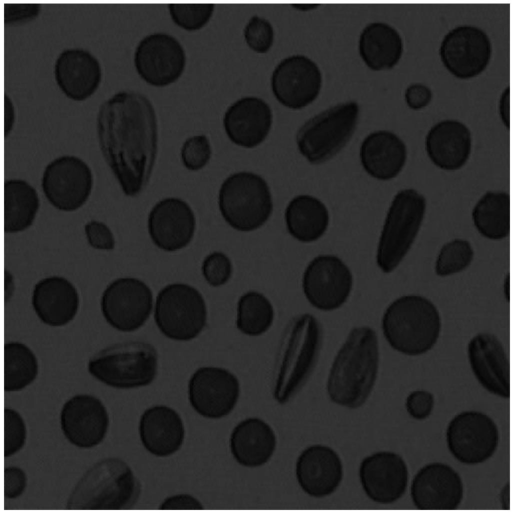


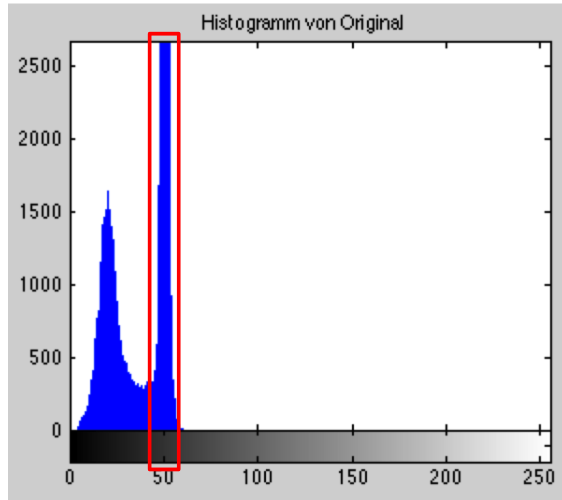


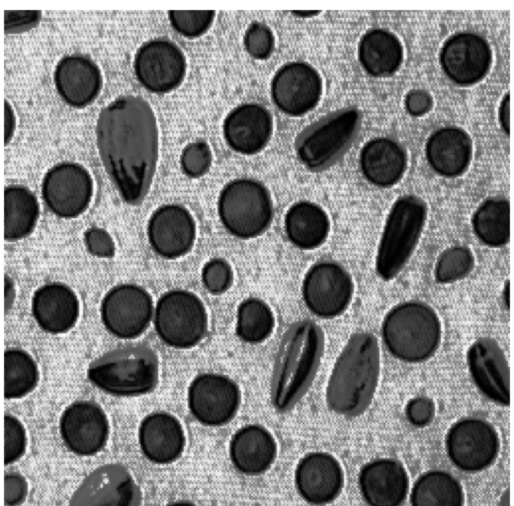


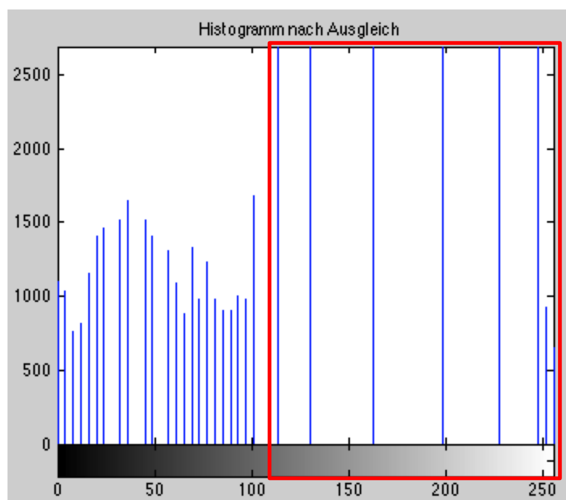
Point Operation: Histogram Equalization

- Histogram Equalization can lead to nois in homogenous regions.
- A few gray levels with lots of pixels get torn apart:





