h_da
HOCHSCHULE DARMSTADT
UNIVERSITY OF APPLIED SCIENCES
fbi
FACHBEREICH INFORMATIK

Visual Computing Digital Images

Darmstadt University

Prof. Dr Elke Hergenröther
Björn Frömmer
Prof. Dr Benjamin Meyer

CHAPTER 11

Image Editing - Dot Operators

Image Editing - Dot Operators

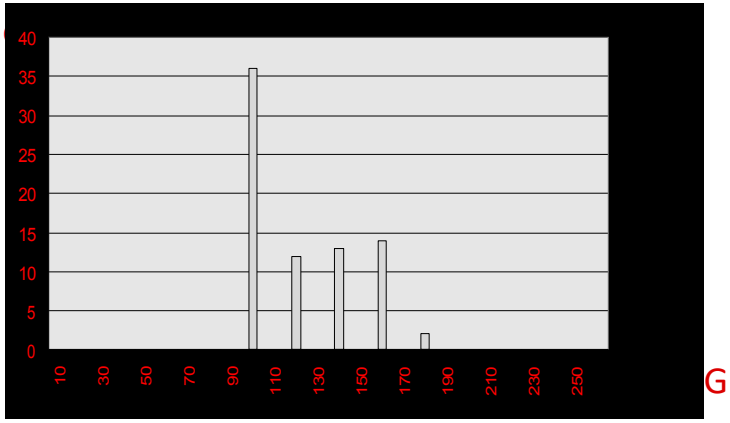
Histograms Point operations

- Linear change of the grey values:
  - Changing the picture brightness
  - Invert the image
  - Changing the contrast
  - Biniarisation through thresholding
- Non-linear change in grey values:
  - Gamma correction
- Colour Transformations (Color Transformation)

Image Editing - Dot Operators

Histograms: A graphical representation of the frequency distribution of grey values in images.

Frequency of th values



Grey values

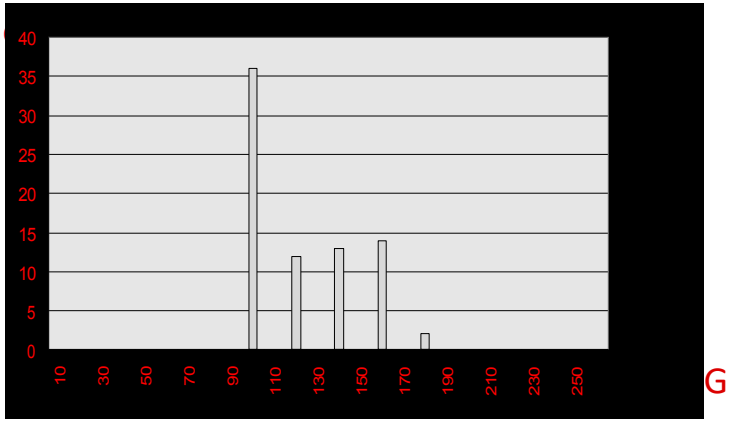
	0	1	2	3	4	5	6	7	8	9	10
0	100	100	100	120	160	160	120	100	100	100	137
1	100	100	100	120	160	160	120	100	100	100	137
2	100	100	100	120	160	160	120	100	100	100	137
3	100	100	100	120	160	160	140	140	140	140	178
4	100	100	100	120	160	160	140	140	140	140	177
5	100	100	100	120	160	160	120	100	100	100	136
6	100	100	100	120	160	160	120	100	100	100	136

Underlying grey tone image in the form of an image matrix in which the individual grey values are represented by numerical values.

Image Editing - Dot Operators

Histograms: A graphical representation of the frequency distribution of grey values in images.

Frequency of th values



Grey values

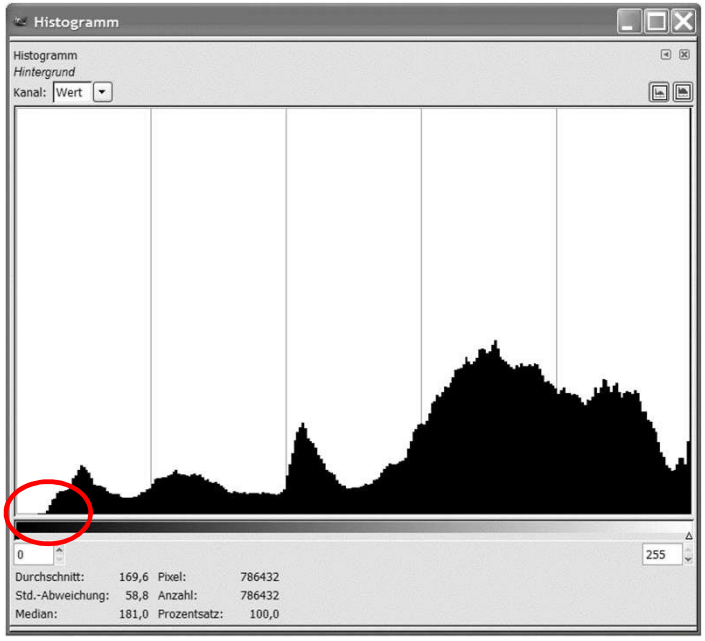
Absolute and relative frequencies:
A distinction is made between the absolute frequency distribution, as shown in the figure on the right, and the relative frequency distribution. In the relative distribution, frequency values are normalised, i.e. transformed into an interval between 0 and 1.

	0	1	2	3	4	5	6	7	8	9	10
0	100	100	100	120	160	160	120	100	100	100	137
1	100	100	100	120	160	160	120	100	100	100	137
2	100	100	100	120	160	160	120	100	100	100	137
3	100	100	100	120	160	160	140	140	140	140	178
4	100	100	100	120	160	160	140	140	140	140	177
5	100	100	100	120	160	160	120	100	100	100	136
6	100	100	100	120	160	160	120	100	100	100	136

Underlying grey tone image in the form of an image matrix in which the individual grey values are represented by numerical values.

Image Editing - Dot Operators

Histograms: A measure used to assess image quality.



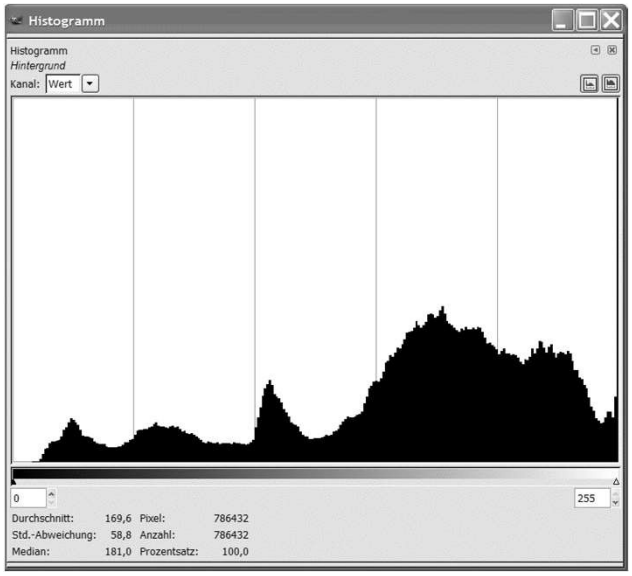
The histogram of the brightness channel of an image can be used to decide whether an image is overexposed or underexposed. The picture is overexposed because the dark grey tones are missing (see red mark in the histogram).

Image Editing - Dot Operators

Histograms: A measure used to assess image quality.

Exposure error*)

One end of the grey value scale remains unused while at the other end of the scale there are clusters. On the left of the histogram are the dark grey values (grey value 0 = black), on the right the light grey values (maximum grey value = white).



*) Definitions from: W. Burger, M. J. Burge, "Digital Image Processing", Springer Verlag

Image Editing - Dot Operators

Histograms: A measure used to assess image quality.

Contrasts*)

Contrast is the range between the minimum and maximum grey values in the image. An image with a full contrast range therefore uses the entire range of intensity values (= grey values). To evaluate the contrast, one can form the difference between the maximum and minimum intensity value.

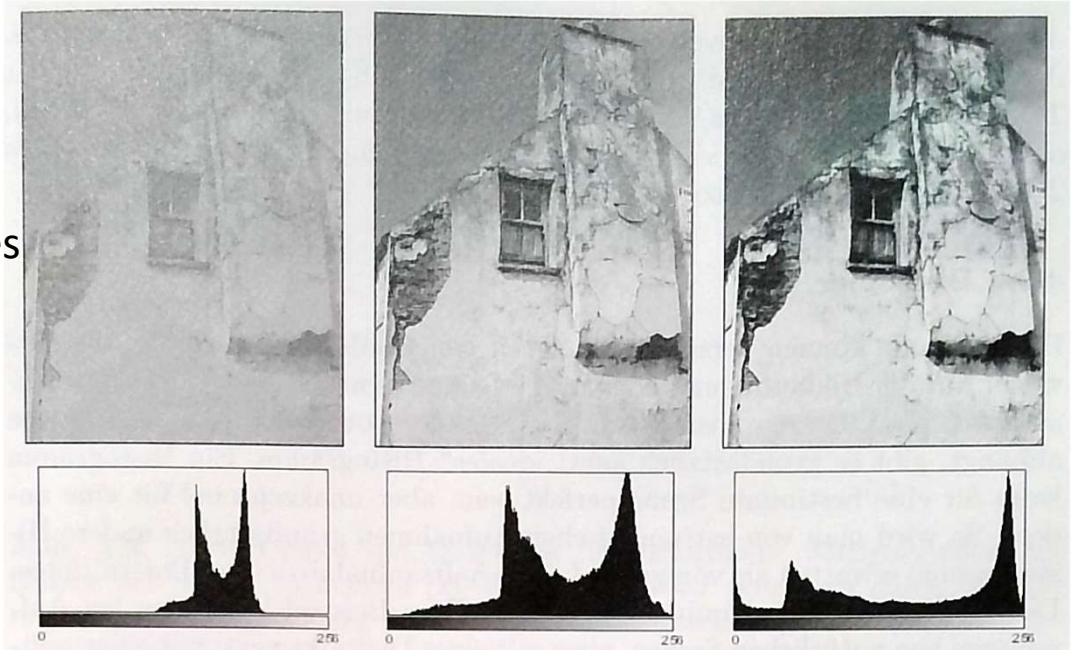


Abb. 4.7. Unterschiedlicher Kontrast und Auswirkungen im Histogramm: niedriger Kontrast (a), normaler Kontrast (b), hoher Kontrast (c).

*) Definitions and images from: W. Burger, M. J. Burge, "Digital Image Processing", Springer Verlag

Image Editing - Dot Operators

Histograms: A measure used to assess image quality.

Dynamics*)

Dynamic range is the number of different grey values (intensity values) used in an image. Ideally, every grey value is present in the image.

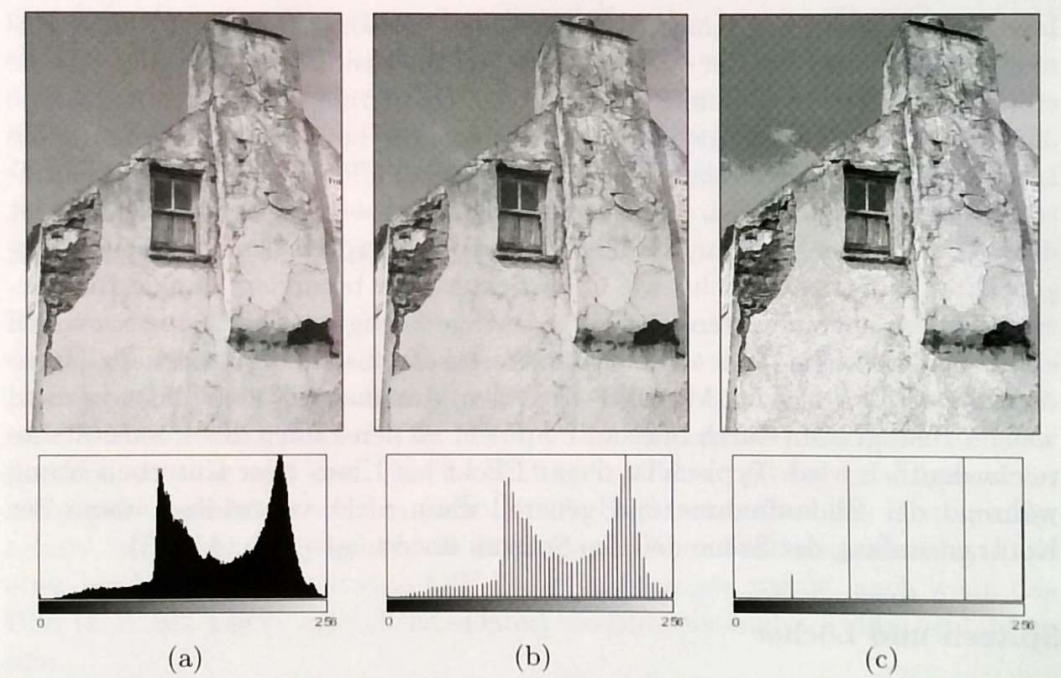


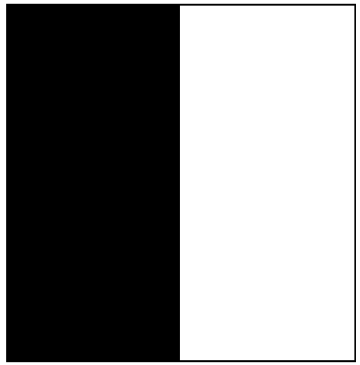
Abb. 4.8. Unterschiedliche Dynamik und Auswirkungen im Histogramm. Hohe Dynamik (a), niedrige Dynamik mit 64 Intensitätswerten (b), extrem niedrige Dynamik mit nur 6 Intensitätswerten (c).

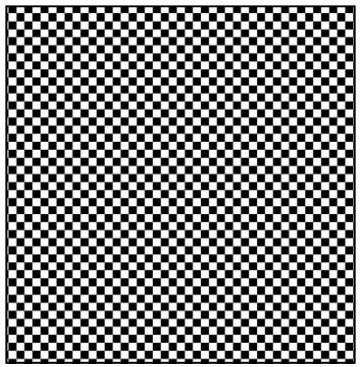
*) Definitions and images from: W. Burger, M. J. Burge, "Digital Image Processing", Springer Verlag

Image Editing - Dot Operators

Histograms: Also a measure for assessing image content?

What does the relative frequency distribution look like in the histograms of the three images?





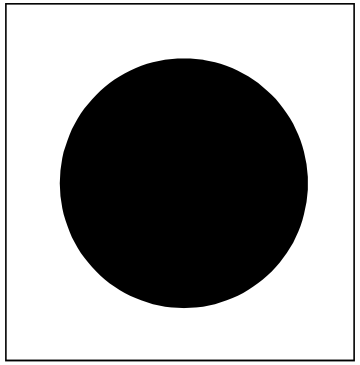
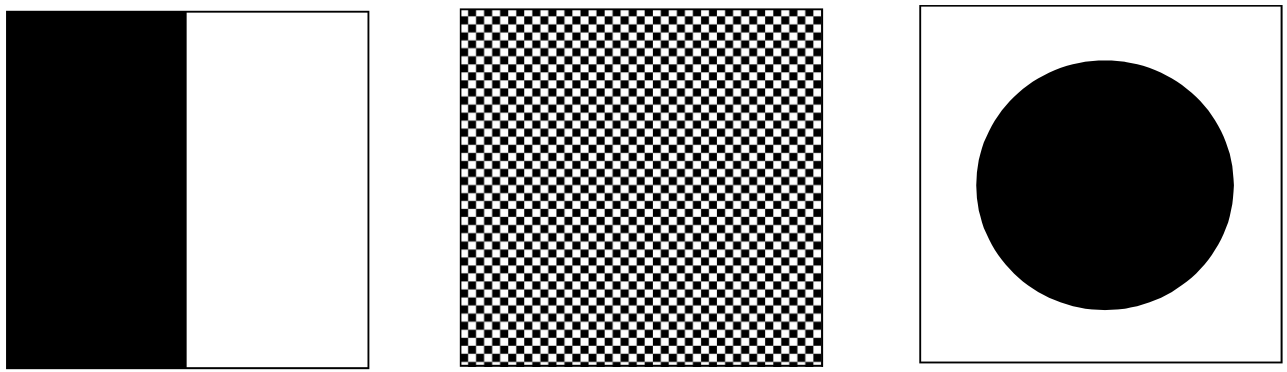


Image Editing - Dot Operators

Histograms: Also a measure for assessing image content?

What does the relative frequency distribution look like in the histograms of the three images?



The histograms of all three images look the same. There are as many black pixels as white pixels.

Image Editing - Dot Operators

Histograms: **Not a** measure for assessing image content, but image manipulations can be recognised in them.

The effects of JPEG compression can be seen in the histogram.

An image that consists only of black and white pixels.

JPEG compression has added more grey values.

Image Editing - Dot Operators

Histograms: **Not a** measure for assessing image content, but image manipulations can be recognised in them.

Reducing the contrast range can cause histogram peaks.

