Computer Graphics Charles University

Image Filtering

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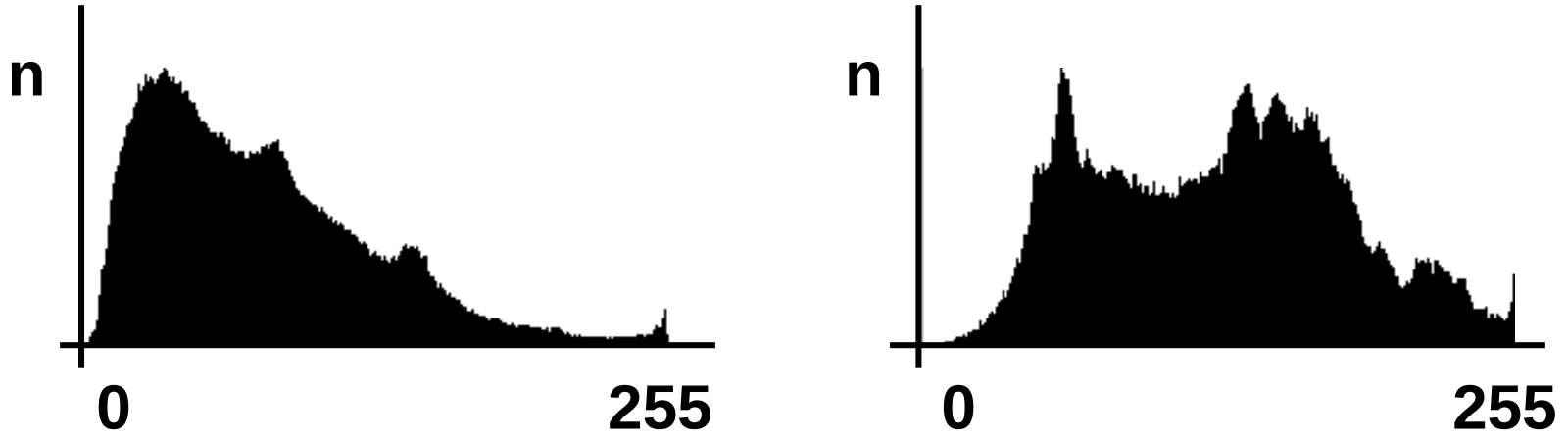
Image Histograms

- **Frequency table** of individual brightness (and sometimes also colour) values
  - **Continous case** – probability density
- Main use – photography



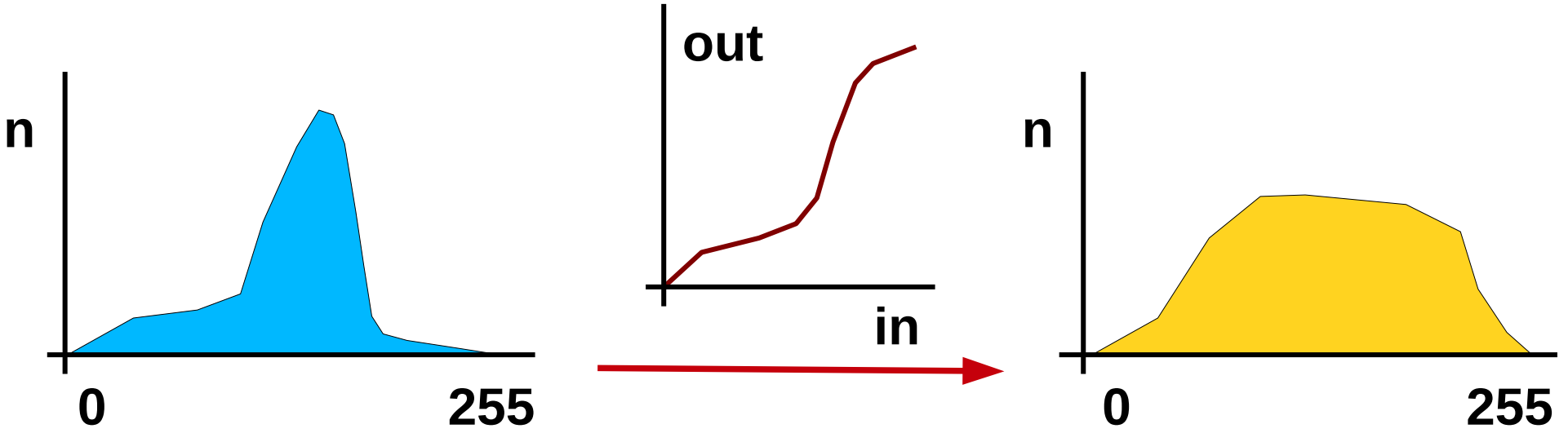
Brightness measures

- Histogram → first overview of **exposure**
- Over- or underexposed images
- Insufficient or too large c**ontrast**
- „**Good histogram**“
  - Image has shades in all brightness ranges
  - ~ retains details both in dark and bright parts

→ Is it possible to „fix“ a bad histogram?