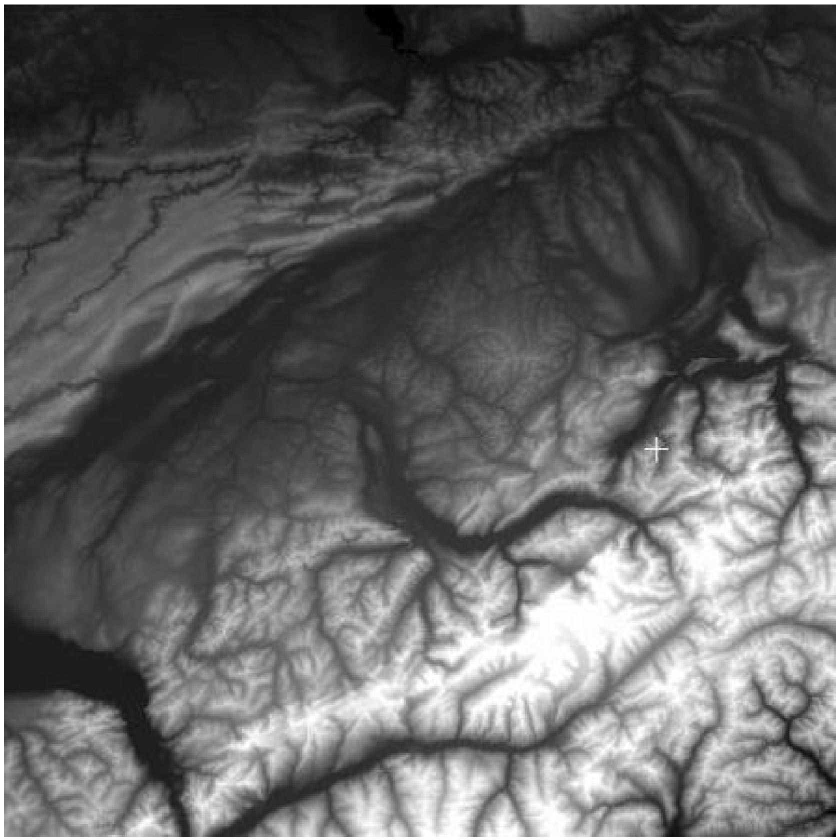


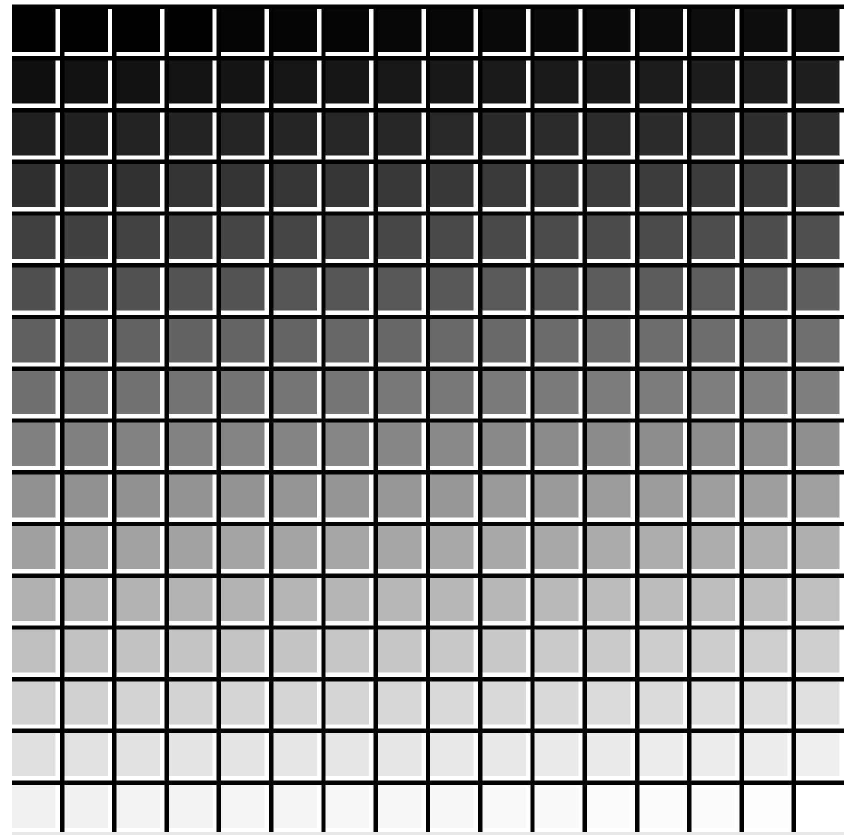


Point Operation: Increase Contrast with Colors

- The human eye can **distinct only 60 gray levels**.
- With **color lookup tables** we can visualize **more information**.

- Height map of Switzerland with 256 gray scales:

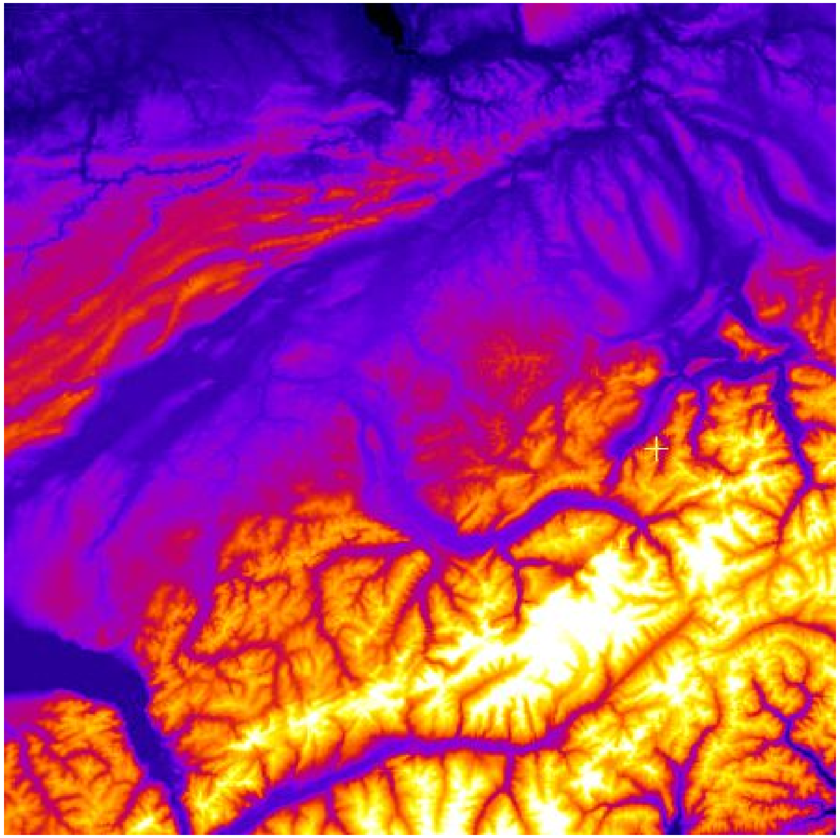


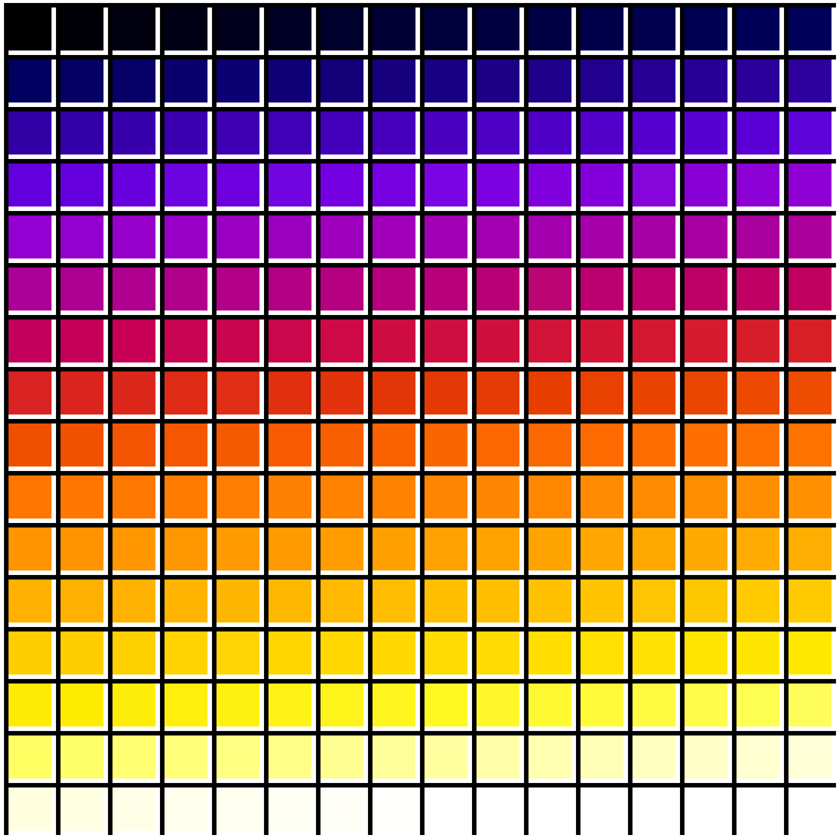


Point Operation: Increase Contrast with Colors

- The human eye can **distinct only 60 gray levels**.
- With **colors** we can visualize **more information**.