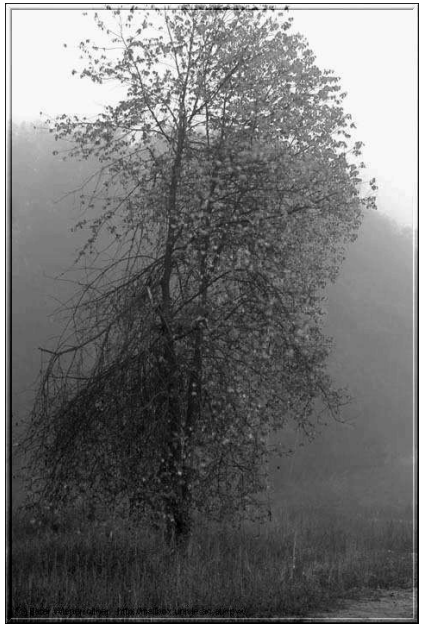


Image with full contrast and dynamic range

Transformation of the Grey value range

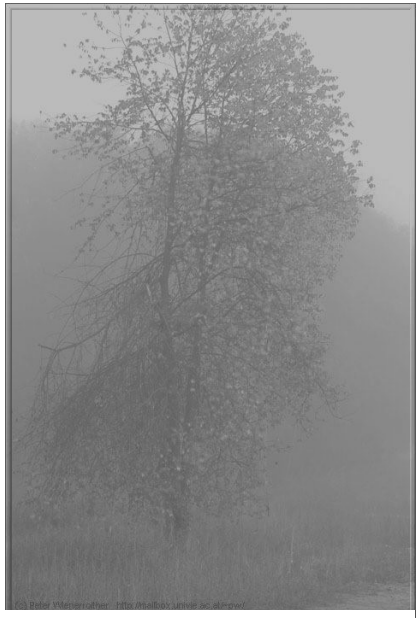
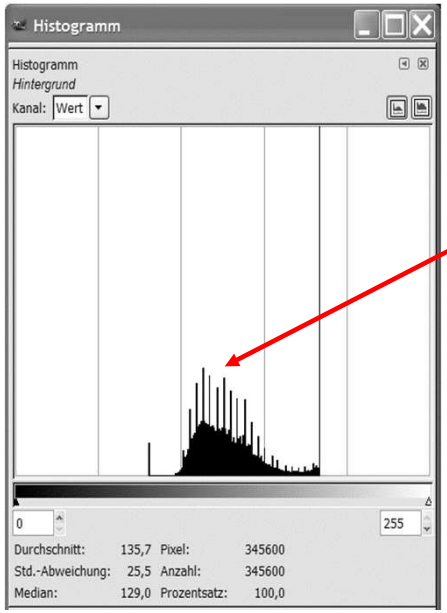


Image with limited Contrast and dynamic range



Histogram peaks

Histogram of the image with restricted Contrast and dynamic range

Image Editing - Dot Operators

Histograms Point operations

- Linear change of the grey values:
  - Changing the picture brightness
  - Invert the image
  - Changing the contrast
  - Biniarisation through thresholding
- Non-linear change in grey values:
  - Gamma correction
- Colour Transformations (Color Transformation)

Image Editing - Dot Operators

Point operation:

- denote operations on images that are calculated pixel by pixel
- the grey values of the neighbouring pixels are not used by the operators
- the size and geometry of the image is not changed

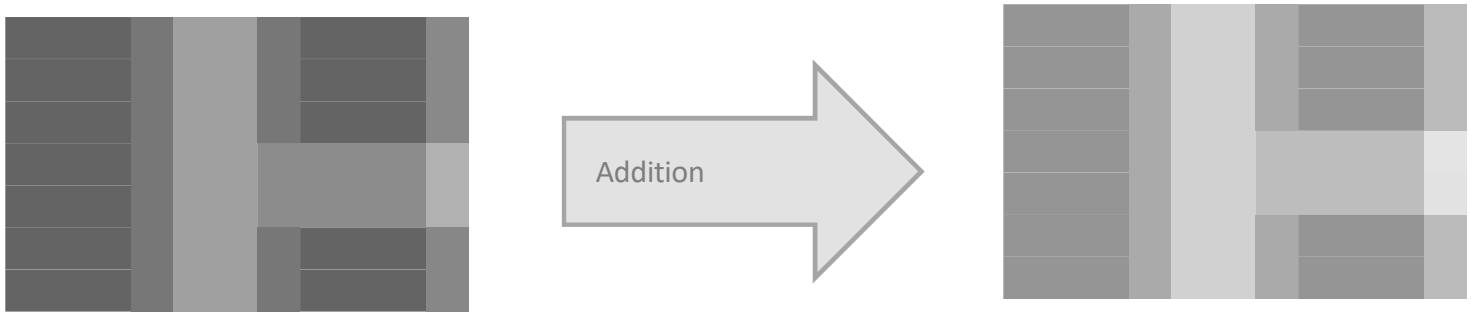
Possible point operations are:

- Changing the picture brightness
- Invert the image
- Changing the contrast
- Biniarisation through thresholding
- Gamma correction
- Colour transformations

Image Editing - Dot Operators

Point operations: Changing the image brightness

Lighten the image by adding a value > 0



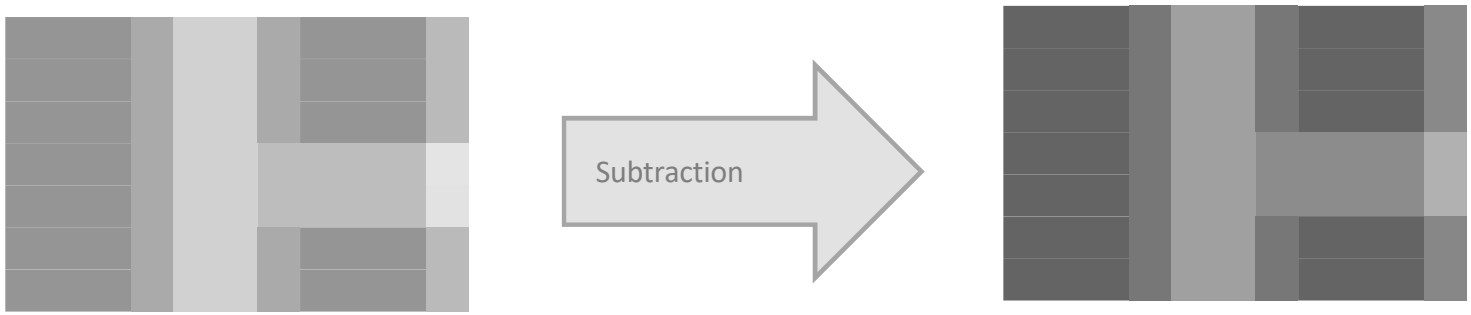
$g(x, y) <= 205$ then $g'(x, y) = g(x, y) + 50$

$g(x, y) > 205$ then $g'(x, y) = 255$

Image Editing - Dot Operators

Point operations: Changing the image brightness

Darkening the image by subtracting a value > 0



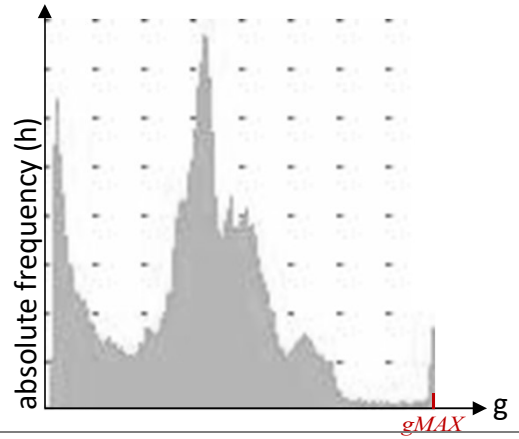
$g(x, y) >= 50$ then $g'(, y) = g(x, y) - 50$

$g(x, y < 50$ then $g'(x, y) = 0$

Image Editing - Dot Operators

Point operations: Invert the image

Inversion



$g'(x, y) = g_{MAX} - g(x, y)$ it

follows:

$h(g_i') = h(g_{MAX-i})$

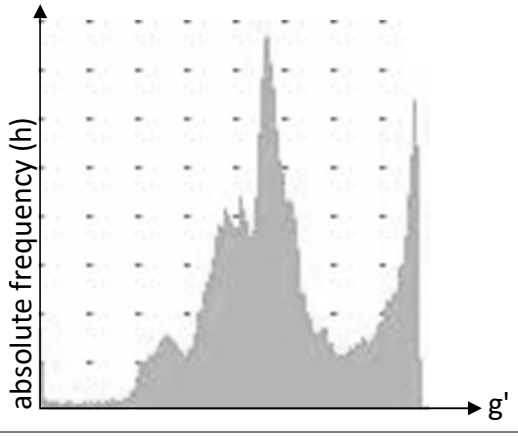
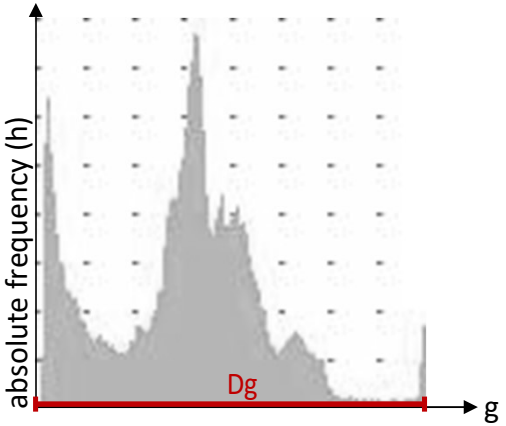


Image Editing - Dot Operators

Point operations: Changing the contrast

Changing the contrast



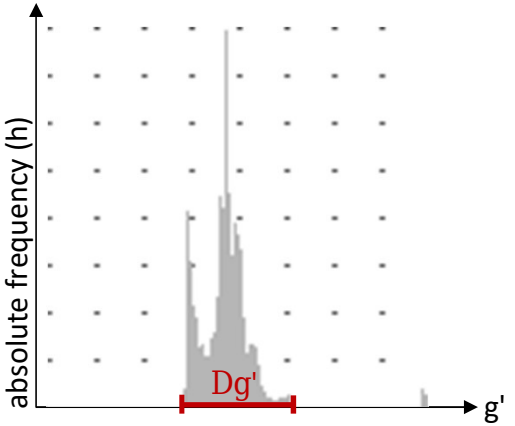


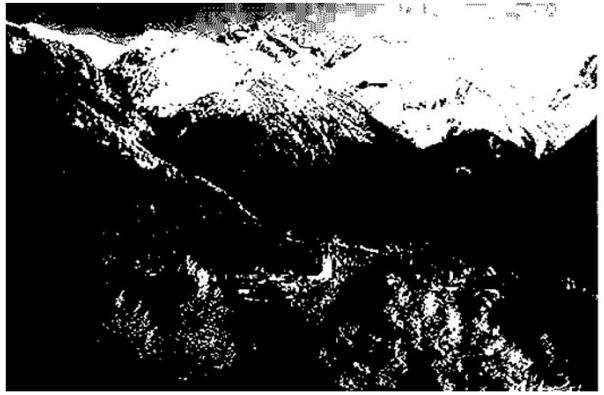
Image Editing - Dot Operators

Point operations: Biniarisation through thresholding

$g'(x, y) = 0$ if $g(x, y) < g_S$

$g'(x, y) = 1$ or 255 if $g(x, y) >= g_S$

Biniarisation with threshold gS= 127



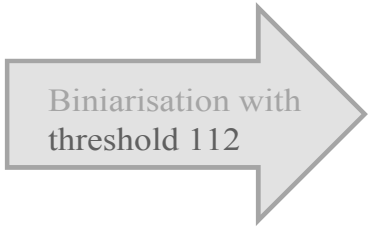
Biniarisation with threshold gS= 180

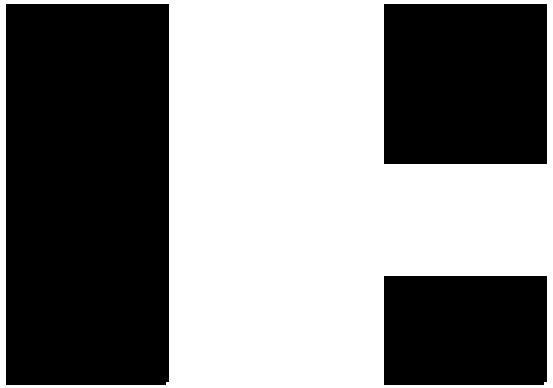
Image Editing - Dot Operators

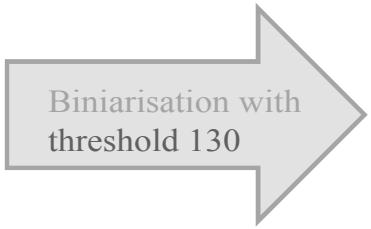
Point operations: Biniarisation through thresholding

$g'(x, y) = 0$ if $g(x, y) < g_s$

$g'(x, y) = 1$ or 255 if $g(x, y) >= g_s$







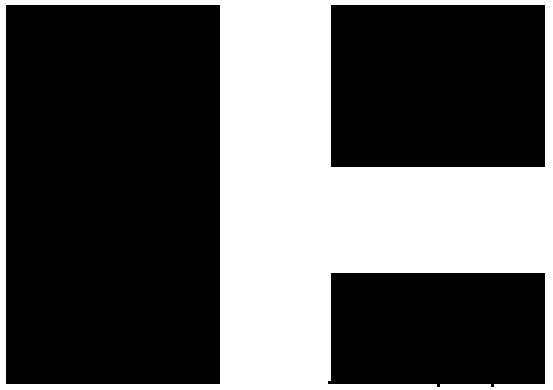


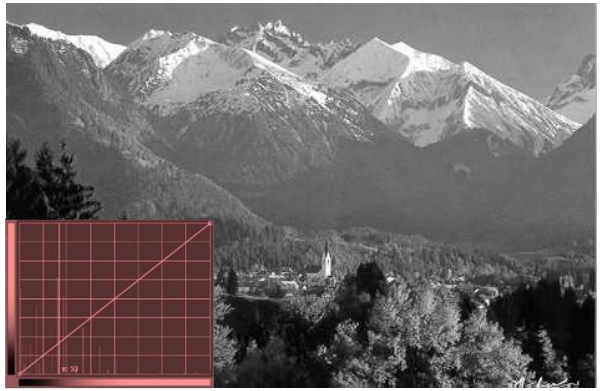
Image Editing - Dot Operators

Histograms Point operations

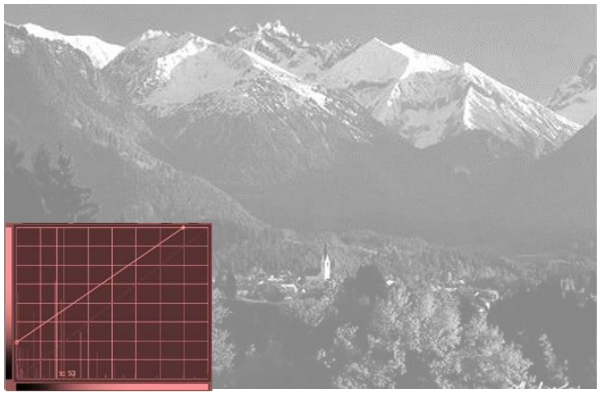
- Linear change of the grey values:
  - Changing the picture brightness
  - Invert the image
  - Changing the contrast
  - Biniarisation through thresholding
- Non-linear change in grey values:
  - Gamma correction
- Colour Transformations (Color Transformation)

Image Editing - Dot Operators

Point operations: Non-linear change of grey values



Linear change of the grey values



Non-linear change of the grey values

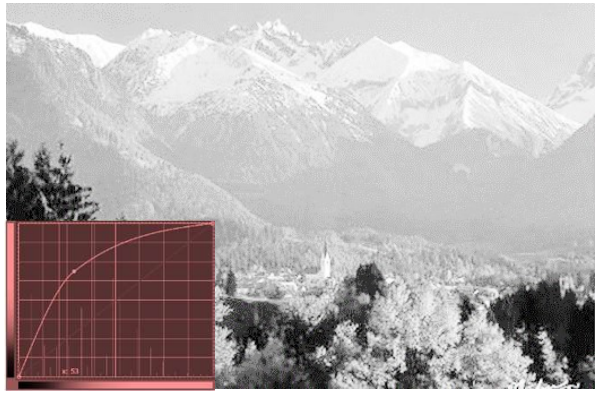
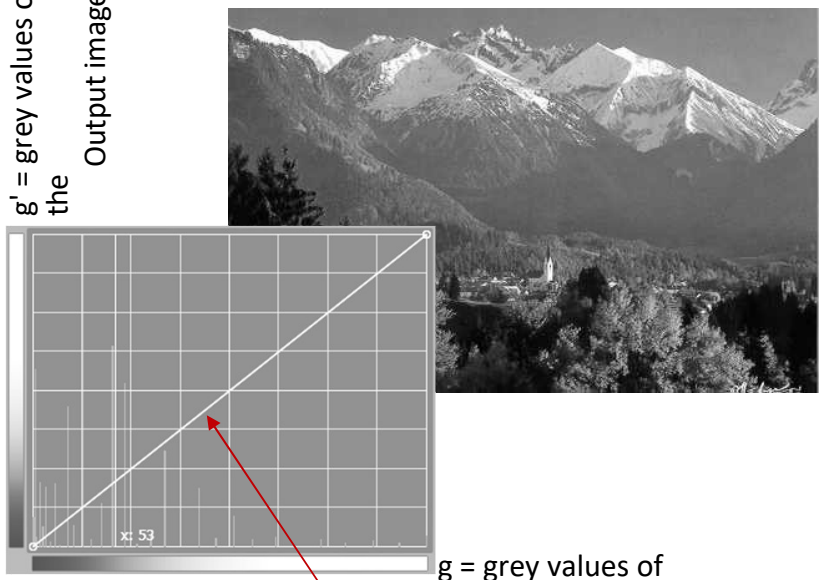
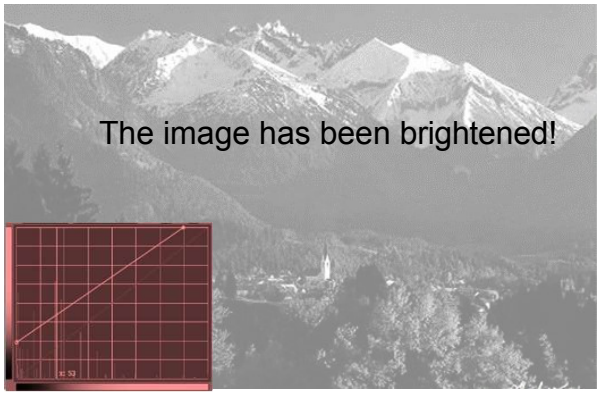


Image Editing - Dot Operators

Point operations: Non-linear change of grey values



Linear change of the grey values



Non-linear change of the grey values

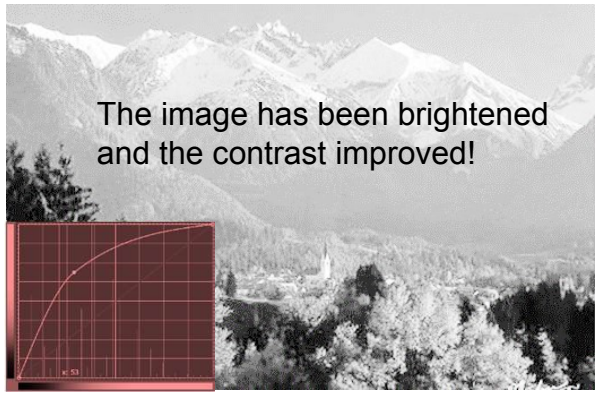


Image Editing - Dot Operators

Histograms

Point operations shown in the gg' diagram

- Linear change of the grey values:
  - Changing the picture brightness
  - Invert the image
  - Changing the contrast
  - Biniarisation through thresholding
- Non-linear change in grey values:
  - Gamma correction
- Colour Transformations (Color Transformation)

Image Editing - Dot Operators

Note: The image becomes brighter when the ab-
The angle bisector is the bisector of the angle

Point operations: Changing the image brightness

Lighten the image by adding a value > 0

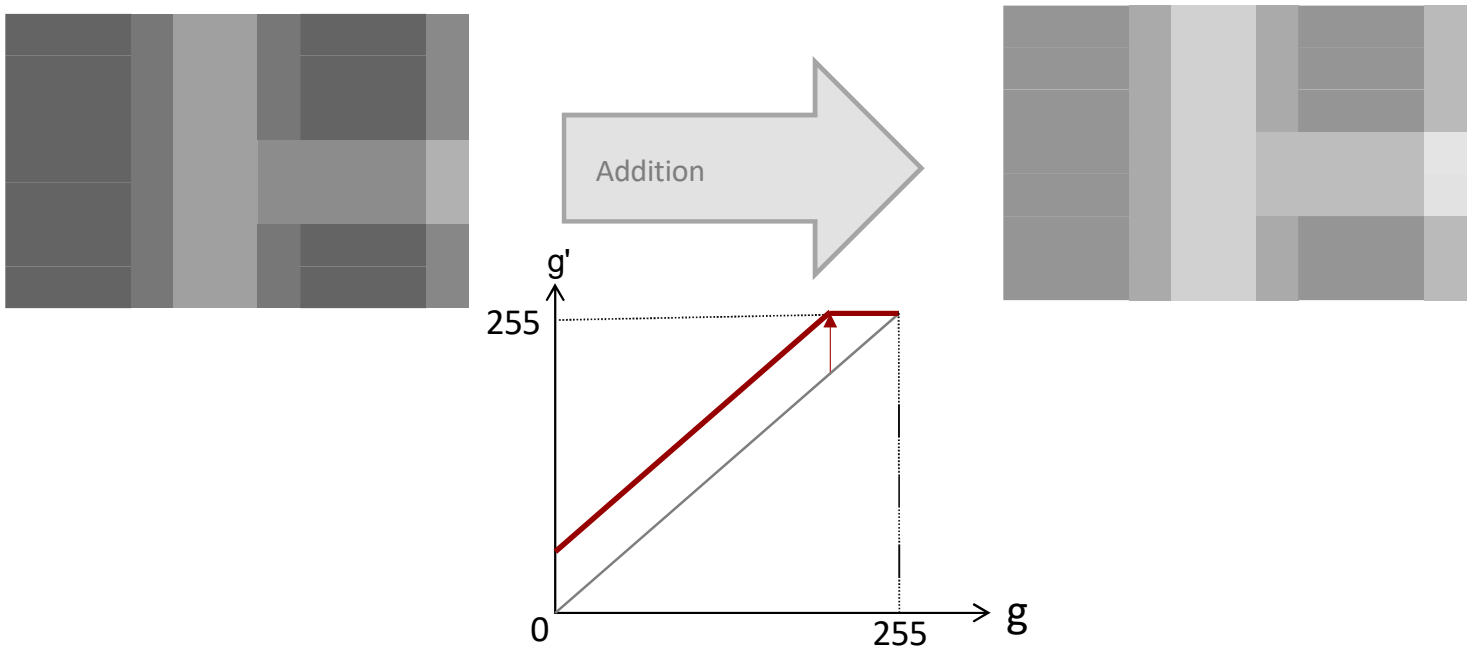


Image Editing - Dot Operators

Note: The picture becomes darker when the mapping function runs below the angle bisector.