- Height map of Switzerland with **ImageJ Fire LUT**:

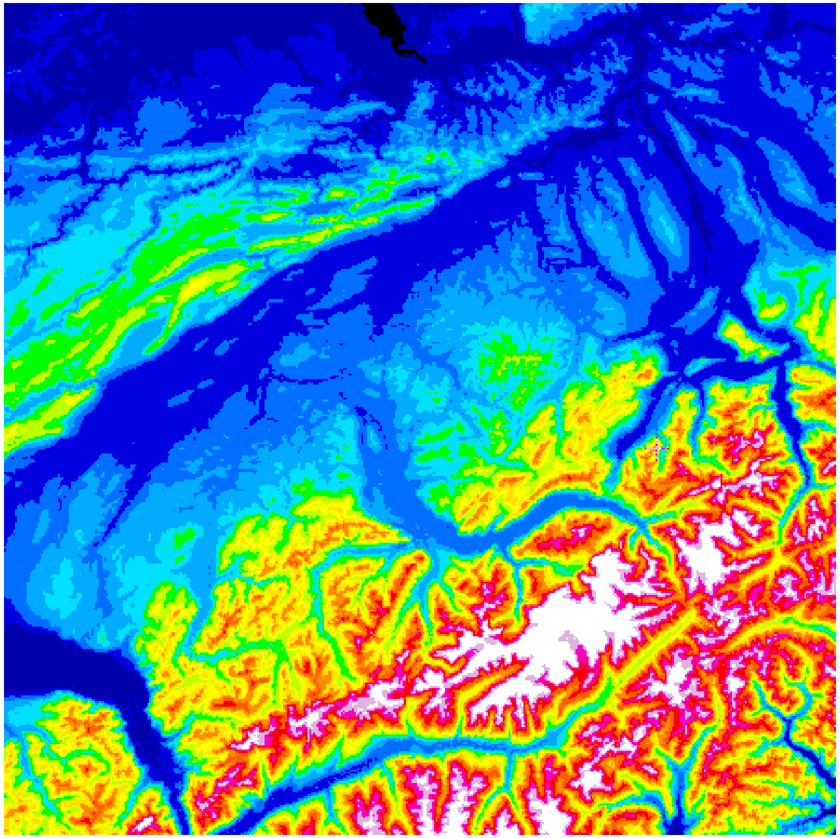


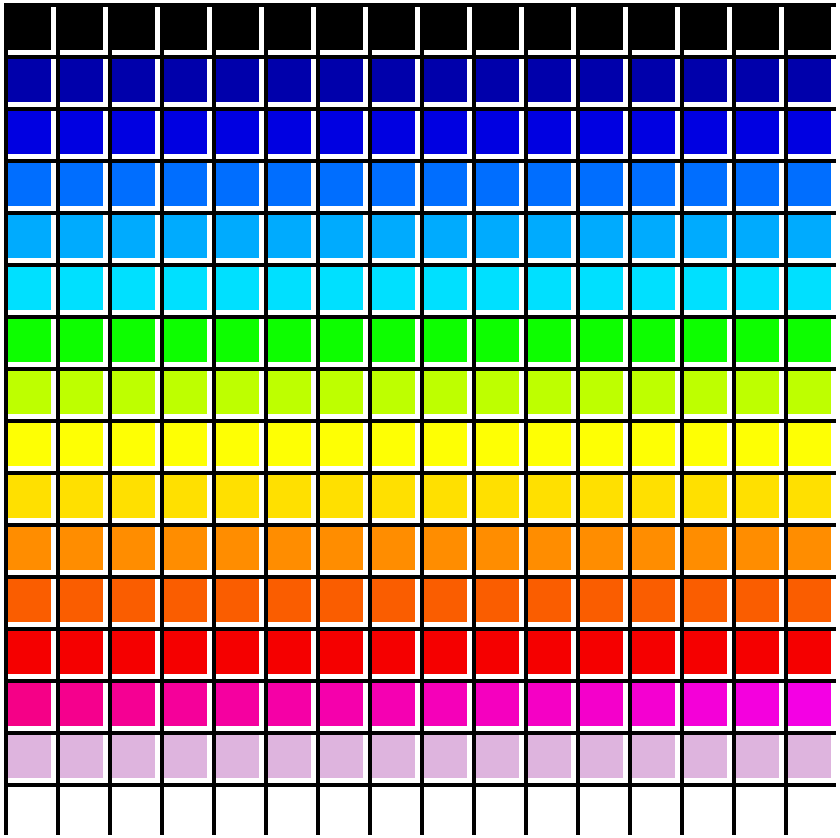


Point Operation: Increase Contrast with Colors

- The human eye can **distinct only 60 gray levels**.
- With **color lookup tables** we can visualize **more information**.

- Height map of Switzerland with **ImageJ 16 Colors LUT**:

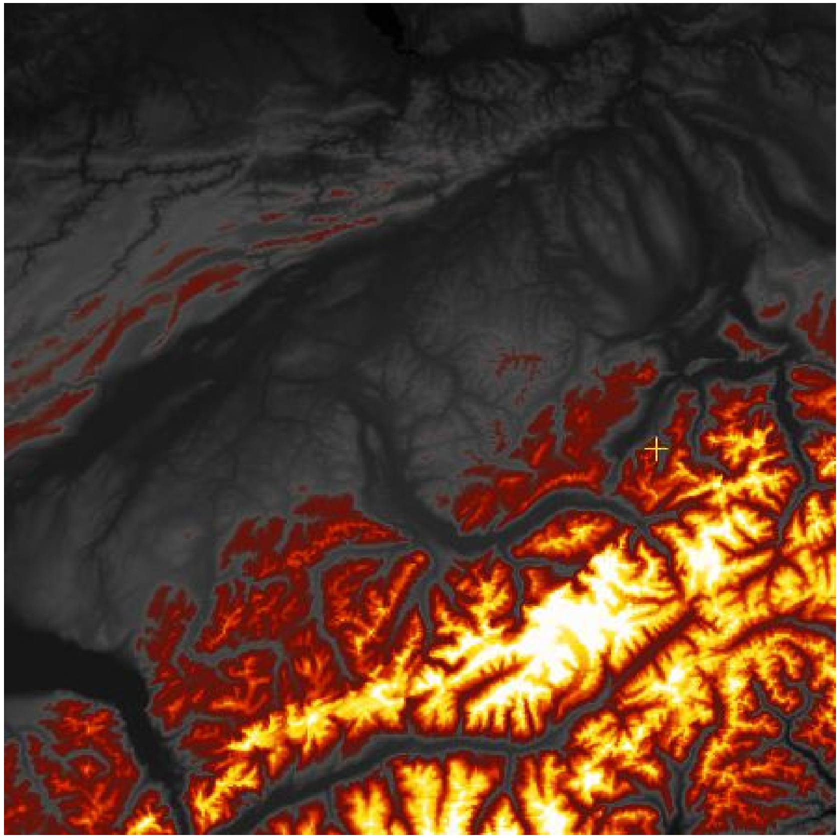


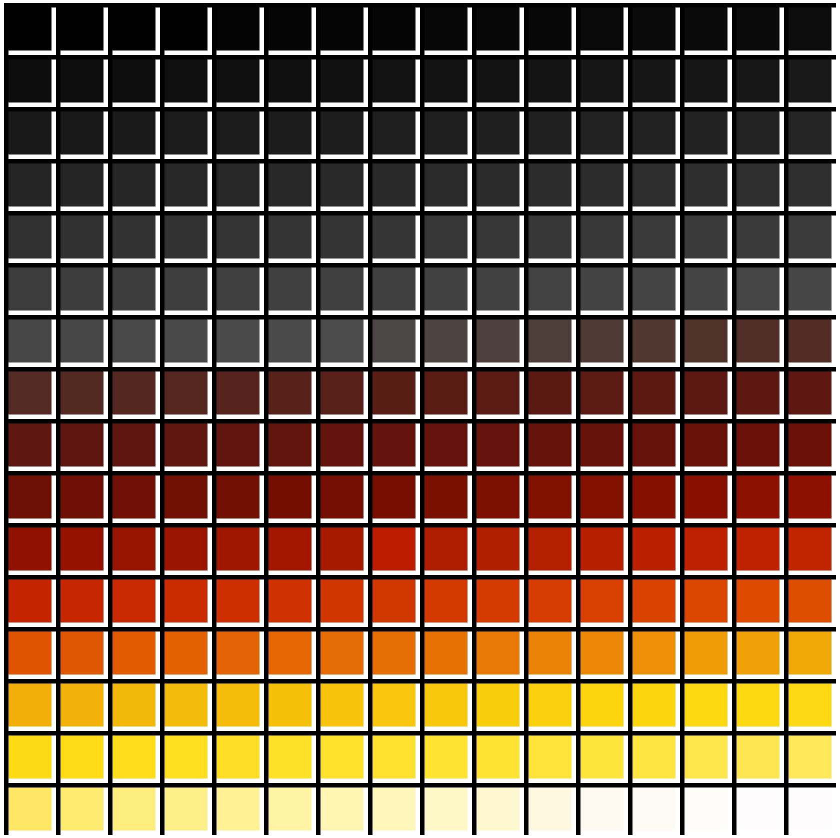


Point Operation: Increase Contrast with Colors

- The human eye can **distinct only 60 gray levels**.
- With **color lookup tables** we can visualize **more information**.

- Height map of Switzerland with **ImageJ Smart LUT**:

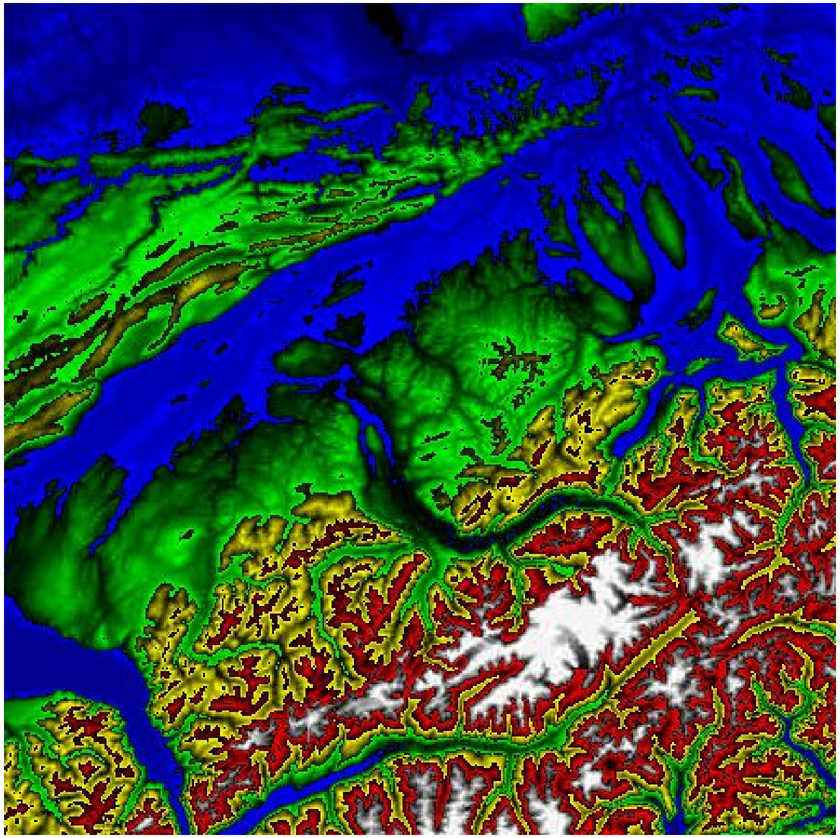


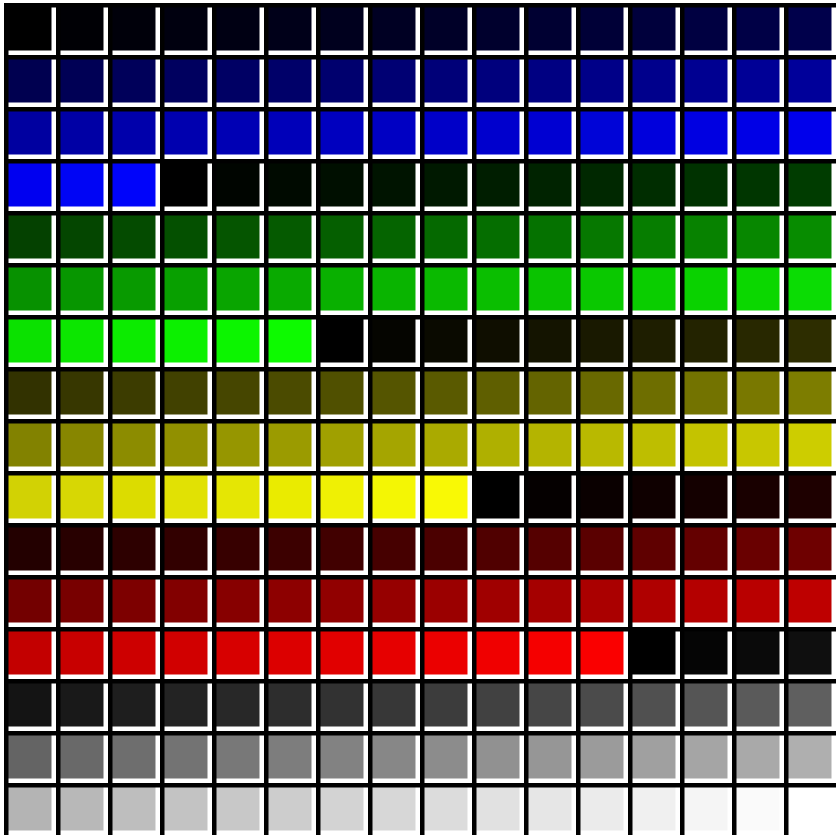


Point Operation: Increase Contrast with Colors

- The human eye can **distinct only 60 gray levels**.
- With **color lookup tables** we can visualize **more information**.

- Height map of Switzerland with **ImageJ 5 Ramps LUT**:

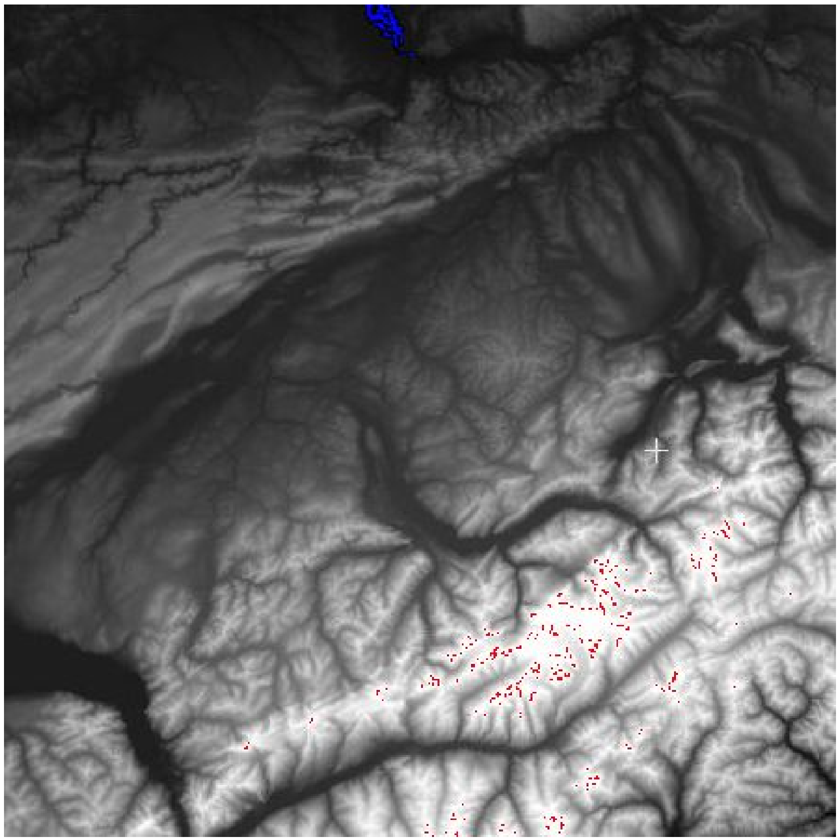


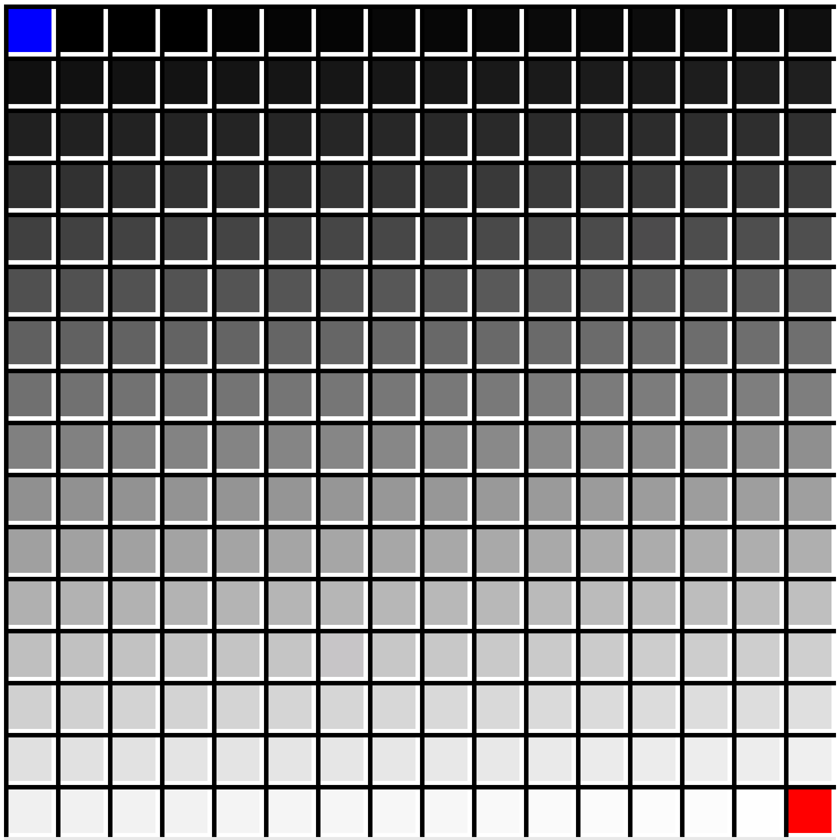


Point Operation: Increase Contrast with Colors

- The human eye can **distinct only 60 gray levels**.
- With **color lookup tables** we can visualize **more information**.

- Height map of Switzerland with **ImageJ HiLo LUT**:





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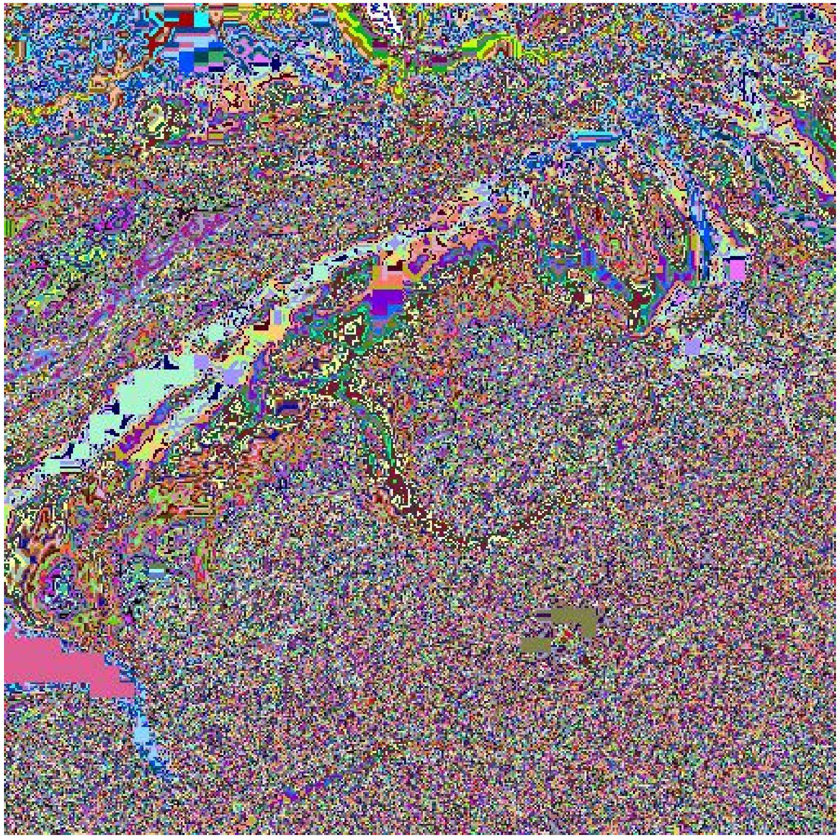


Point Operation: Image Arithmetic

- With brightness & contrast correction we used arithmetics with constant c & b:

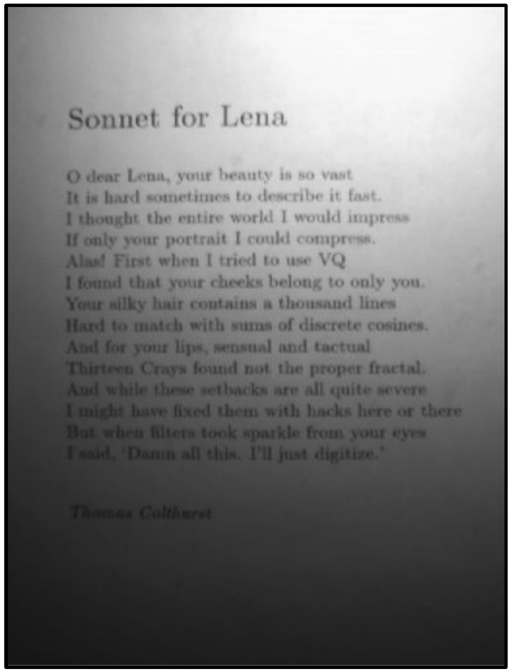
$$g_A(x,y)=c\cdot g_E(x,y)+b$$

- We can do also arithmetics with varying values of 2 images.
- With the constants k1 and k2 we take care to be within the range 0-255:
- Addtion: $g_A(x,y)=(g_{E1}(x,y)+g_{E2}(x,y))\cdot k1+k2$
- Subtraction: $g_A(x,y)=(g_{E1}(x,y)-g_{E2}(x,y))\cdot k1+k2$
- Multiplication: $g_A(x,y)=(g_{E1}(x,y)\cdot g_{E2}(x,y))\cdot k1+k2$
- Division: $g_A(x,y)=(g_{E1}(x,y)/g_{E2}(x,y))\cdot k1+k2$

Point Operation: Image Arithmetic

Example: Separate text from background:

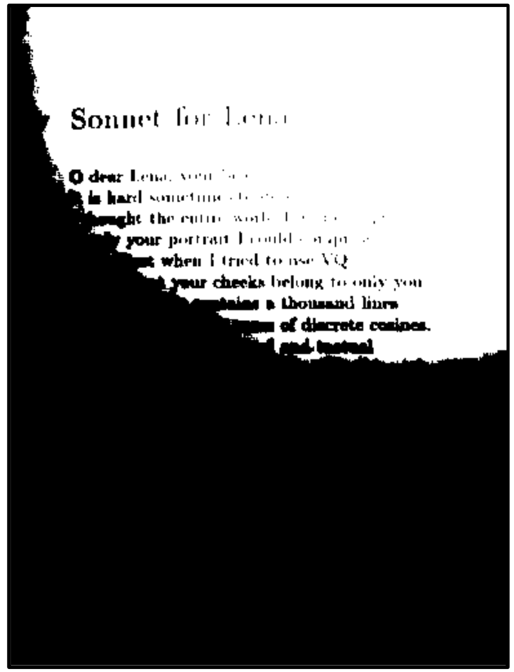
- Not possible with one distinct threshold:



Sonnet for Lena

O dear Lena, your beauty is so vast
It is hard sometimes to describe it fast.
I thought the entire world I would impress
If only your portrait I could compress.
Alas! First when I tried to use VQ
I found that your cheeks belong to only you.
Your silky hair contains a thousand lines
Hard to match with sums of discrete cosines.
And for your lips, sensual and tactual
Thirteen Crays found not the proper fractal.
And while these setbacks are all quite severe
I might have fixed them with hacks here or there
But when filters took sparkle from your eyes
I said, 'Damn all this. I'll just digitize.'

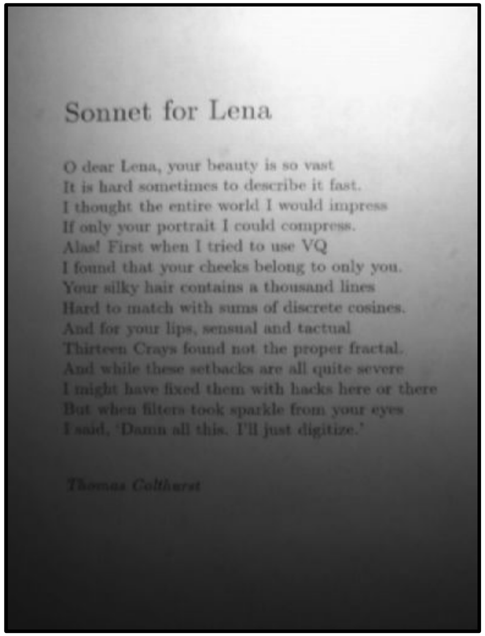
Thomas Colthurst



Point Operation: Image Arithmetic

Example: Separate text from background:

- We can subtract the background:



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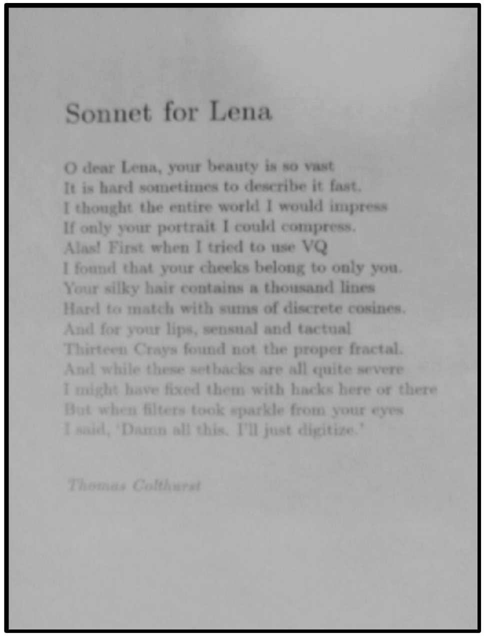
-

+ 180 =



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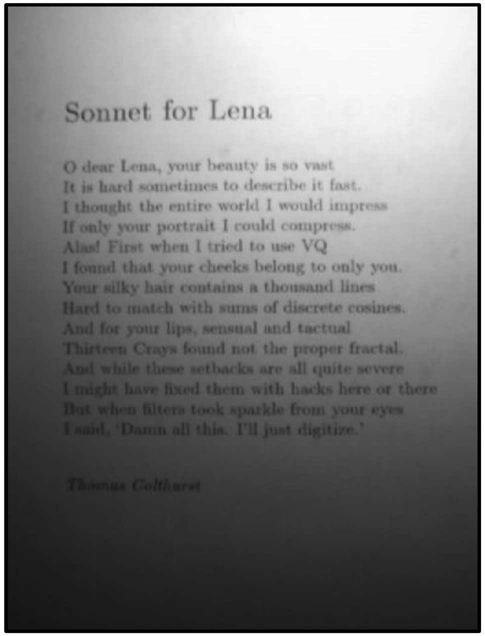
Point Operation: Image Arithmetic

Example: Separate text from background:

- We can devide by the background:



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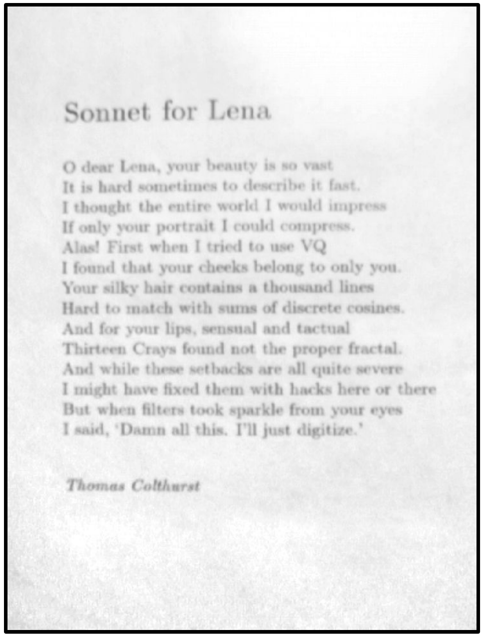
/

x 255 =



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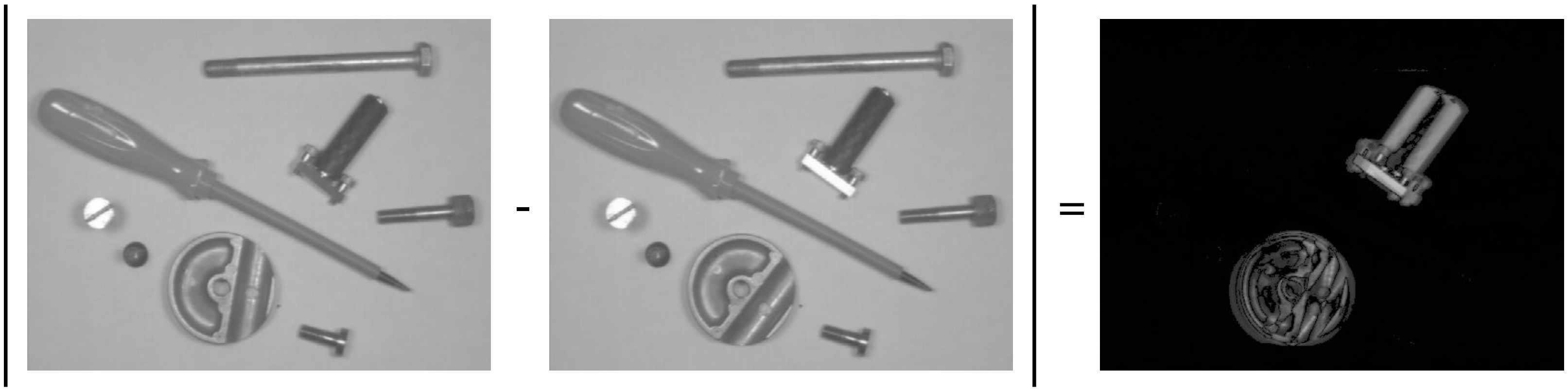
Remains the question how to get the background?

- With a median filter (denoising filter, chapter 6)
- and/or with a gaussian (averaging filter, chapter 6)