Point operations: Changing the image brightness

Darkening the image by subtracting a value > 0

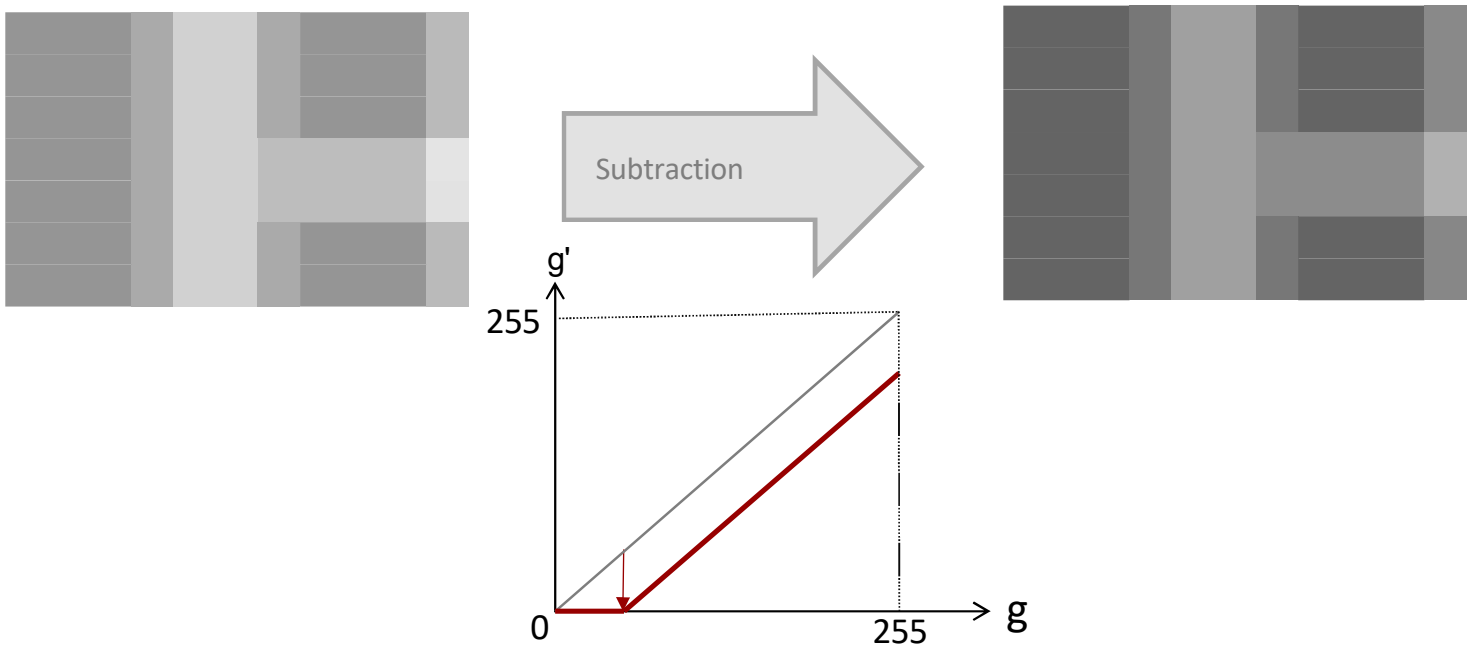
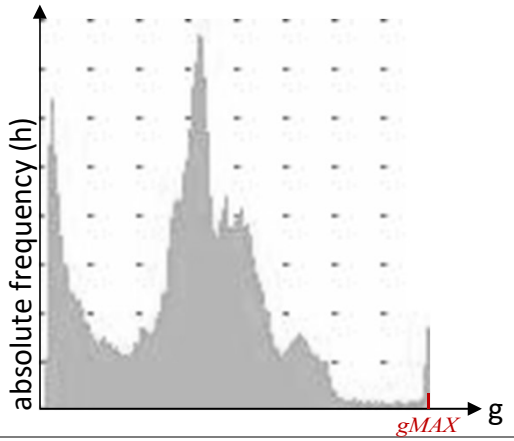


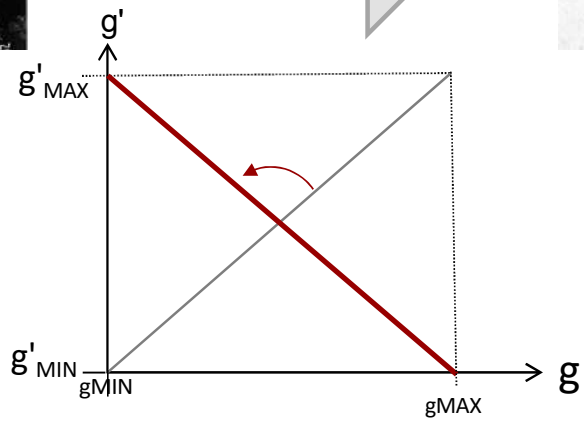
Image Editing - Dot Operators

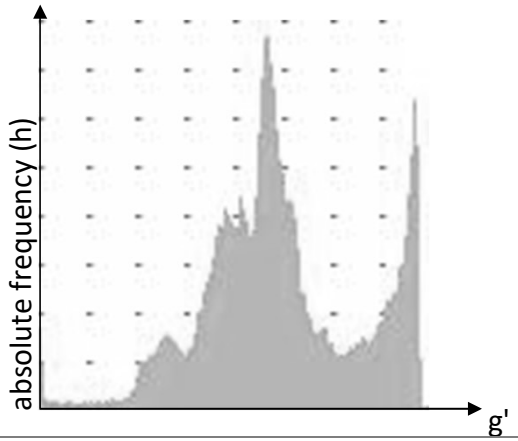
Note: The image is inverted when the slope of the mapping function is negative.

Point operations: Invert the image

Inversion







In this case: $g_{MAX} = g'_{MAX}$

$g_{MIN} = g'_{MIN}$

Image Editing - Dot Operators

Note: The image becomes less contrasty, the smaller the slope of the mapping function is.

Point operations: Changing the contrast

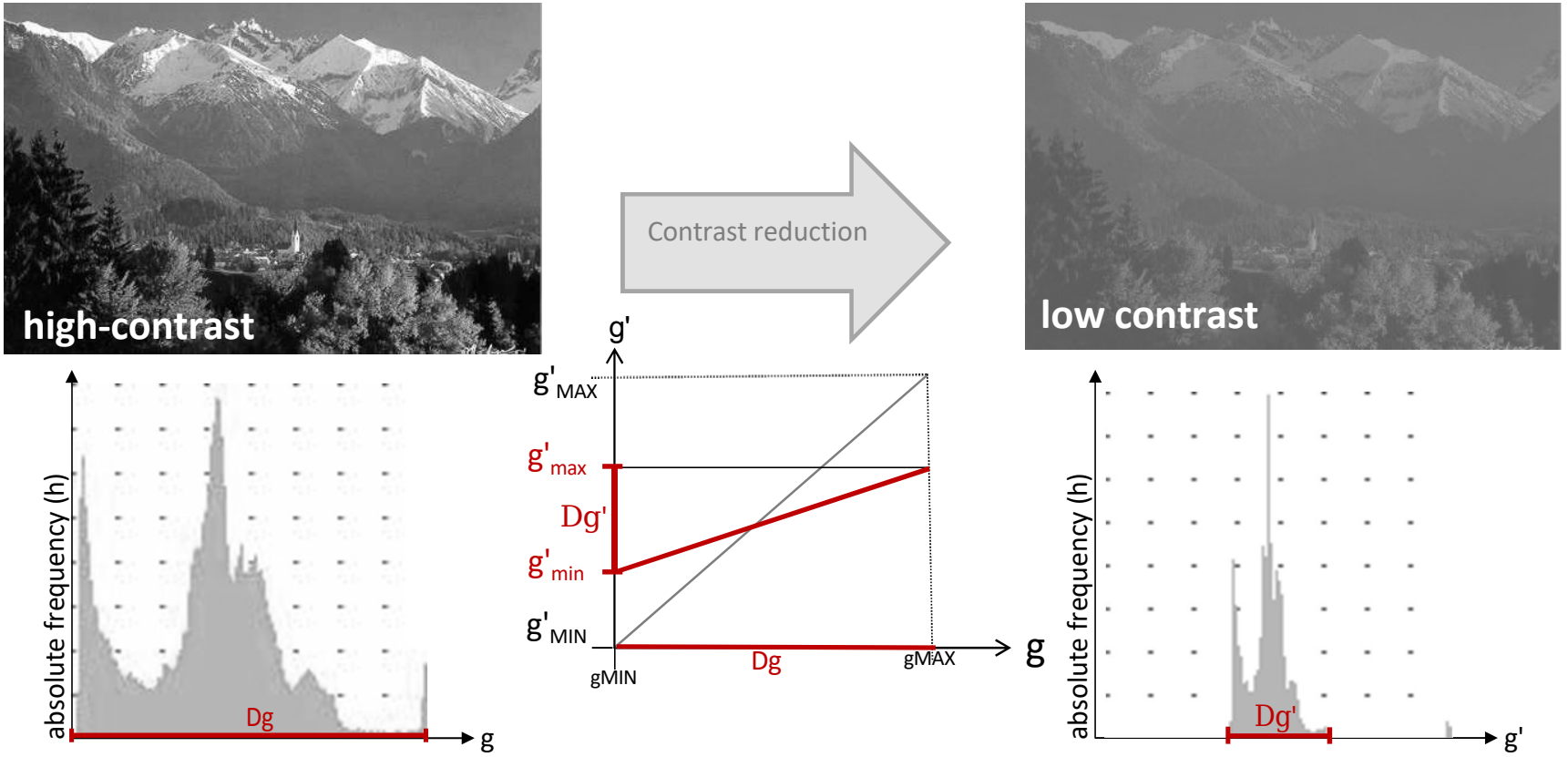
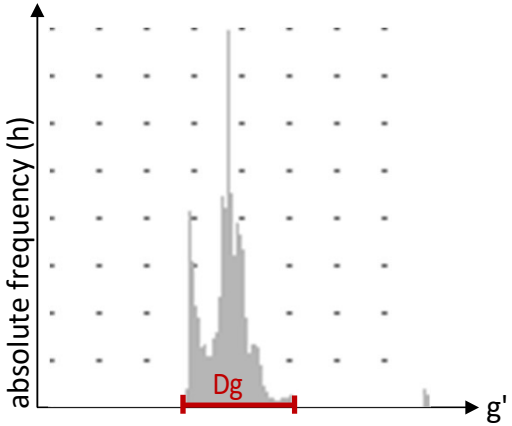


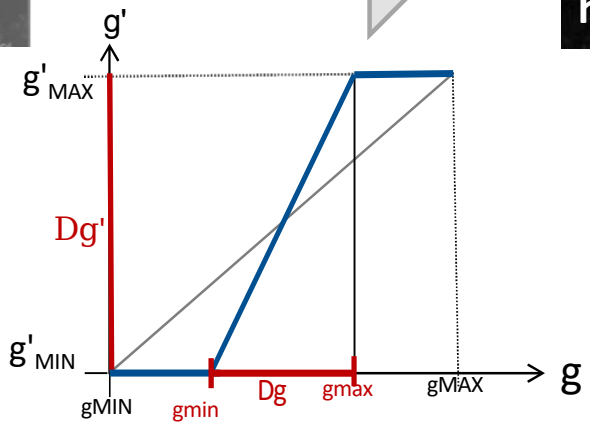
Image Editing - Dot Operators

Note: The image becomes richer in contrast, when the slope of the mapping function > 1.

Point operations: Changing the contrast

Improving the contrast





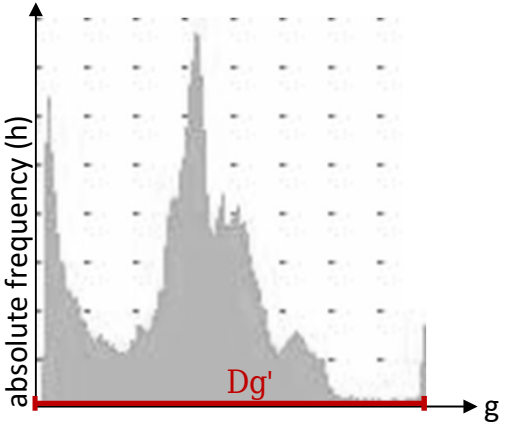
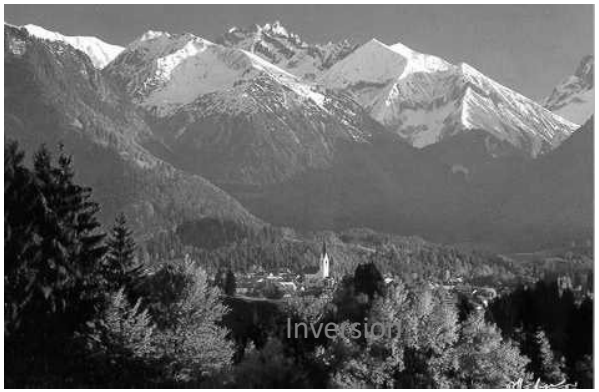


Image Editing - Dot Operators

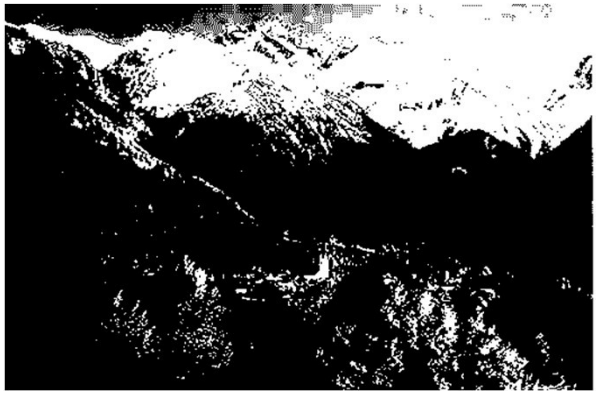
Note: Biniarisation can be used to split an image into the foreground (white by default) and the background (black).

Point operations: Biniarisation through thresholding



Biniarisation with threshold gS= 127

Biniarisierung mit Schwellwert $g_S = 180$



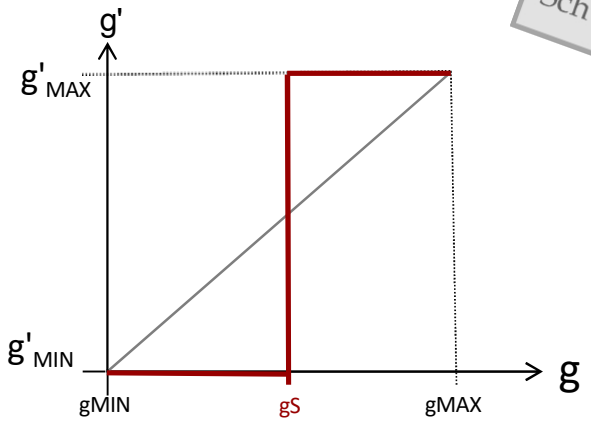
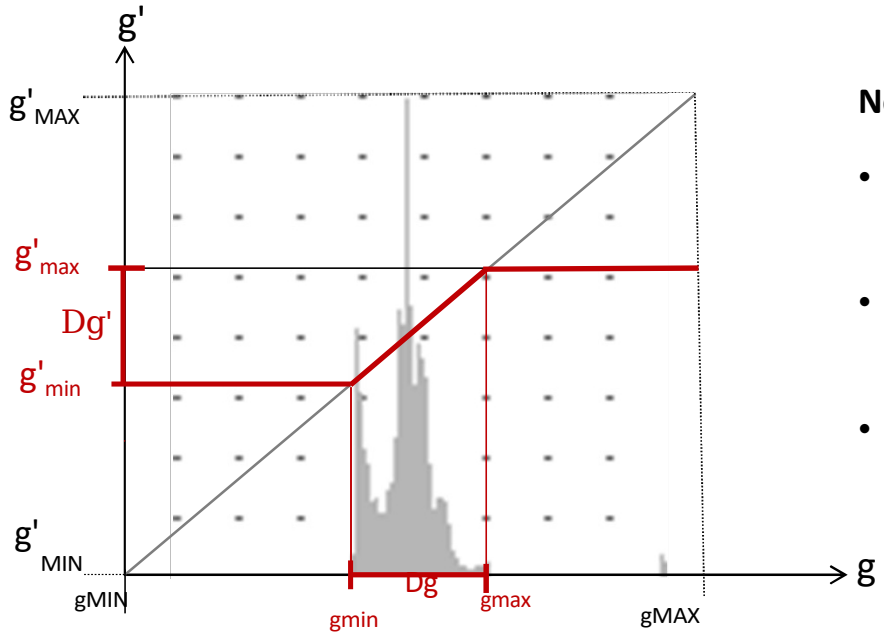


Image Editing - Dot Operators

gg' diagram: An effective form of representation for the point operators is the gg' diagram, which maps the grey values of the input image to the grey values of the output image.
Often the gg'-graph is linked to the histogram of the input image.



Notice:

- g_{min} and g_{max} are the minimum and maximum grey values present in the input image.
- g_{MIN} and g_{MAX} are the minimum and maximum grey values available to display the input image.
- g'_{min} and g'_{max} as well as g'_{MIN} and g'_{MAX} characterise the output image equivalently .

Image Editing - Dot Operators

An example from practice:

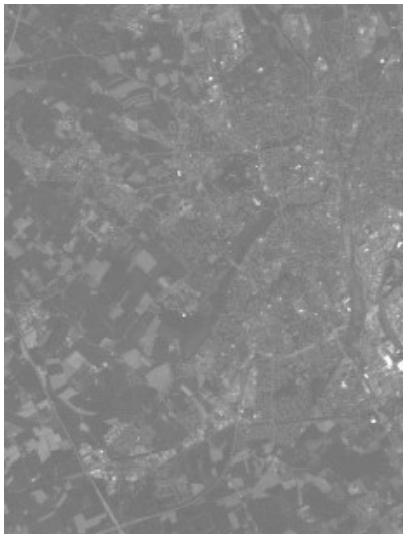
First the motivation: What can you do with satellite images?

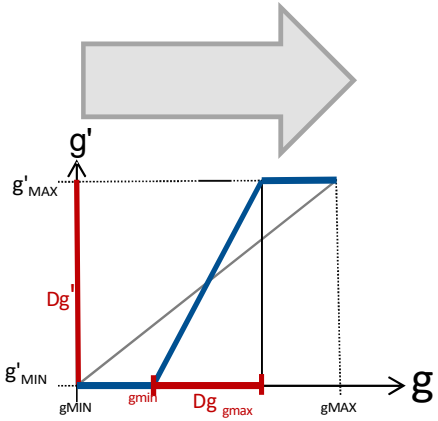
Link:
https://www.youtube.com/watch?v=IrZ-vWzv0as

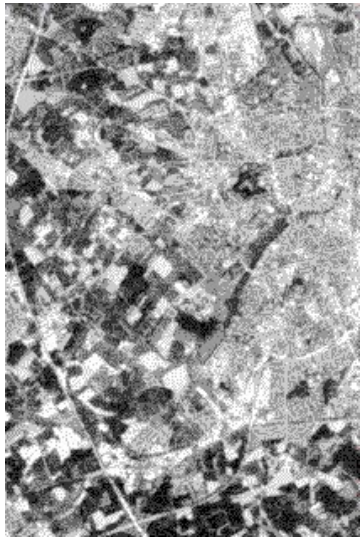
Image Editing - Dot Operators

An example from practice:

A first step is often to prepare the images in such a way that the maximum available colour space is used, if possible without distorting the image data. The data is distorted when image information (grey values) is added or deleted.





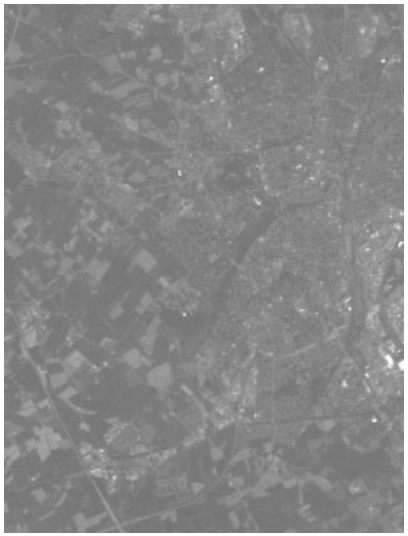


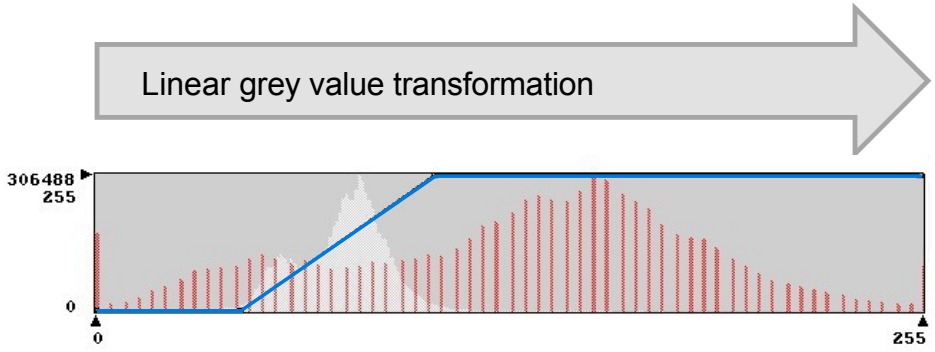
Images from: http://ivvgeo.uni-muenster.de/Vorlesung/FE_Script/kapitel3/main3-2.html (page no longer exists)

Image Editing - Dot Operators

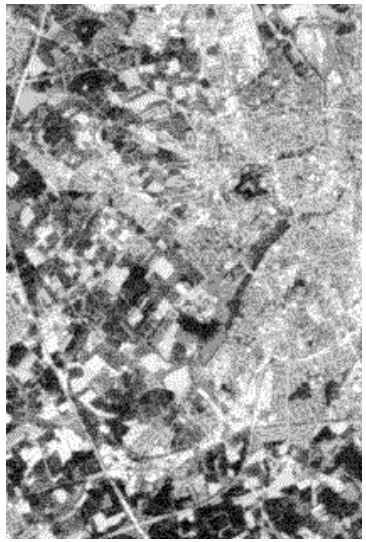
An example from practice:

A first step is often to prepare the images in such a way that the maximum available colour space is used, if possible without distorting the image data. The data is distorted when image information (grey values) is added or deleted.





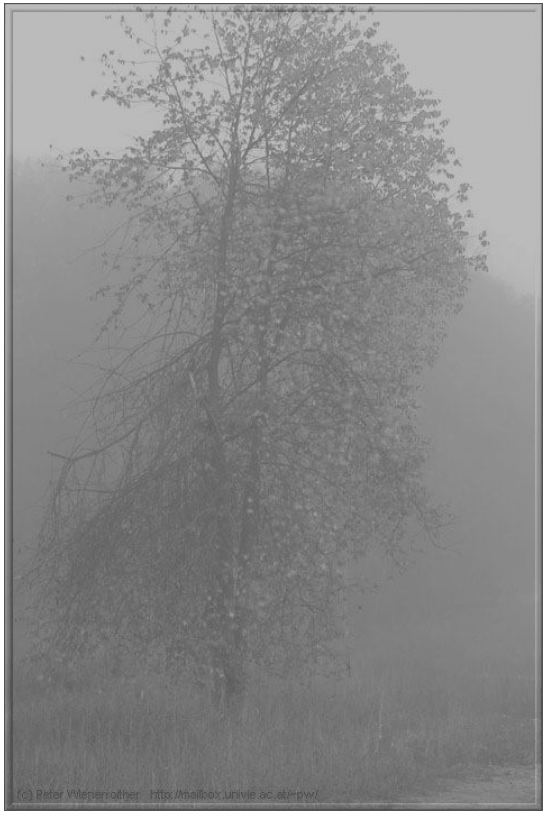
Histogram image left=light grey, image right=red; linear transformation=blue.

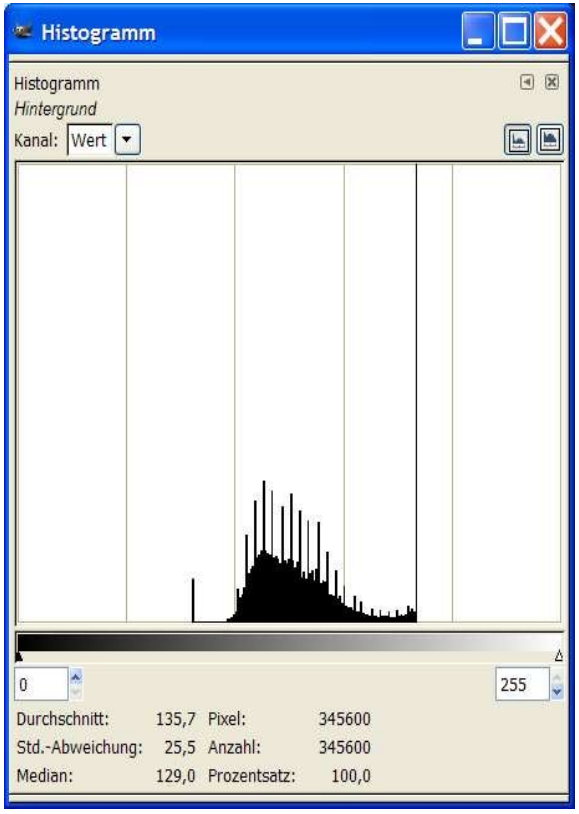


Images from: http://ivvgeo.uni-muenster.de/Vorlesung/FE_Script/kapitel3/main3-2.html (page no longer exists)

Image Editing - Dot Operators

Another example:



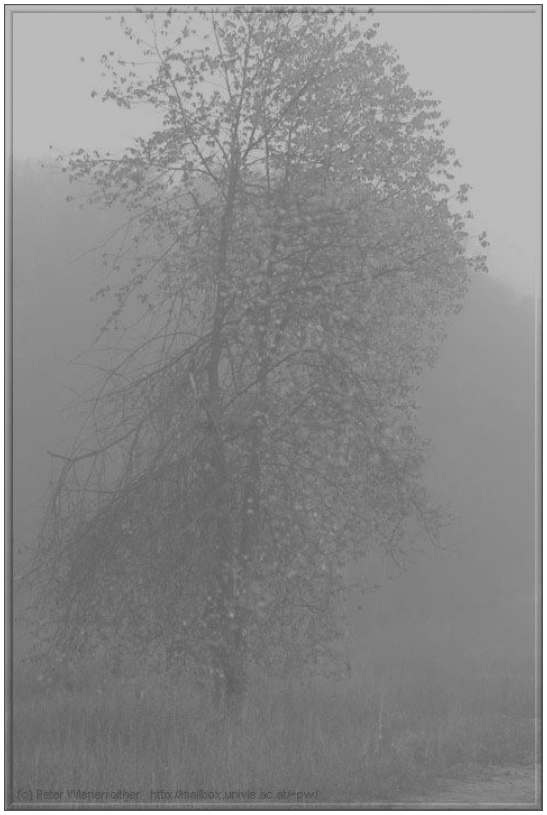


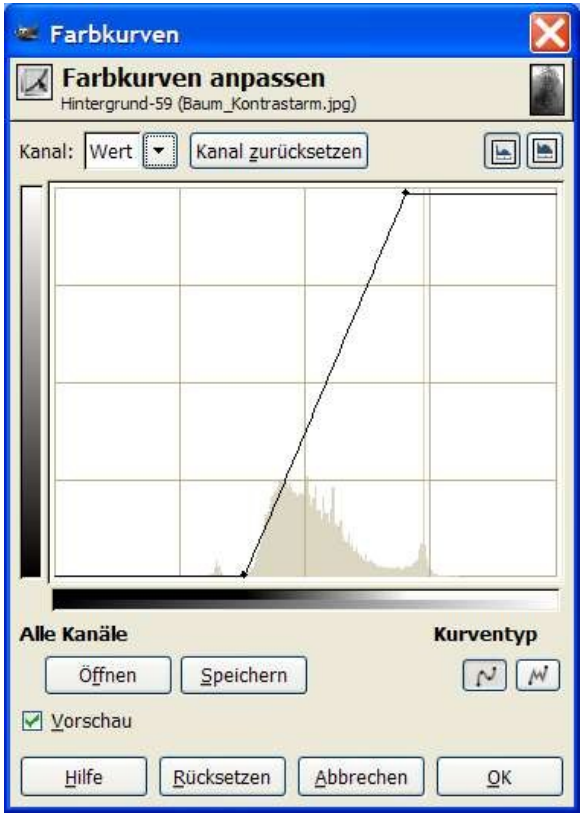
Initial situation:

A low-contrast image whose grey values are all in the middle range.

Image Editing - Dot Operators

Another example:





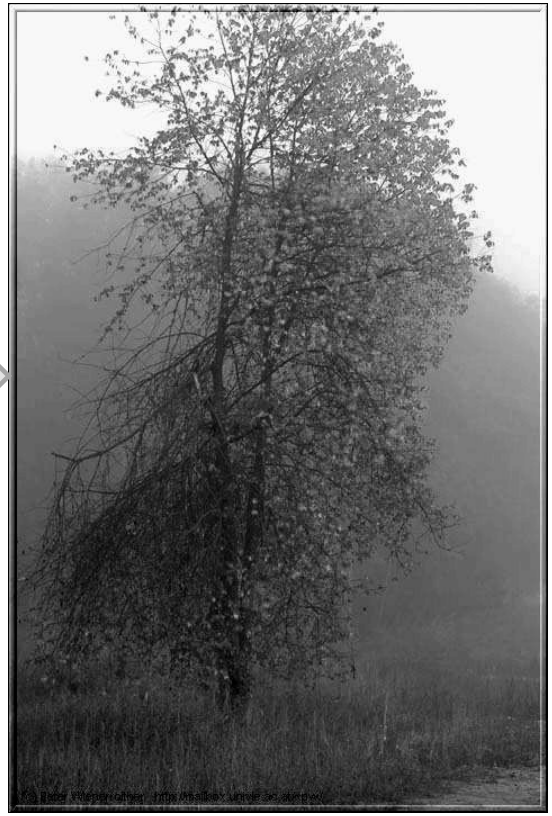
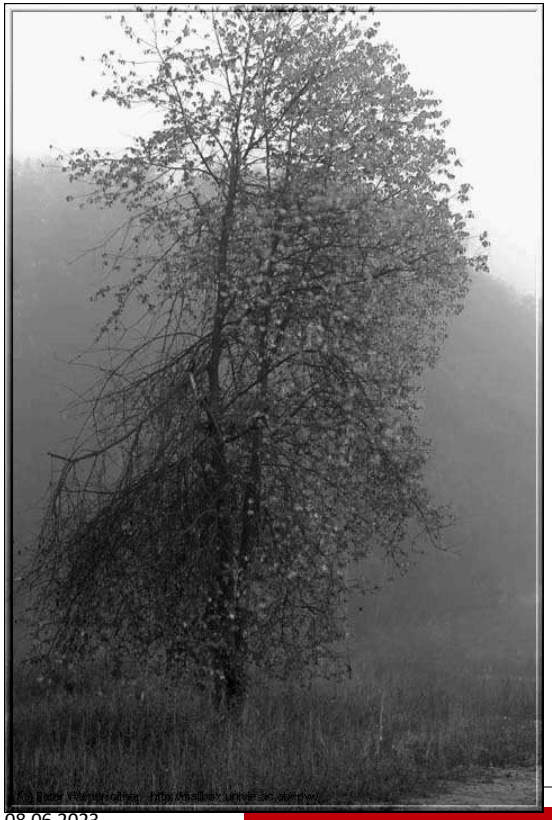
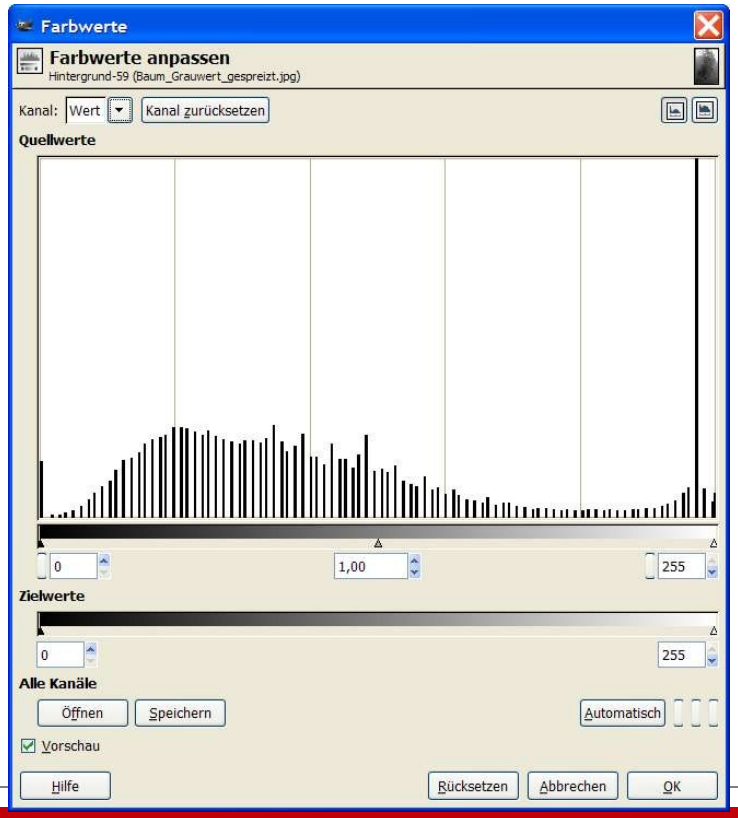


Image Editing - Dot Operators

Another example:





Conclusion:

- The grey values of the low-contrast image were evenly distributed over the available grey value interval.
- Each pixel of the input image was assigned a new grey value g' by the linear grey value transformation, based on the grey value g.
- **Thus, the image information does not seem to have been distorted.**
- **We can only check whether this is really the case if we know how the calculation of the linear grey value transformation is carried out.**

Image Editing - Dot Operators

Calculation of the linear grey value transformation for contrast spreading:

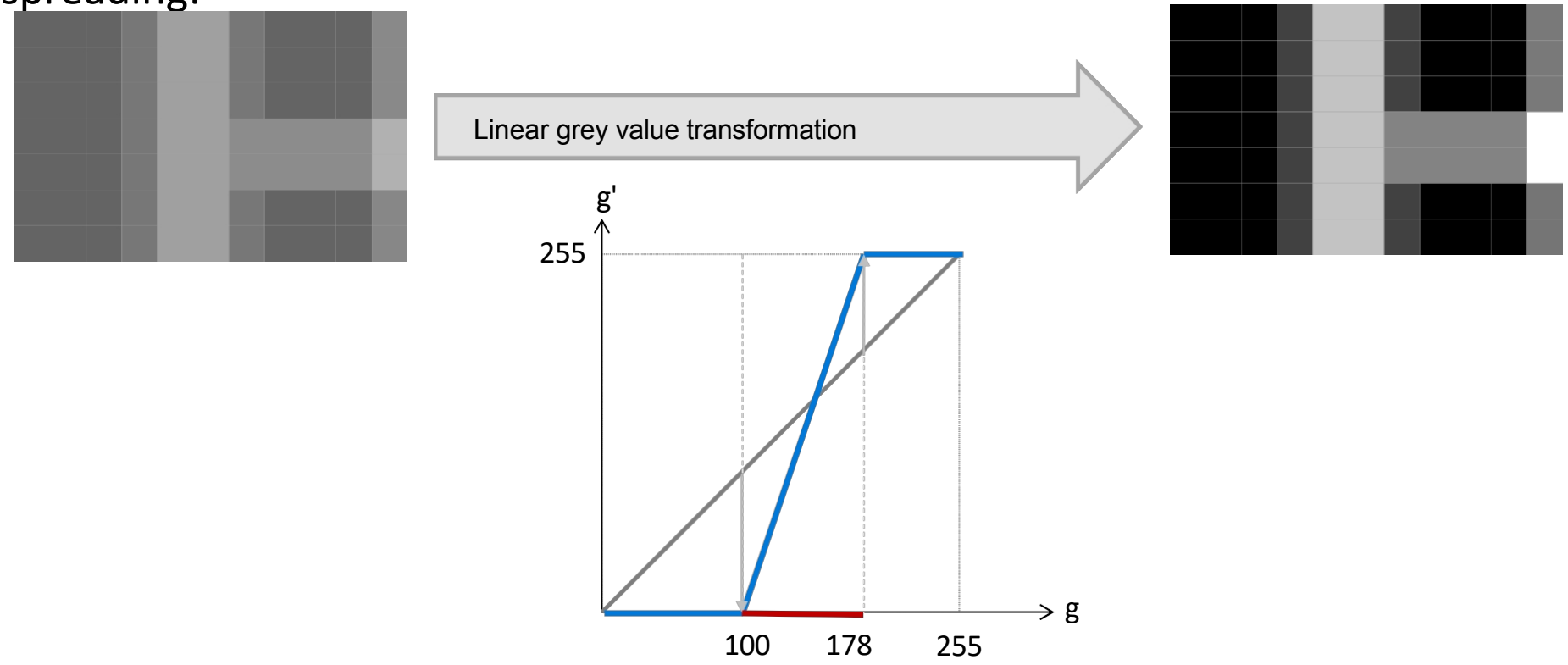
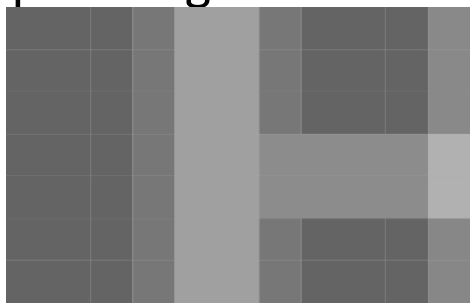
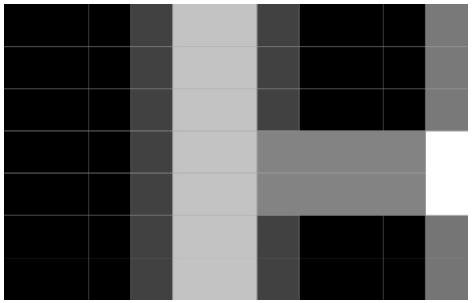