Point Operation: Image Arithmetic

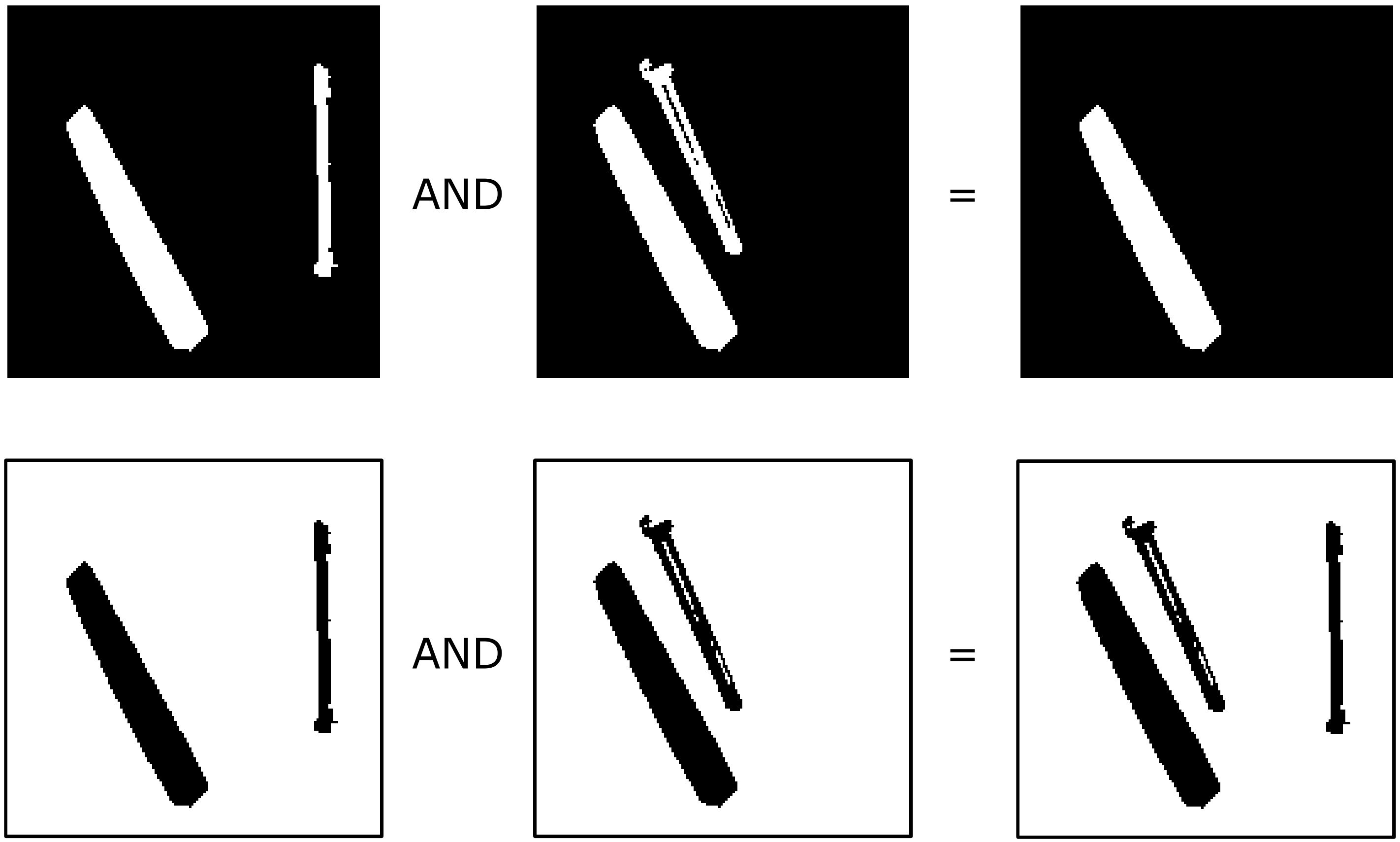
Example: Detecting shifted object with absolute difference:

$$g_A(x,y) = |g_{E1}(x,y) - g_{E2}(x,y)|$$



Point Operation: Logic Operations

- Boolean operations like AND, OR and XOR can be used to combine image:



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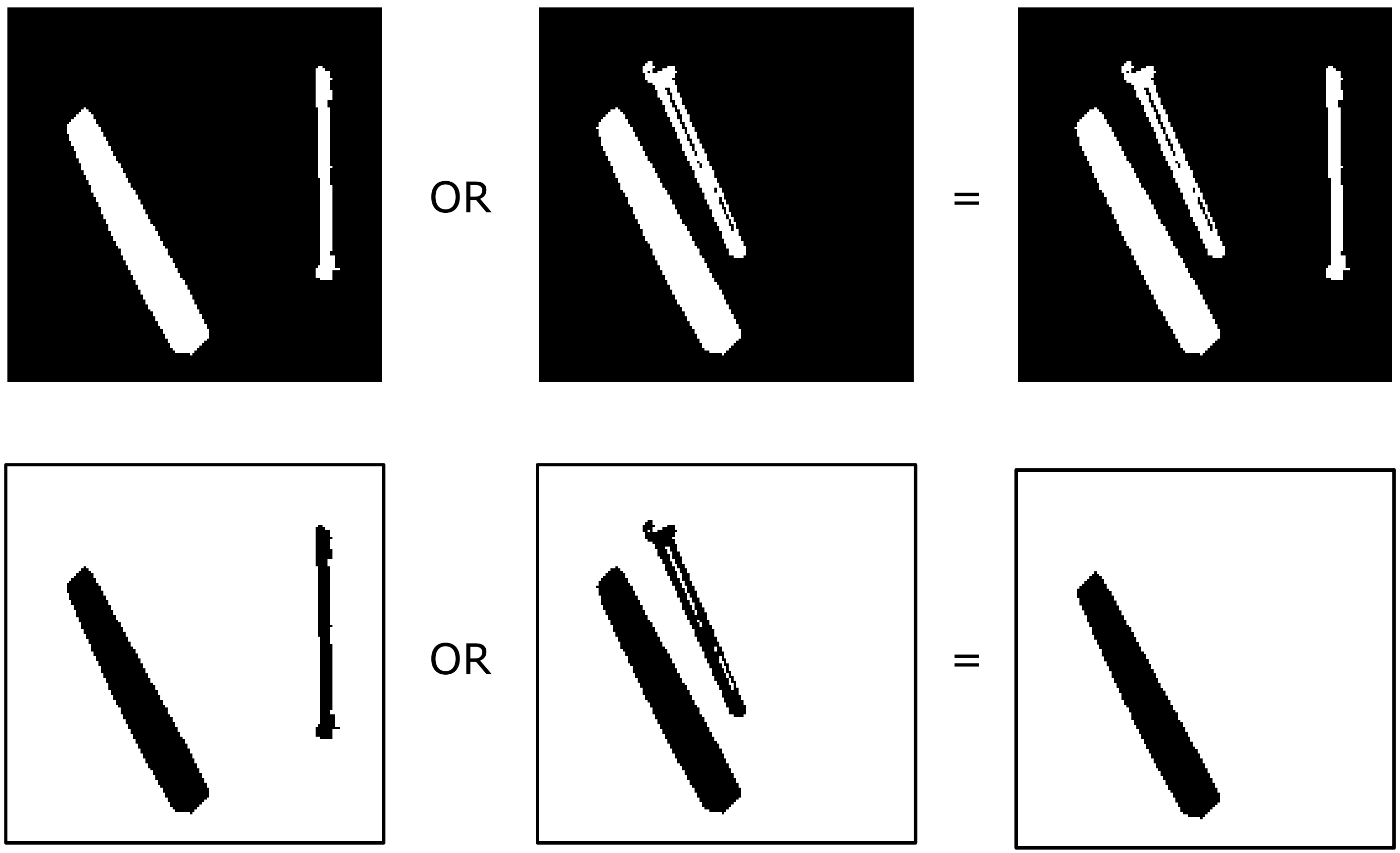

Point Operation: Logic Operations

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