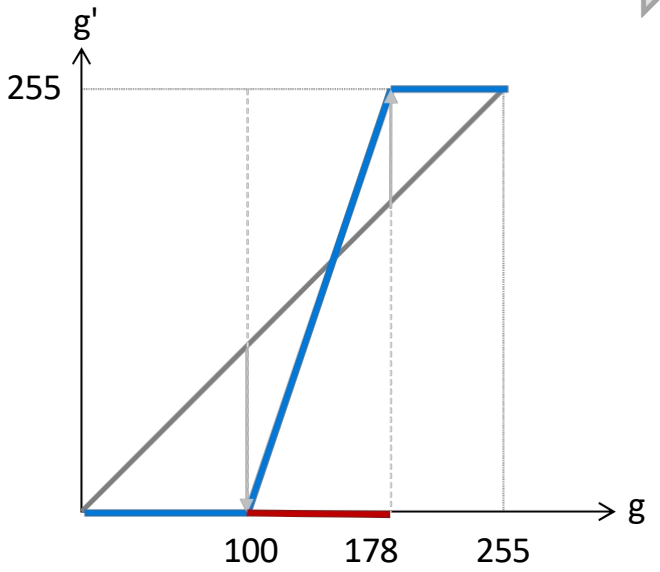
Image Editing - Dot Operators

Calculation of the linear grey value transformation for contrast spreading:



Linear grey value transformation





The linear grey value transformation is described by a straight line equation: $g' = f(g) = m \cdot g + b$

Step 1:
The slope m is calculated: g' = $m \cdot g$

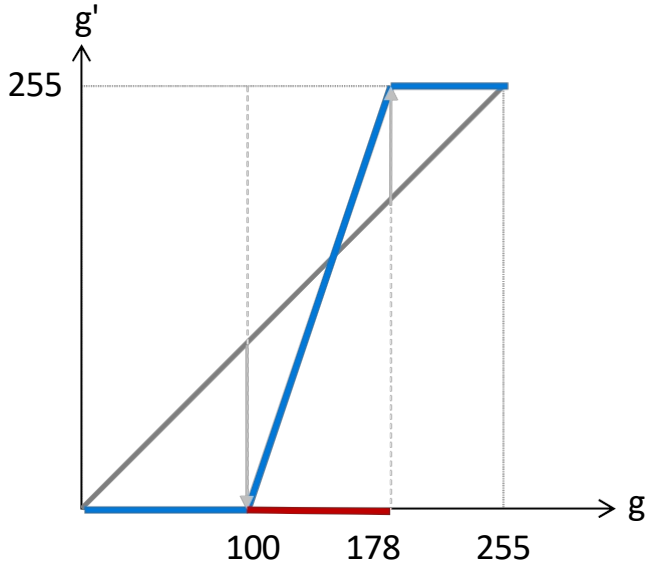
Generally speaking:

$$g_m'(i,j) = g(i,j) \cdot \frac{g'_{MAX} - g'_{MIN}}{g_{max} - g_{min}}$$

In the example: $g'_{MAX=255}$, $g'_{MIN=0}$, $g_{max=178}$, gmin=100

Image Editing - Dot Operators

Calculation of the linear grey value transformation for contrast spreading:



Step 1:
The slope m is calculated: g' = $m \cdot g$

Generally speaking:

$$g_m'(i,j) = g(i,j) \cdot \frac{g'_{MAX} - g'_{MIN}}{g_{max} - g_{min}}$$

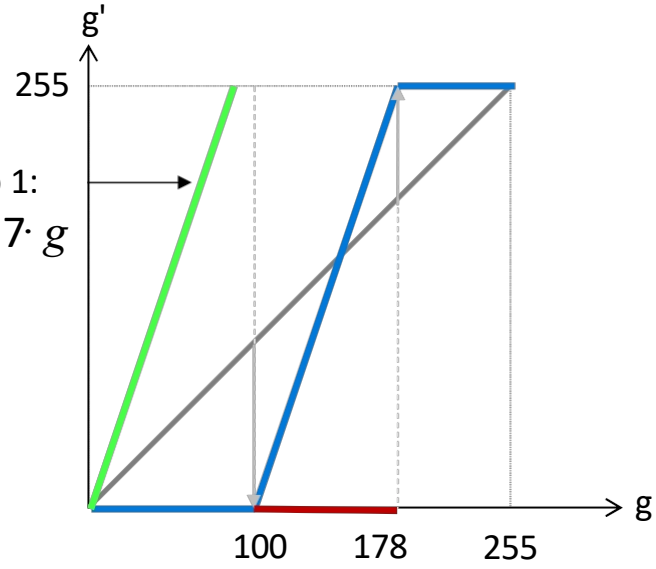
In the example: $g'_{MAX=255}$, $g'_{MIN=0}$, $g_{max=178}$, gmin=100

Image Editing - Dot Operators

Calculation of the linear grey value transformation ...
:

Linear grey value transformation after step 1:

$$g' = 3.27 \cdot g$$



1. Step:
The slope m is calculated: g' = $m \cdot g$

Generally speaking:

$$g_m'(i,j) = g(i,j) \cdot \frac{g'_{MAX} - g'_{MIN}}{g_{max} - g_{min}}$$

In the example: $g'_{MAX=255}$, $g'_{MIN=0}$, $g_{max=178}$, gmin=100

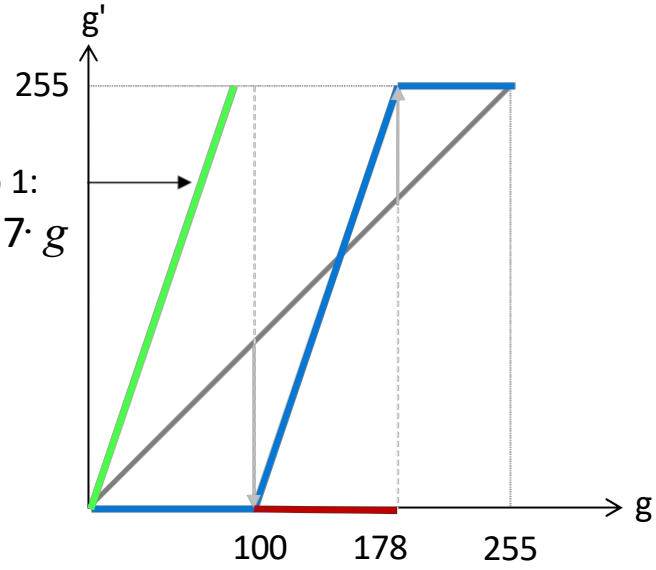
The slope m *of* the linear grey value transformation g' = $m \cdot g$ is therefore:
m = (255-0) / (178-100) = 3.27

Image Editing - Dot Operators

Calculation of the linear grey value transformation ...
:

Linear grey value transformation after step 1:

$$g' = 3.27 \cdot g$$



1. Step:
The slope m is calculated: g' = $m \cdot g$

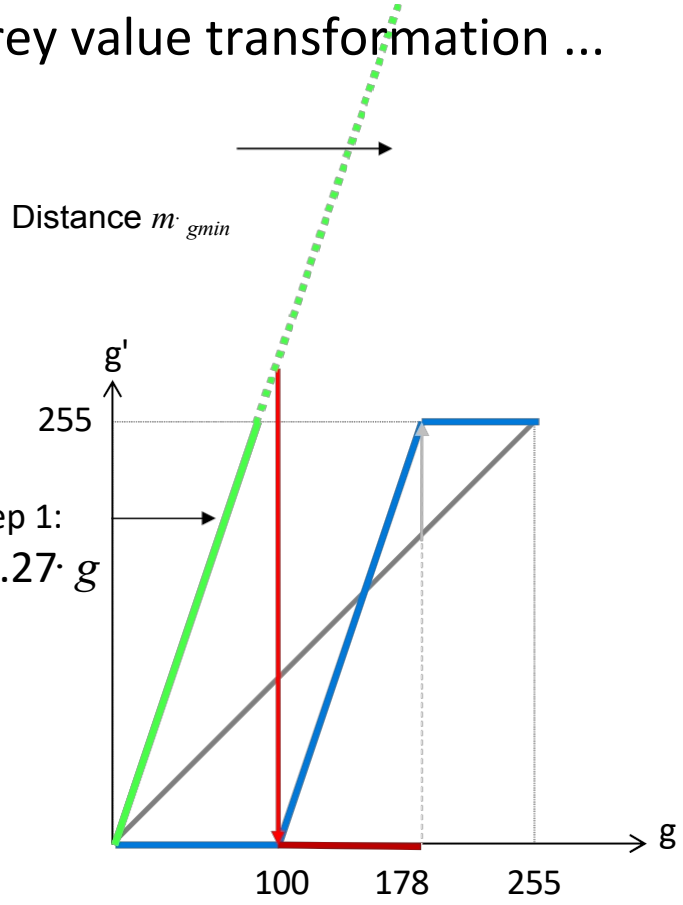
Generally speaking:

$$g_m'(i,j) = g(i,j) \cdot \frac{g'_{MAX} - g'_{MIN}}{g_{max} - g_{min}}$$

2. Step:
Y-axis intersection point b is calculated:

Image Editing - Dot Operators

Calculation of the linear grey value transformation ... :



Linear grey value transformation after step 1:

$$g' = 3.27 \cdot g$$

1. Step:
The slope m is calculated: g' = $m \cdot g$

Generally speaking:

$$g'_m(i,j) = g(i,j) \cdot \frac{g'_{MAX} - g'_{MIN}}{g_{max} - g_{min}}$$

2. Step:
Y-axis intersection point b is calculated:

Conclusion: The Y-axis intersection point b *is* calculated by subtracting the distance $m \cdot g_{min}$ from the straight line $g' = m \cdot g$.

$$b = -g_{min} \cdot \frac{g'_{MAX} - g'_{MIN}}{g_{max} - g_{min}}$$

In our case: $g' = m \cdot g - (100 \cdot m)$

Image Editing - Dot Operators

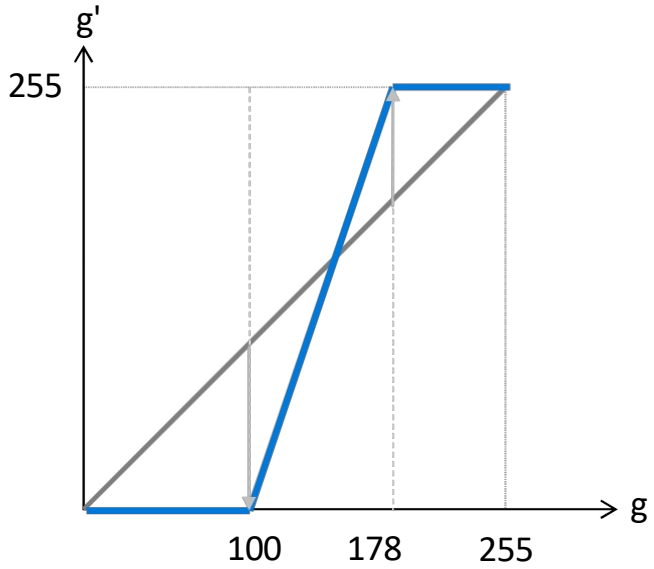
Calculation of the linear grey value transformation for contrast spreading :

General wording:

Slope

Y-axis intersection

$$g'(i,j) = g(i,j) \left[\frac{g'_{MAX} - g'_{MIN}}{gmax - gmin} \right] + \left[g'_{MIN} - gmin \left[\frac{g'_{MAX} - g'_{MIN}}{gmax - gmin} \right] \right]$$



associated linear grey value transformation:

$g' = 3.27 \cdot g$ - (327)

with $g' = 0$ for $g < 100$ and $g' = 255$ for $g > 178$

Image Editing - Dot Operators

Calculation of the linear grey value transformation for contrast spreading :

General wording:

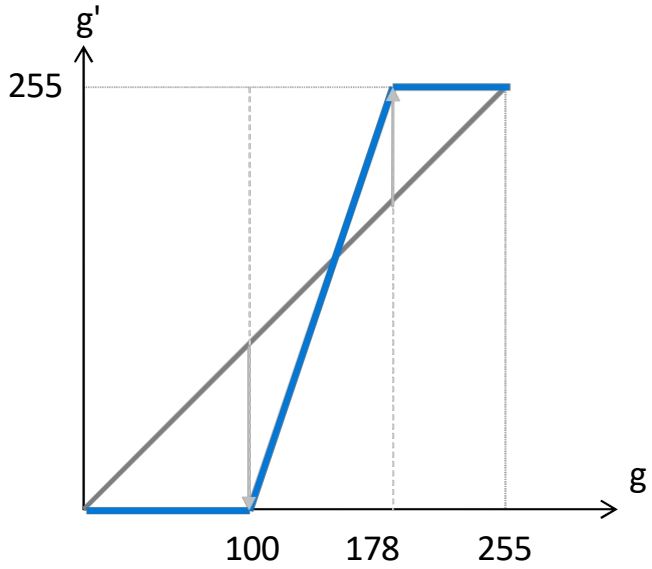
$$g'(i,j) = g(i,j) \cdot \underbrace{\frac{g'_{MAX} - g'_{MIN}}{gmax - gmin}}_{mult} + \underbrace{\left[g'_{MIN} - gmin \cdot \frac{g'_{MAX} - g'_{MIN}}{gmax - gmin} \right]}_{add}$$

$$g'(i,j,) = g(i,j) \cdot mult + add$$

mit

$$mult = \frac{g'_{MAX} - g'_{MIN}}{gmax - gmin}$$

$$add = g'_{MIN} - gmin \cdot mult$$



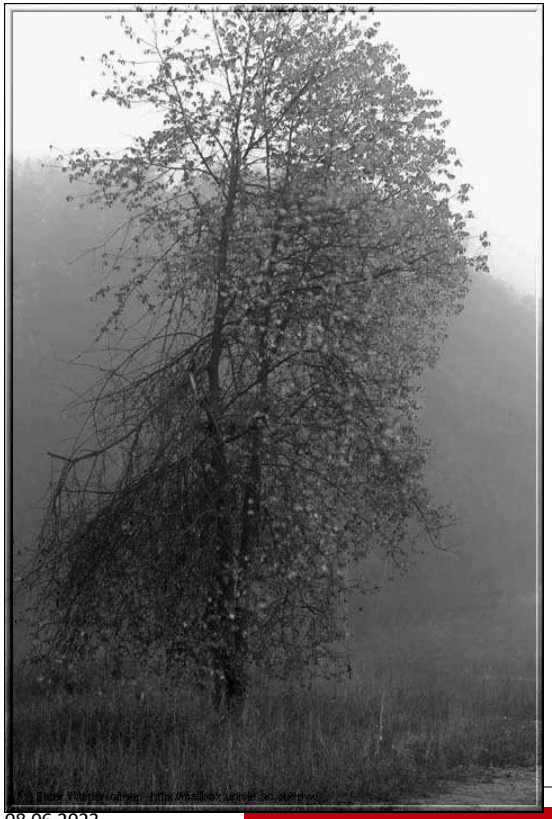
associated linear grey value transformation:

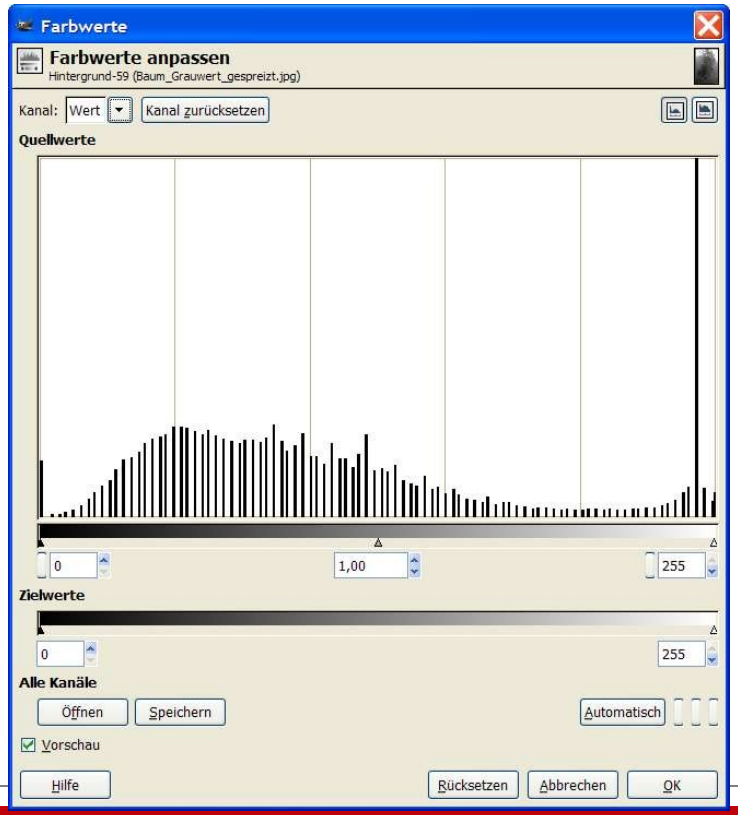
$g' = 3.27 \cdot g - (327)$

with $g' = 0$ for $g < 100$ and $g' = 255$ for $g > 178$

Image Editing - Dot Operators

One question is still open: Does the linear grey value transformation distort image information?



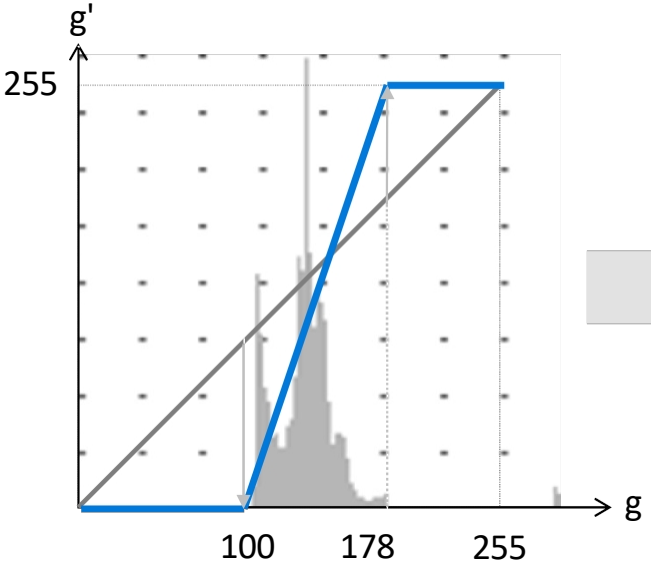


Conclusion:

- The grey values of the low-contrast image were evenly distributed over the available grey value interval.
- Each pixel of the input image was assigned a new grey value g' by the linear grey value transformation based on the grey value g.
- Thus, the image information does not seem to have been distorted.
- We can only check whether this is really the case if we know how the calculation of the linear grey value transformation is carried out.

Image Editing - Dot Operators

Is image information distorted by the linear grey value transformation?



g	g'	Displayable grey value
100	0	0
101	3,27	3
102	6,54	6
...	...	...
139	127,53	128
...	...	...
176	248,52	249
177	251,79	252
178	255,06	255

Linear grey value transformation:
$g' = 3.27 \cdot g - (327)$

with $g' = 0$ for $g < 100$ and
$g' = 255$ for $g > 178$

Calculate the linear grey value transformation for the grey values of the input image that lie between g_{min} and g_{max}.

Objective: check whether two grey values are mapped onto one grey value

- If two grey values are mapped onto one grey value, image information is lost that can no longer be reconstructed.
- with our contrast spreading, image distortion can be excluded, as no two grey values are mapped onto one grey value
- This is not generally valid proof, but it is a strong indication that contrast enhancement does not distort image content and can therefore also be used for sensitive data (medical images, satellite images).

Image Editing - Dot Operators

Histograms Point operations

- Linear change of the grey values:
  - Changing the picture brightness
  - Invert the image
  - Changing the contrast
  - Biniarisation through thresholding
- Non-linear change in grey values:
  - Gamma correction
- Colour Transformations (Color Transformation)

Image Editing - Dot Operators

Non-linear change of grey values: Gamma correction

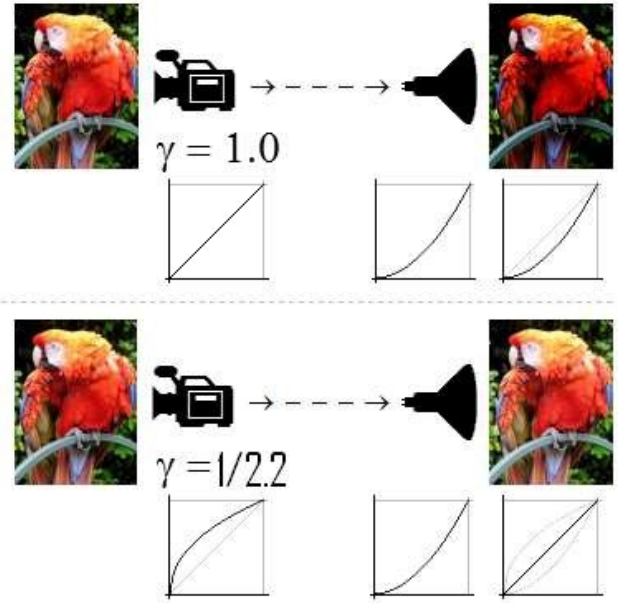
Assumptions so far:

- When taking pictures and videos, the grey values change linearly with our perception.
- When representing the grey value on displays, the screen pixels change linearly to our perception

It is not so.

Gamma correction is used to correct the non-linear behaviour when taking and reproducing pictures.

Image from: Gamma correction - Wikipedia



Above: linear image sensor without gamma correction (g=1) captures a high-contrast but unnatural image

below: Image sensor with gamma correction captures a faithfully perceptible image

Image Editing - Dot Operators

Non-linear change of grey values: Gamma correction

Exemplary representation of the course of the gamma function

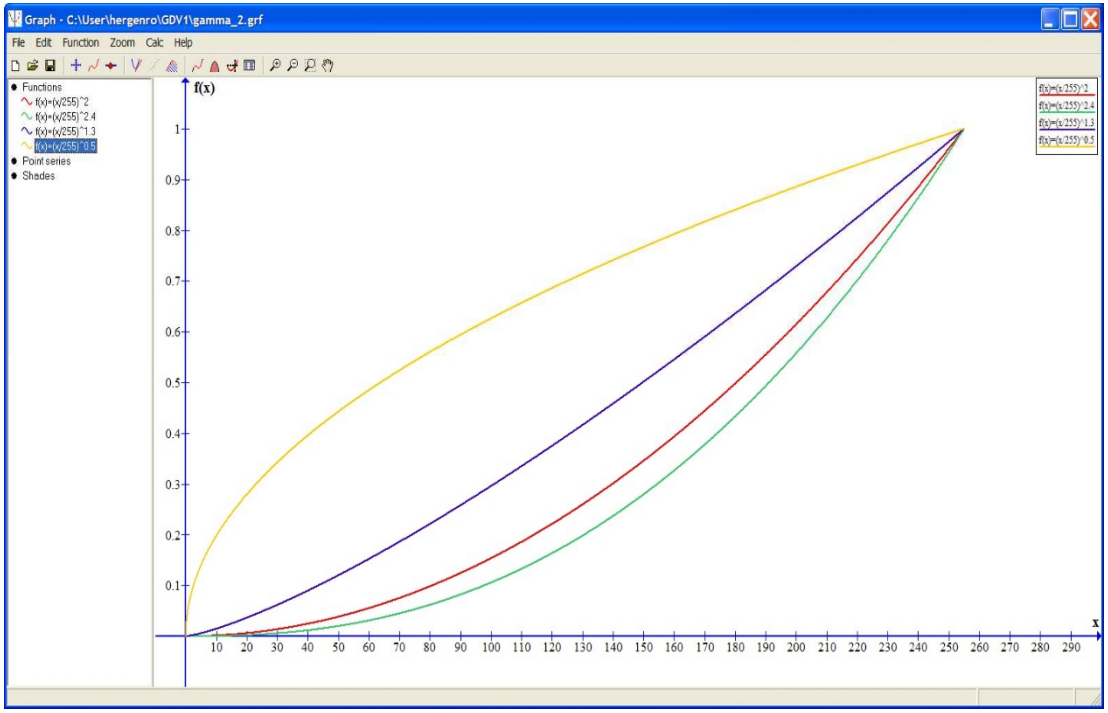
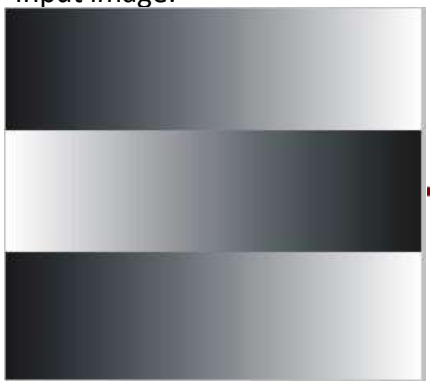


Image Editing - Dot Operators

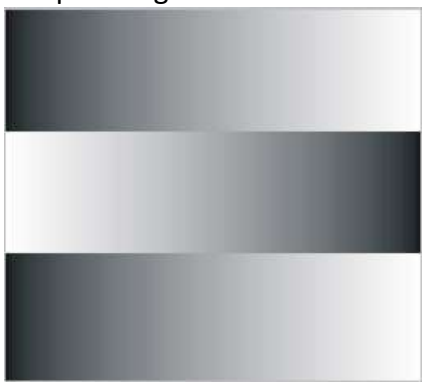
Non-linear change of grey values: Gamma correction

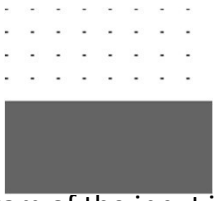
Non-linear brightening of the image content

Input image:

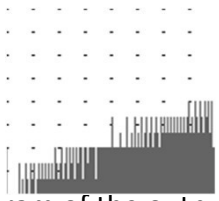


Output image:





Histogram of the input image



Histogram of the output image

Gamma function that transforms the input image into the output image.

transformed:

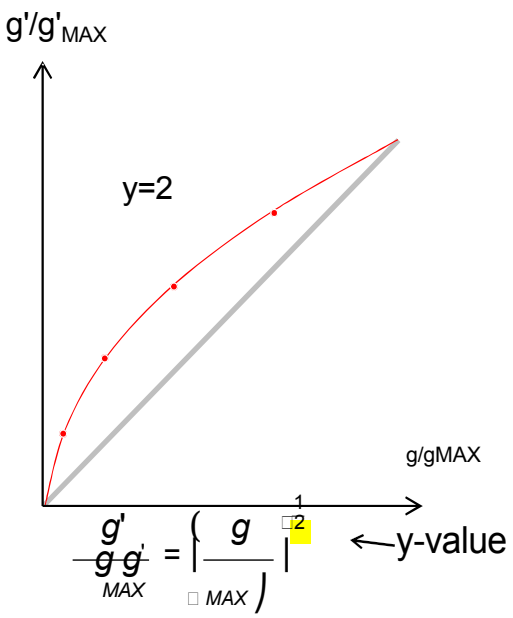
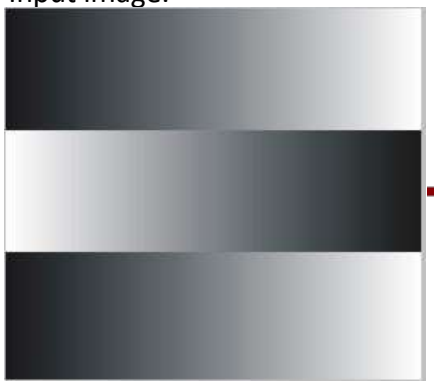


Image Editing - Dot Operators

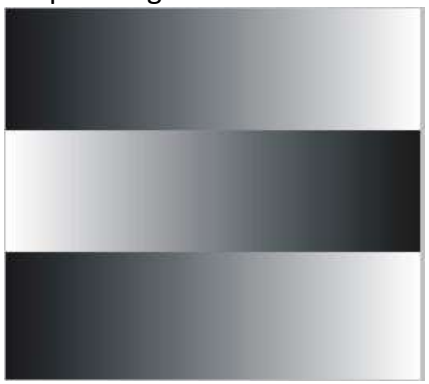
Non-linear change of grey values: Gamma correction

Non-linear darkening of the image content

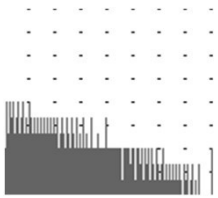
Input image:



Output image:



Histogram of the input image



Histogram of the output image

Gamma function that transforms the input image into the output image.

transformed:

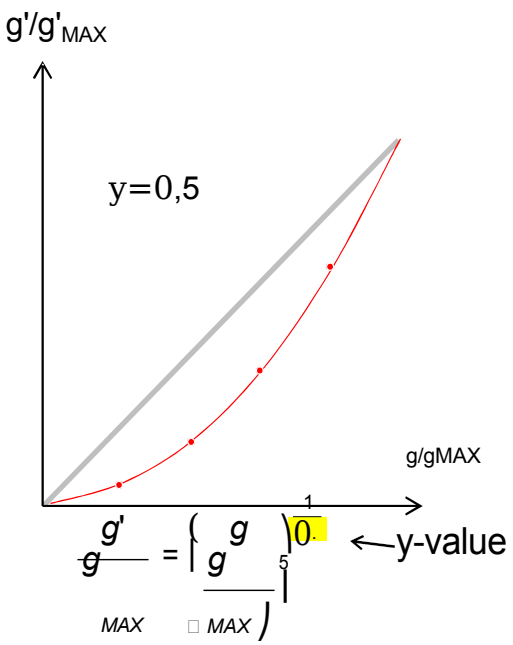


Image Editing - Dot Operators

Non-linear change of grey values: Gamma correction

Has the contrast in the bright areas been increased?
How can you tell where the contrast has been increased or reduced?

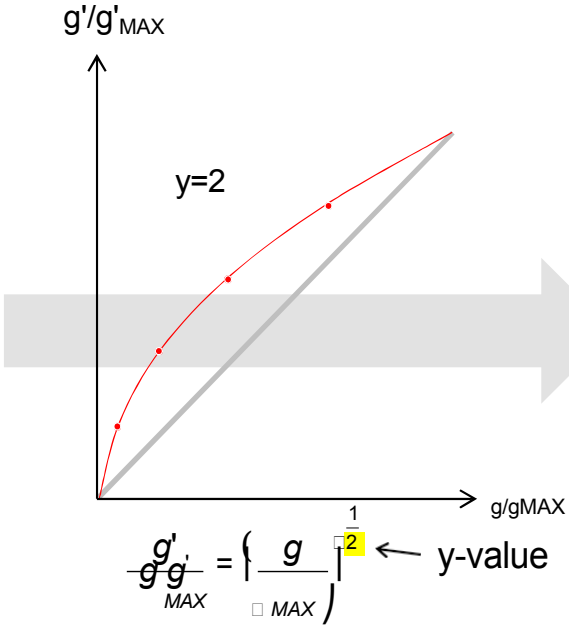
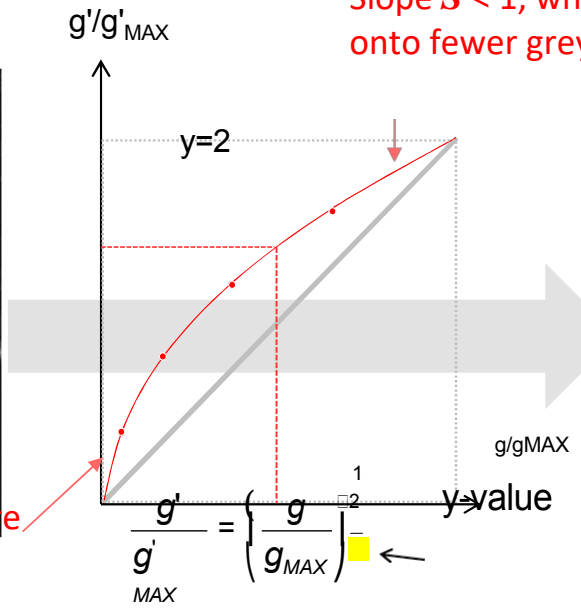


Image Editing - Dot Operators

Non-linear change of grey values: Gamma correction

Has the contrast in the bright areas been increased?
How can you tell where the contrast has been increased or reduced?

Slope S < 1, which means: half of the grey values g are mapped onto fewer grey values g', image information is lost



Slope S > 1, which means: half of the grey values g are mapped onto considerably more grey values g'.

Image Editing - Dot Operators

FIGURE 6.33 Tonal corrections for flat, light (high key), and dark (low key) color images. Adjusting the red, green, and blue components equally does not always alter the image hues significantly.

Combined gamma correction in all rgb channels the same

Gamma correction $\gamma < 1$ the same in all rgb channels

Gamma correction $\gamma > 1$ the same in all rgb channels

- Up to now, gamma correction has only been applied to greyscale images.
- In the examples on the left, the same gamma corrections were applied to all three colour channels. In the three cases shown, the corrections were successful. However, this is not always the case.
- Better transfer the images to HSV, YCbCr or a similar colour system and then correct the intensity channel.
- **Remember:** Gamma correction alters image information. For this reason, it should not be used in sensitive application areas.

Image from: Digital Image Processing, 4th Edition, R. C. Gonzalez, R. E. Woods, p. 438

Image Editing - Dot Operators

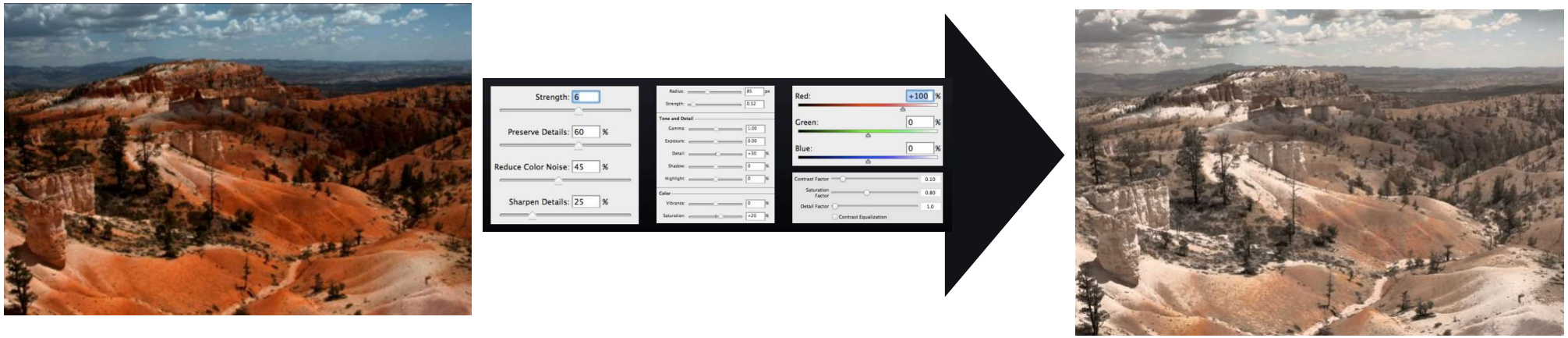
Histograms Point operations

- Linear change of the grey values:
  - Changing the picture brightness
  - Invert the image
  - Changing the contrast
  - Biniarisation through thresholding
- Non-linear change in grey values:
  - Gamma correction
- Colour Transformations (Color Transformation)

Image Editing - Dot Operators

Colour Transformations (Color Transformation)

- To perform image transformations, you have to set a lot of parameters.
- However, this only works well if you have knowledge about how the parameters work.

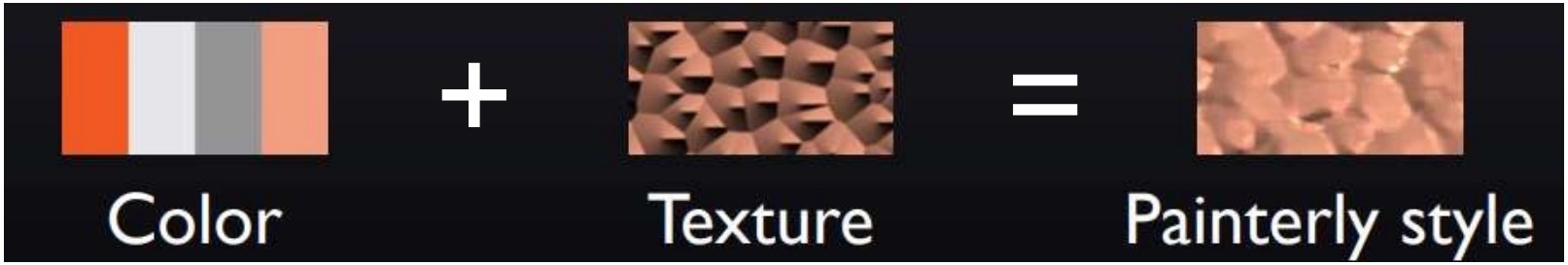


From: T. Pouli, E. Reinhard: "Example-based colour image manipulation and enhancement", SIGGRAPH 2012 Courses, Example-based colour image manipulation and enhancement | ACM SIGGRAPH 2012 Courses

Image Editing - Dot Operators

Colour Transformations (Color Transformation)

- It would be more intuitive if you could transfer the properties of one image to another.
- This is exactly what we are dealing with in the field of colour transformations.



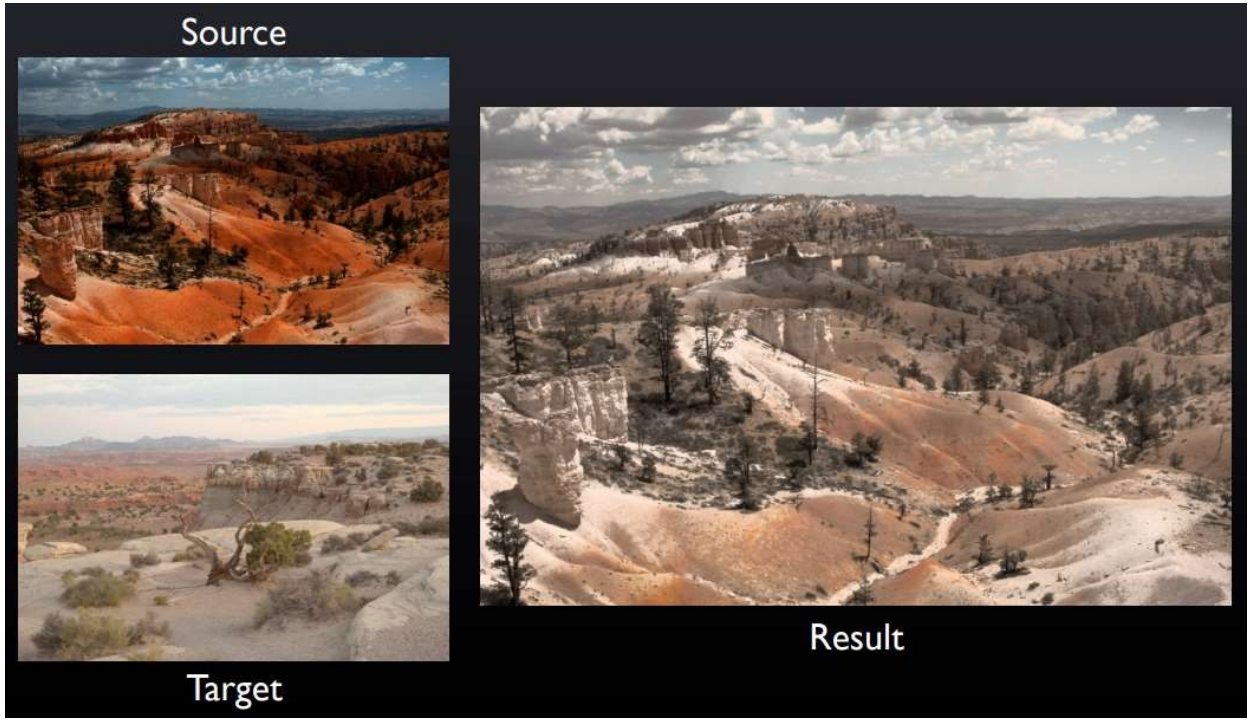
From: T. Pouli, E. Reinhard: "Example-based colour image manipulation and enhancement", SIGGRAPH 2012 Courses, Example-based colour image manipulation and enhancement | ACM SIGGRAPH 2012 Courses

Image Editing - Dot Operators

Colour Transformations (Color Transformation)

The goal is:

- Transfer the colour composition of the target image to the input image (Source).
- A method must be developed with which the colour design of the target image can be captured and transferred to the input image (source). The image content of the source should be preserved as much as possible in the result image.



From: T. Pouli, E. Reinhard: "Example-based colour image manipulation and enhancement", SIGGRAPH 2012 Courses, Example-based colour image manipulation and enhancement | ACM SIGGRAPH 2012 Courses

Image Editing - Dot Operators

Colour Transformations (Color Transformation)

The concept for implementing the idea is:

- To capture the colour distribution in source and target, transform both images into the Lab colour system (why will be explained later).
- Per Lab colour channel (l, a, b) one reco
  - the average image brightness, corresponds to the average grey value (mean value as floating point number)
  - the dispersion of the grey values around the mean value in the histogram (standard deviation s, floating point number)

From: T. Pouli, E. Reinhard: "Example-based colour image manipulation and enhancement", SIGGRAPH 2012 Courses, Example-based colour image manipulation and enhancement | ACM SIGGRAPH 2012 Courses

Image Editing - Dot Operators

Colour transformations (Color Transformation): Reinhard et al, 'Color Transfer between Images', IEEE Computer Graphics and Applications 21(5), 2001

Calculation of the average image brightness by forming the mean value:

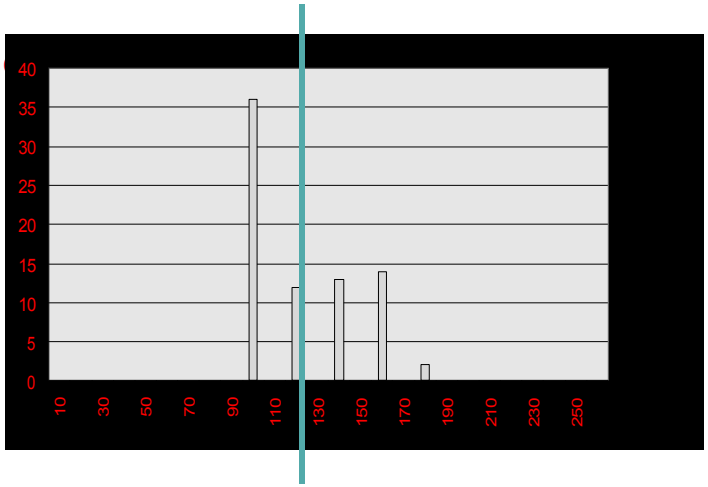
The mean value is the average value.

$$\bar{x} = \frac{x_1 + x_2 + x_3 + \ldots + x_n}{n} = \frac{1}{n} \sum_{i=1}^{n} x_i$$

Mittelwert

Number of grey values

Grey values at the i. position



Mean value (=mean image brightness) $_{xi}$:

122.857

From *DATAtab* - very informative: https://datatab.de/tutorial/standardabweichung-varianz-spannweite

Image Editing - Dot Operators

Colour transformations (Color Transformation): Reinhard et al, 'Color Transfer between Images', IEEE Computer Graphics and Applications 21(5), 2001

Standard deviation depends on the contrast range of the image :

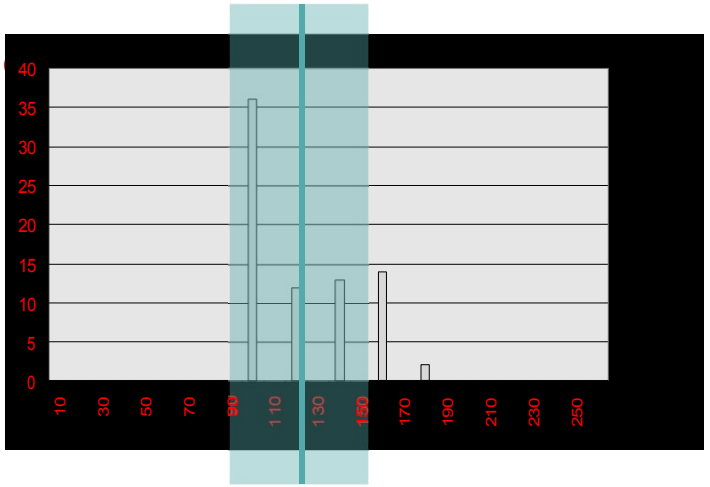
$$\sigma = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})^2}$$

Number of grey values

Grey values at the i. Place

Mean image brightness = average value

Frequency of th values



Grey values (x_i)

Standard deviation s: approx. 30

From *DATAtab* - very informative: https://datatab.de/tutorial/standardabweichung-varianz-spannweite

Image Editing - Dot Operators

Colour transformations (Color Transformation): Reinhard et al, 'Color Transfer between Images', IEEE Computer Graphics and Applications 21(5), 2001

Standard deviation depends on the contrast range of the image :

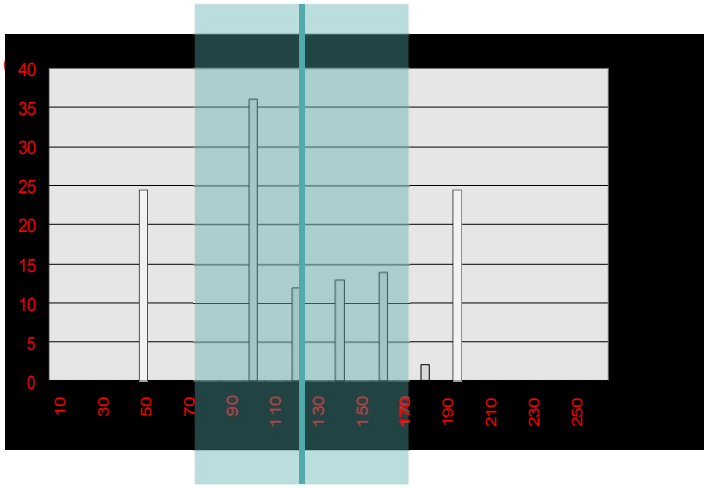
$$\sigma = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})^2}$$

Number of grey values

Grey values at the i. Place

Mean image brightness = average value

Frequency of th values



Grey values (x_i)

Standard deviation s: approx. 50

From *DATAtab* - very informative: https://datatab.de/tutorial/standardabweichung-varianz-spannweite

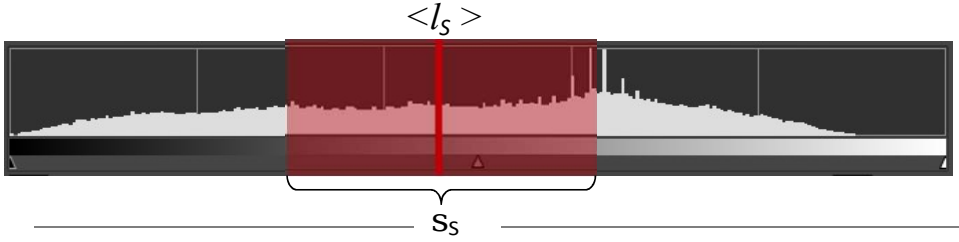
Image Editing - Dot Operators

Colour transformations (Color Transformation): Reinhard et al, 'Color Transfer between Images', IEEE Computer Graphics and Applications 21(5), 2001

1. Calculate mean values and standard deviation for the Lab channels of the source and the target :

Source 

Target 



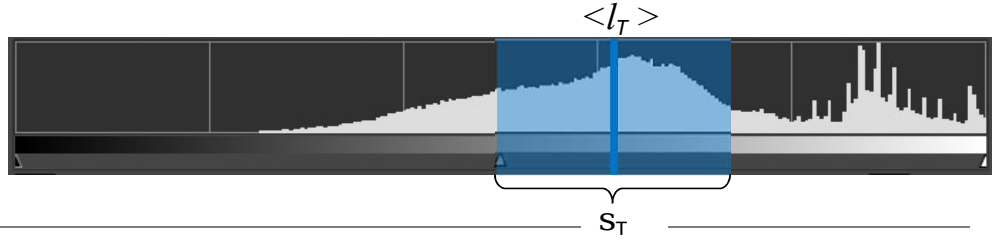
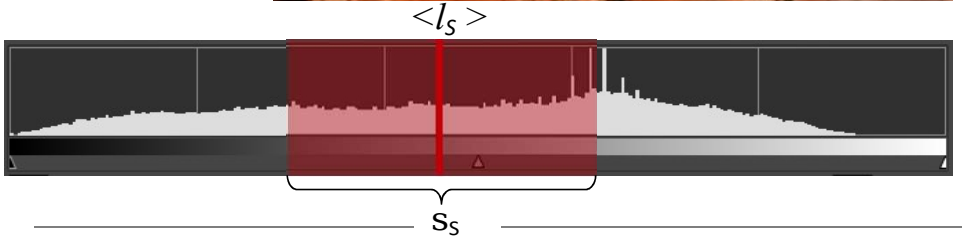


Image Editing - Dot Operators

Colour transformations (Color Transformation): Reinhard et al, 'Color Transfer between Images', IEEE Computer Graphics and Applications 21(5), 2001

2. Subtract the mean values $<l_s>$, $<a_s>$, $<b_s>$ of the source from the values of the corresponding source channels :

Source



$$l_s^* = l_s - \langle l_s \rangle$$

$$a_s^* = a_s - \langle a_s \rangle$$

$$b_s^* = b_s - \langle b_s \rangle$$

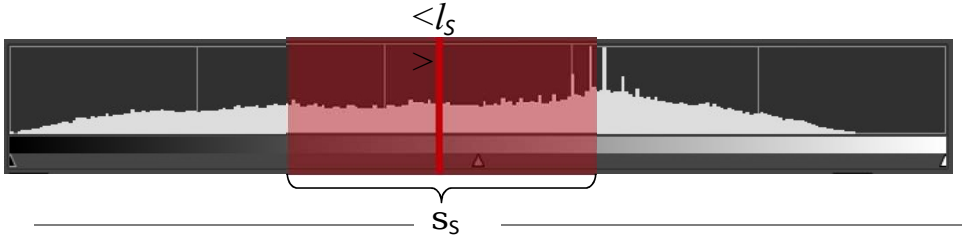
- All Lab colour channels now have the mean value 0.
- The grey values of the channels can also be negative after this subtraction.

Image Editing - Dot Operators

Colour transformations (Color Transformation): Reinhard et al, 'Color Transfer between Images', IEEE Computer Graphics and Applications 21(5), 2001

3. Scale the values of the source transformed by subtraction using the standard deviations (s_T /s):$_s$

Source



s_S

$$l'_s = \frac{s^l_T}{s^l_S} l^*$$

$$a'_s = \frac{s^a_T}{s^a_S} a^*$$

$$b'_s - \frac{s^b_T}{s^b_S} b^*$$

Image Editing - Dot Operators

Colour transformations (Color Transformation): Reinhard et al, 'Color Transfer between Images', IEEE Computer Graphics and Applications 21(5), 2001

Scale the values of the source transformed by subtraction using the standard deviations (s_T /s_S):

Scaling brings the contrast range of the source closer t the target image.

This transformation takes place in all Lab colour channels. The mean values of all colour channels of the source image are still 0.

Source

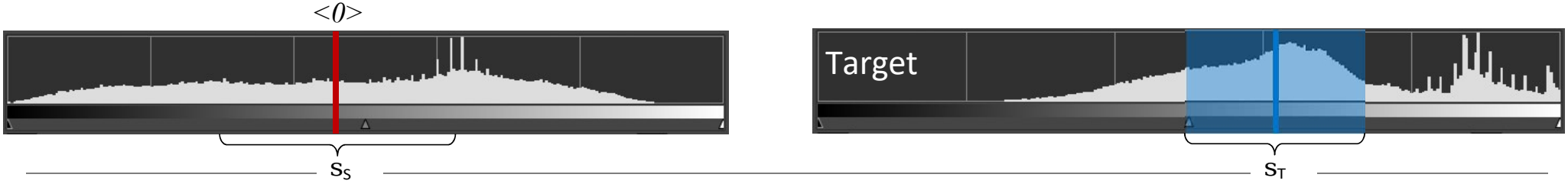
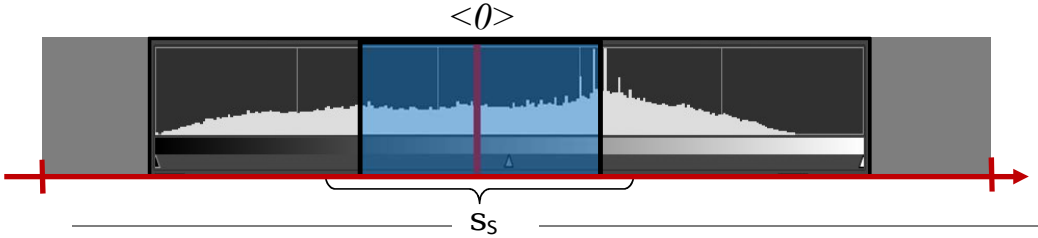


Image Editing - Dot Operators

Colour transformations (Color Transformation): Reinhard et al, 'Color Transfer between Images', IEEE Computer Graphics and Applications 21(5), 2001

Scale the values of the source transformed by subtraction using the standard deviations (s_T /s_S):

Source



Scaling brings the contrast range of the source closer to the target image.

See picture above left, the negative values are shown in black.

This transformation takes place in all Lab colour channels. The mean values of all colour channels of the source image are still 0.

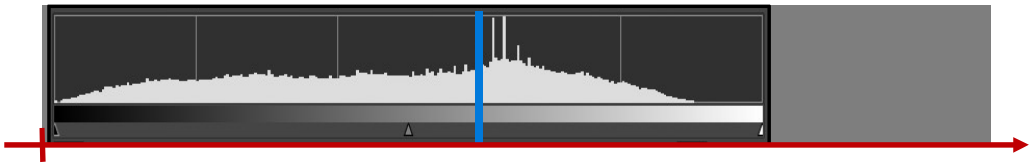
Image Editing - Dot Operators

Colour transformations (Color Transformation): Reinhard et al, 'Color Transfer between Images', IEEE Computer Graphics and Applications 21(5), 2001

Add the mean values of the respective target channels to the matching transformed source channels (L, a, b):

Source

$<l_T>$



s_T

This shifts the values into the positive range and the value become displayable again.

If there are still negative values, they are mapped to the value 0. Values greater than 255 are mapped on 255.

Image Editing - Dot Operators

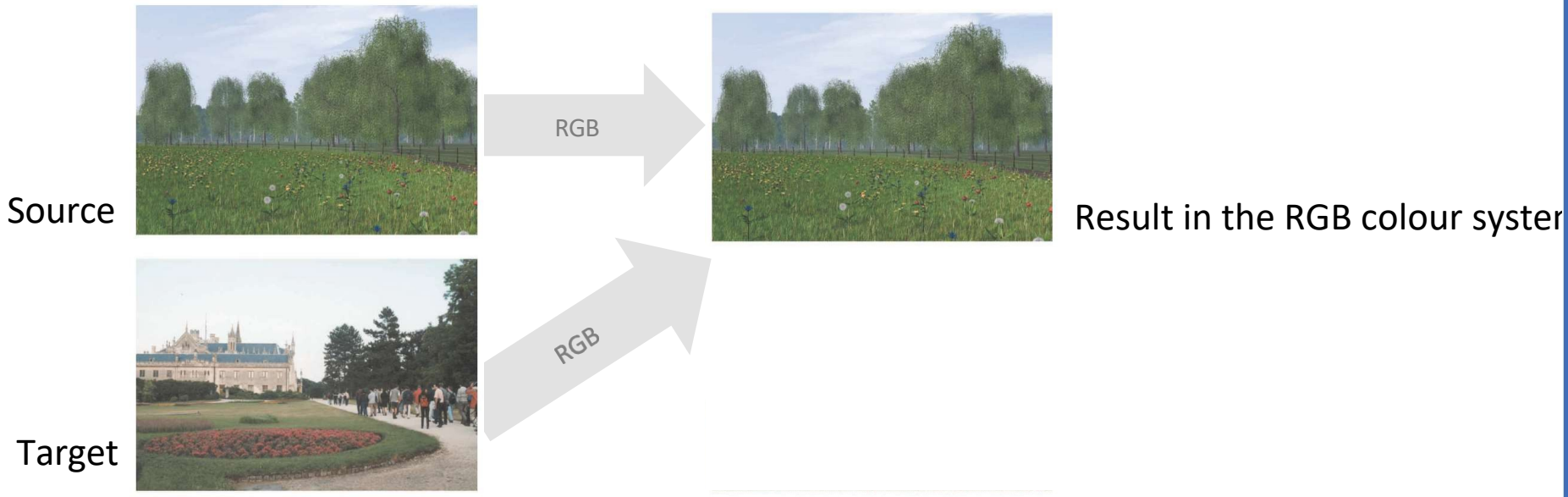
Colour transformations (Color Transformation): Reinhard et al, 'Color Transfer between Images', IEEE Computer Graphics and Applications 21(5), 2001

From: T. Pouli, E. Reinhard: "Example-based colour image manipulation and enhancement", SIGGRAPH 2012 Courses, Example-based colour image manipulation and enhancement | ACM SIGGRAPH 2012 Courses

Image Editing - Dot Operators

Colour transformations (Color Transformation): Reinhard et al, 'Color Transfer between Images', IEEE Computer Graphics and Applications 21(5), 2001

Why does this transformation work in the Lab system but not (in all cases) in the RGB colour system?

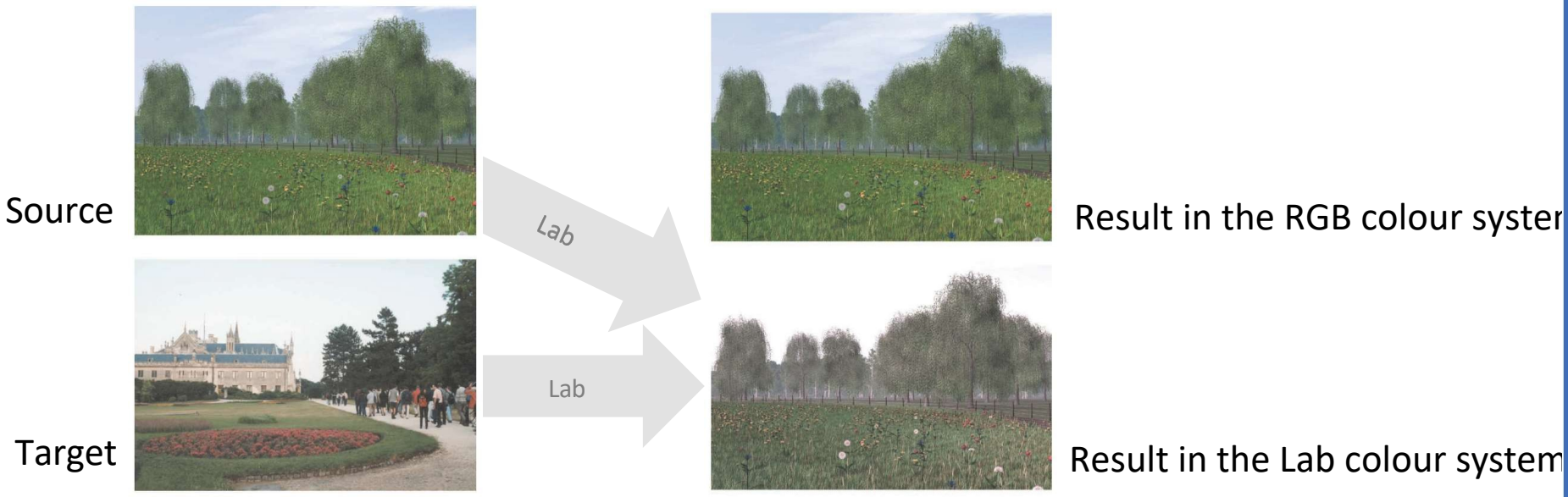


From: T. Pouli, E. Reinhard: "Example-based colour image manipulation and enhancement", SIGGRAPH 2012 Courses, Example-based colour image manipulation and enhancement | ACM SIGGRAPH 2012 Courses

Image Editing - Dot Operators

Colour transformations (Color Transformation): Reinhard et al, 'Color Transfer between Images', IEEE Computer Graphics and Applications 21(5), 2001

Why does this transformation work in the Lab system but not (in all cases) in the RGB colour system?



From: T. Pouli, E. Reinhard: "Example-based colour image manipulation and enhancement", SIGGRAPH 2012 Courses, Example-based colour image manipulation and enhancement | ACM SIGGRAPH 2012 Courses

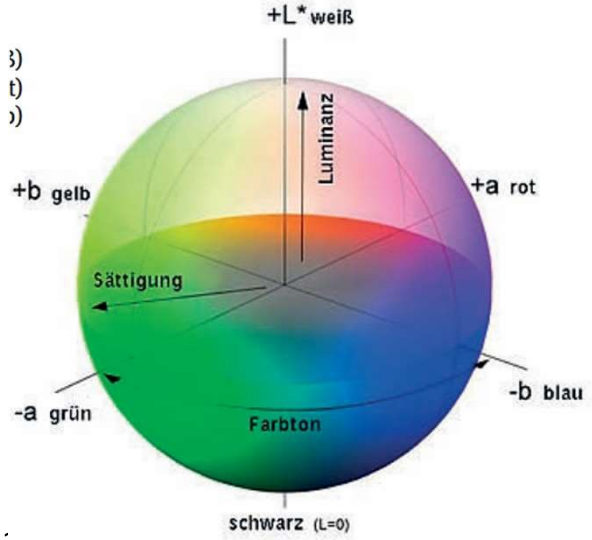
Image Editing - Dot Operators

Colour transformations (Color Transformation): Reinhard et al, 'Color Transfer between Images', IEEE Computer Graphics and Applications 21(5), 2001

Why does this transformation work in the Lab system but not (in all cases) in the RGB colour system?

There are two main reasons for this:

1. In the Lab colour space, the length of the distance between two colours is in direct proportion to our ability to distinguish these colours. This is not the case in the RGB colour space.
2. In the RGB colour space, all three colour channels together model a hue. In the Lab system, the hues are modelled by complementary colours and intensity values that have less influence on each other in relation to RGB.



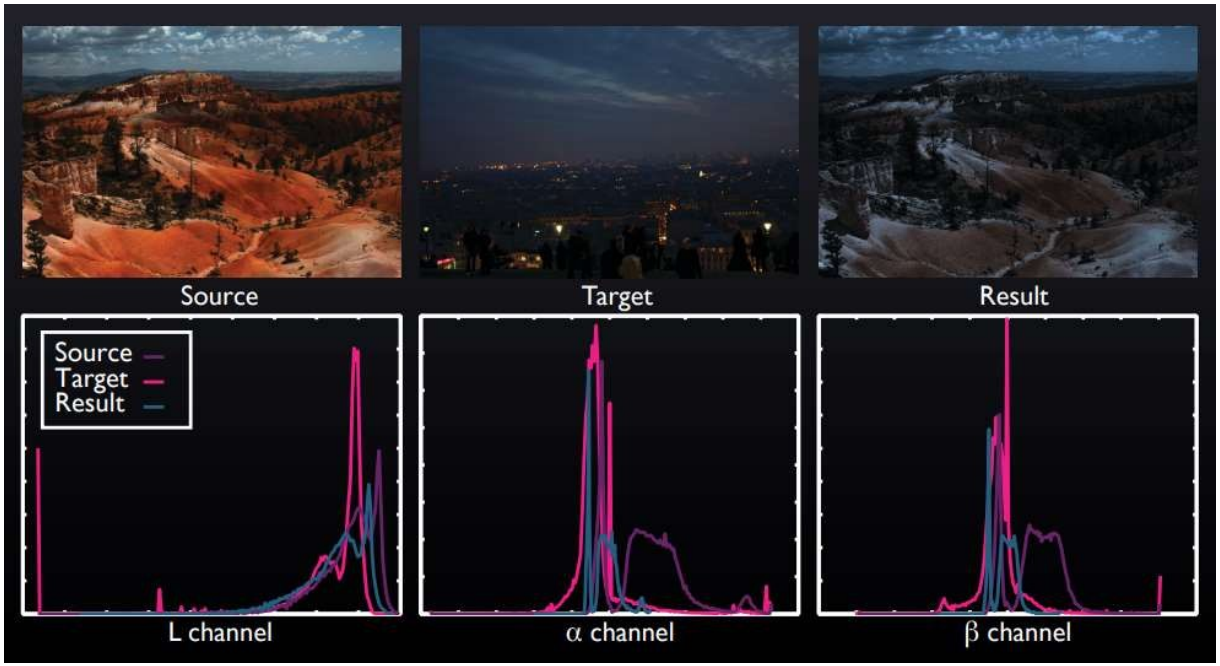
From: T. Pouli, E. Reinhard: "Example-based colour image manipulation and enhancement", SIGGRAPH 2012 Courses, Example-based colour image manipulation and enhancement | ACM SIGGRAPH 2012 Courses

Image Editing - Dot Operators

Colour transformations (Color Transformation): Reinhard et al, 'Color Transfer between Images', IEEE Computer Graphics and Applications 21(5), 2001

Why does this transformation work in the Lab system but not (in all cases) in the RGB colour system?

- The aim is to avoid that the target values deviate too much from the source values after the transformation. In this way, the image content is largely preserved.

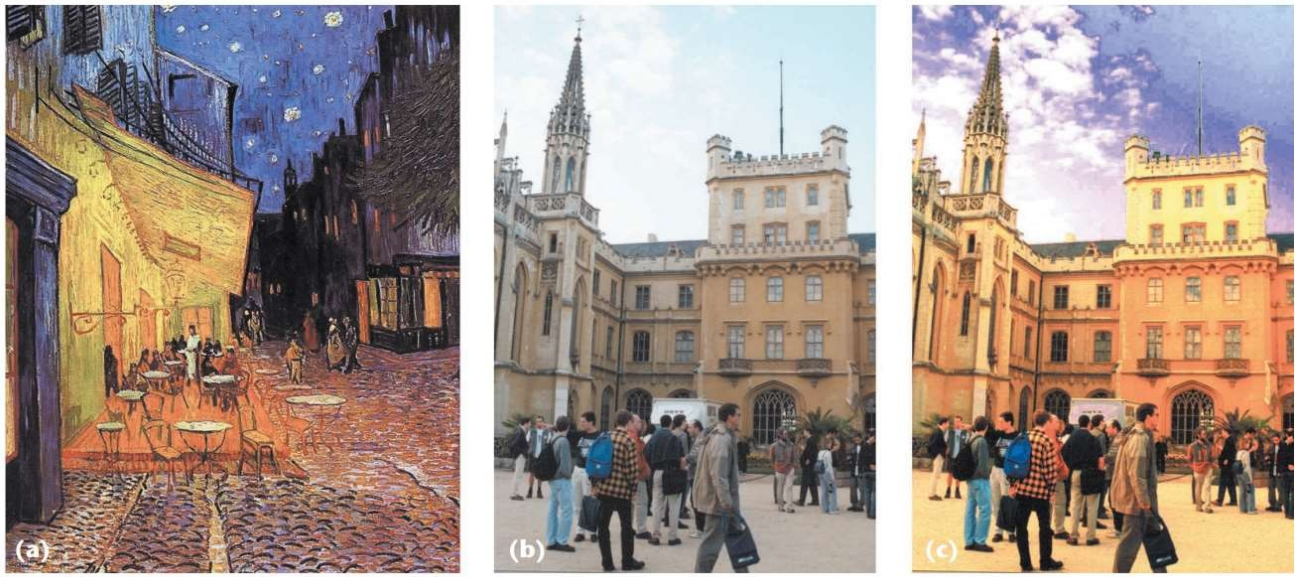


From: T. Pouli, E. Reinhard: "Example-based colour image manipulation and enhancement", SIGGRAPH 2012 Courses, Example-based colour image manipulation and enhancement | ACM SIGGRAPH 2012 Courses

Image Editing - Dot Operators

Colour transformations (Color Transformation): Reinhard et al, 'Color Transfer between Images', IEEE

A result:



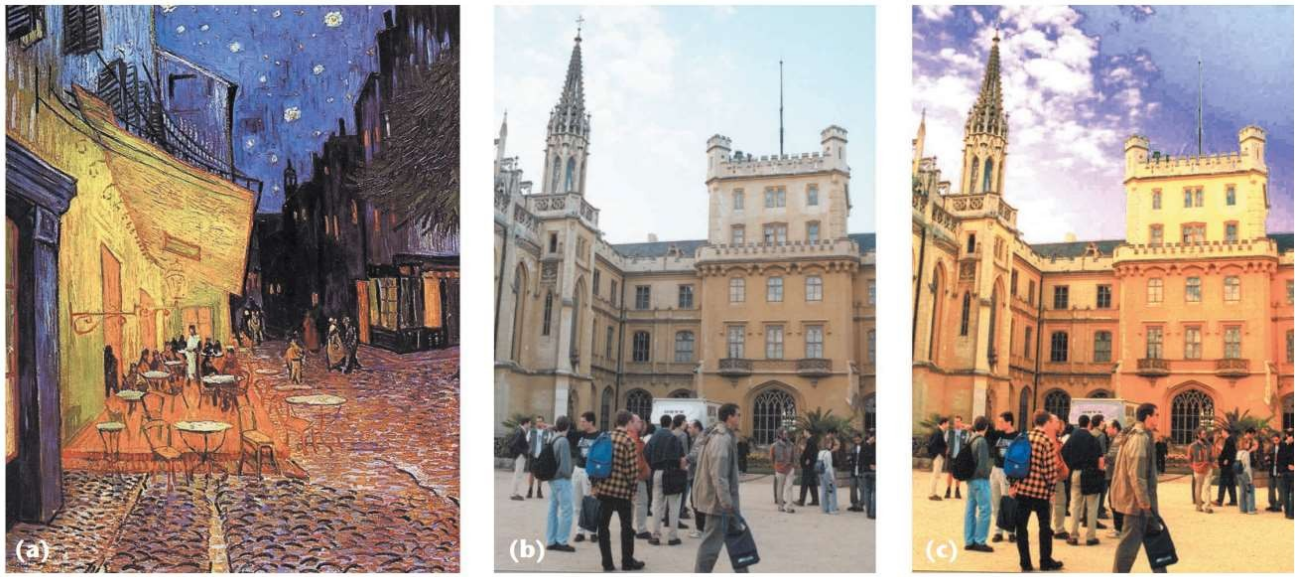
4 Using swatches. We applied (a) the atmosphere of Vincent van Gogh's *Cafe Terrace on the Place du Forum, Arles, at Night* (Arles, September 1888, oil on canvas; image from the Vincent van Gogh Gallery, http://www.vangoghgallery.com) to (b) a photograph of Lednice Castle near Brno in the Czech Republic. (c) We matched the blues of the sky in both images, the yellows of the cafe and the castle, and the browns of the tables at the cafe and the people at the castle separately.

Image Editing - Dot Operators

Colour transformations (Color Transformation): Reinhard et al, 'Color Transfer between Images', IEEE

Food for thought:

Are the image contents distorted by the colour transfer, so that the colour transfer is not suitable for use on sensitive data, such as in the medical field or for the evaluation of satellite images?



4 Using swatches. We applied (a) the atmosphere of Vincent van Gogh's *Cafe Terrace on the Place du Forum, Arles, at Night* (Arles, September 1888, oil on canvas; image from the Vincent van Gogh Gallery, http://www.vangoghgallery.com) to (b) a photograph of Lednice Castle near Brno in the Czech Republic. (c) We matched the blues of the sky in both images, the yellows of the cafe and the castle, and the browns of the tables at the cafe and the people at the castle separately.

Image Editing - Dot Operators

Colour transformations (Color Transformation): Reinhard et al, 'Color Transfer between Images', IEEE Computer Graphics and Applications 21(5), 2001

More result pictures:

From: T. Pouli, E. Reinhard: "Example-based colour image manipulation and enhancement", SIGGRAPH 2012 Courses, Example-based colour image manipulation and enhancement | ACM SIGGRAPH 2012 Courses

Image Editing - Dot Operators

Colour transformations (Color Transformation): Reinhard et al, 'Color Transfer between Images', IEEE Computer Graphics and Applications 21(5), 2001

More result pictures:

From: T. Pouli, E. Reinhard: "Example-based colour image manipulation and enhancement", SIGGRAPH 2012 Courses, Example-based colour image manipulation and enhancement | ACM SIGGRAPH 2012 Courses

Image Editing - Dot Operators

Colour transformations (Color Transformation): Reinhard et al, 'Color Transfer between Images', IEEE

Computer Graphics and Applications 21(5), 2001

Concluding remarks:

Implementation and evaluation of the colour transfer of Reinhard et al. take place in the practical course:

Assumptions are that

- ... the process also works well in the HSV colour space
- ... Images that concentrate on one colour tone (e.g. blue) also work in the RGB colour space.

Outlook:

The normalisation of images by means of mean value and standard deviation is also used in other image processing methods. For example, this transformation technique is also used in convolutional neural networks.

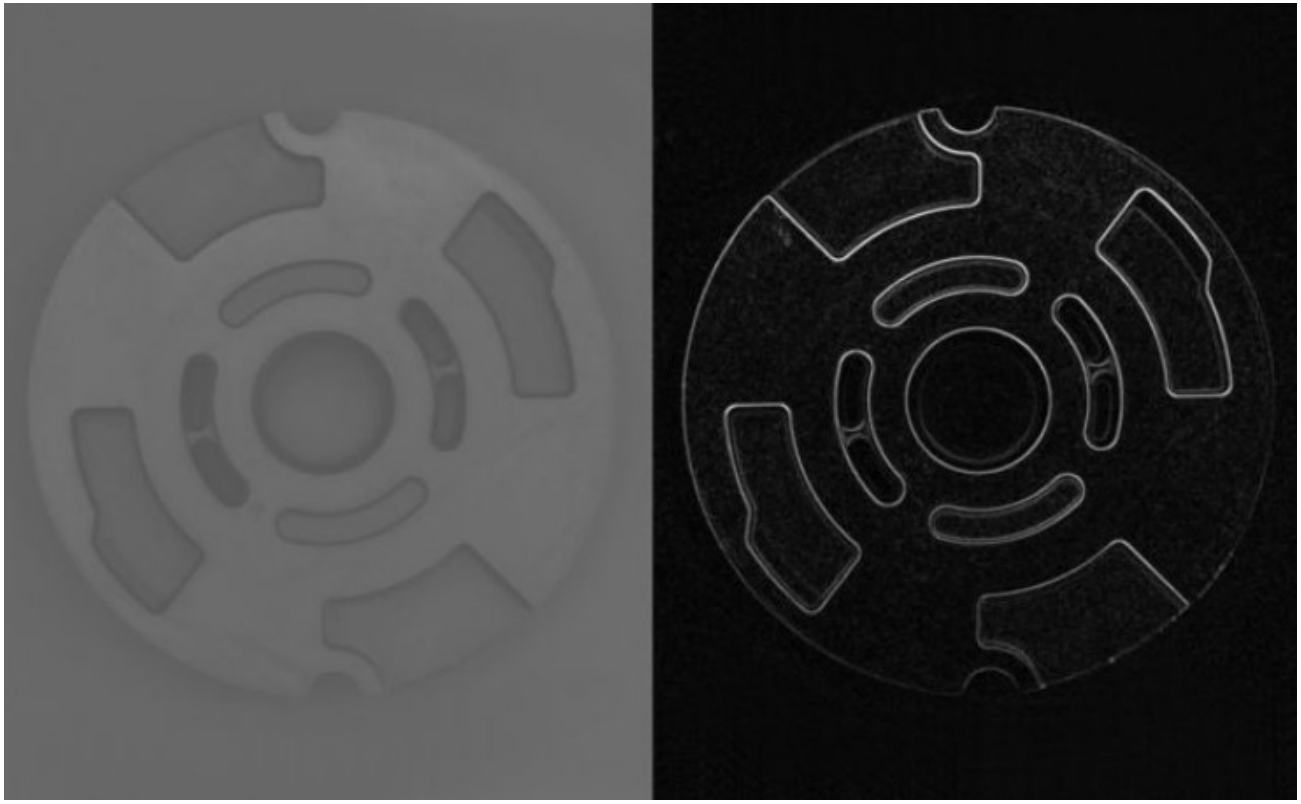
Image Editing - Dot Operators

Histograms Point operations

- Linear change of the grey values:
  - Changing the picture brightness
  - Invert the image
  - Changing the contrast
  - Biniarisation through thresholding
- Non-linear change in grey values:
  - Gamma correction
- Colour Transformations (Color Transformation

What happens next?

Image Processing - Local Operators



Pictures from: https://invision-news.de/invision/bildvorverarbeitung/

Left: Poorly contrasted image
Right: Edges highlighted by contrast spreading and edge filters