Brightness transform

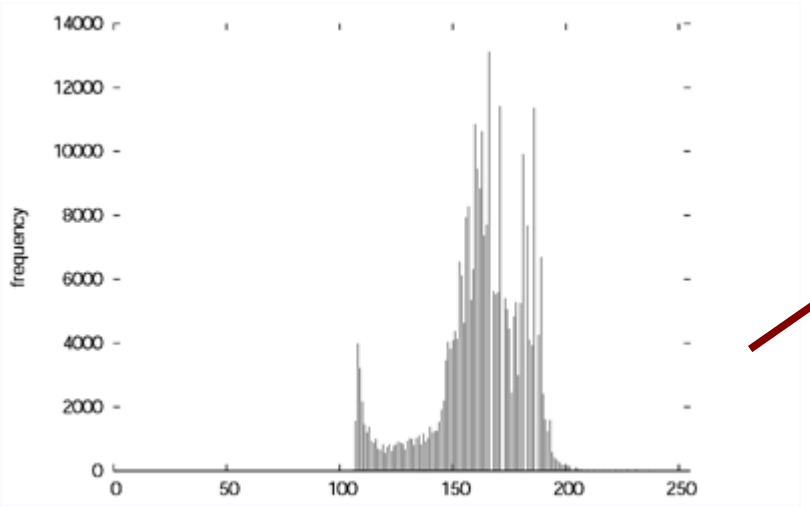
- **Transfer function** between brightness before and after
  - t: R → R (usually [0; 1] → [0; 1])
- Gamma correction
- Contrast enlargement

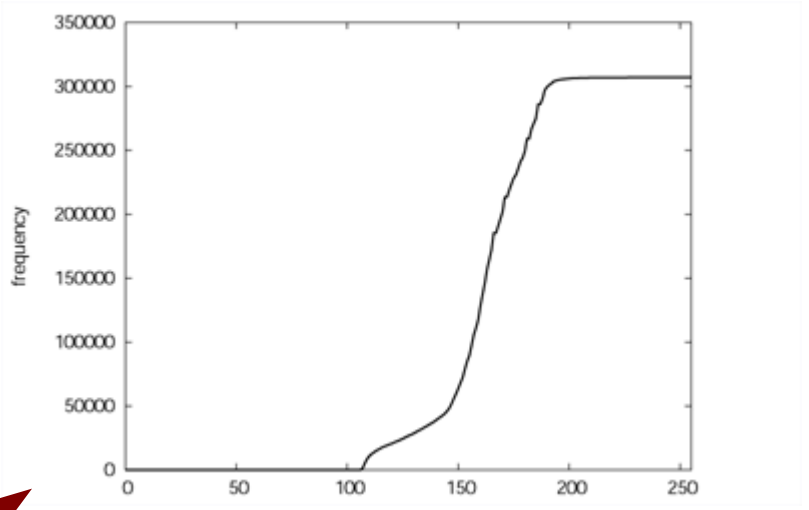


Histogram Equalisation

- Artificial brightness transform
  - Seeks to equalise histogram
- Manipuation of all brightness „columns“
  - Distributes shades stochastically
- **Local histogram equalisation**
  - Analysis only of of pixel surround
  - Can improve readability of the overall image
  - Does not preserve uniformly coloured areas!

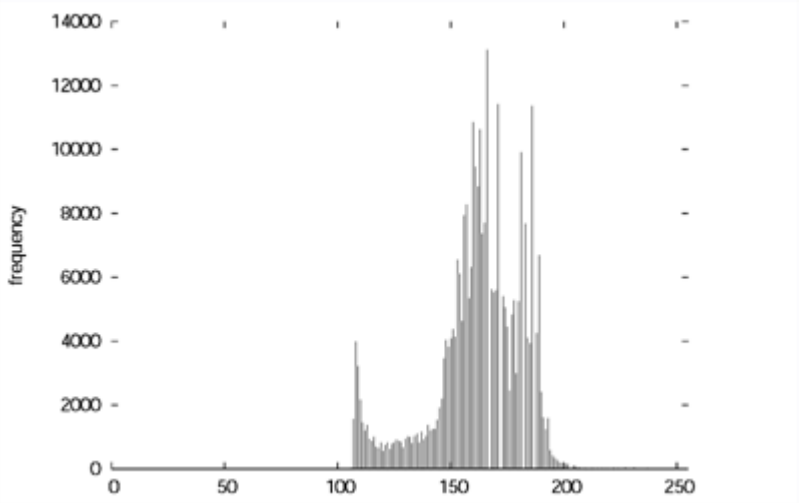
Global equalisation example

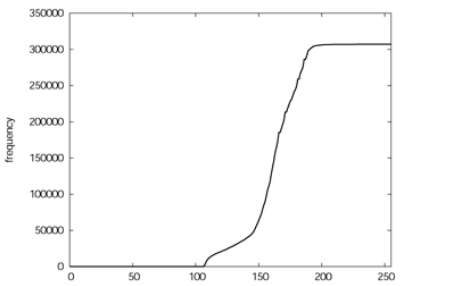


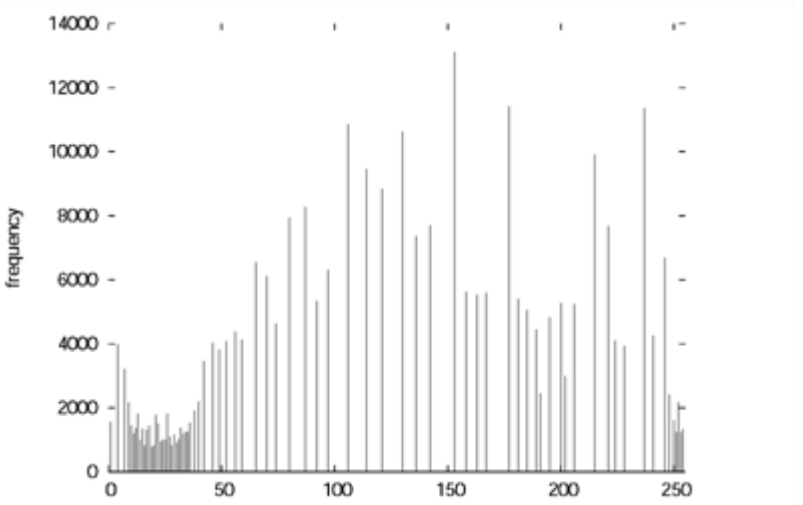


Cumulative histogram (luminance transform)

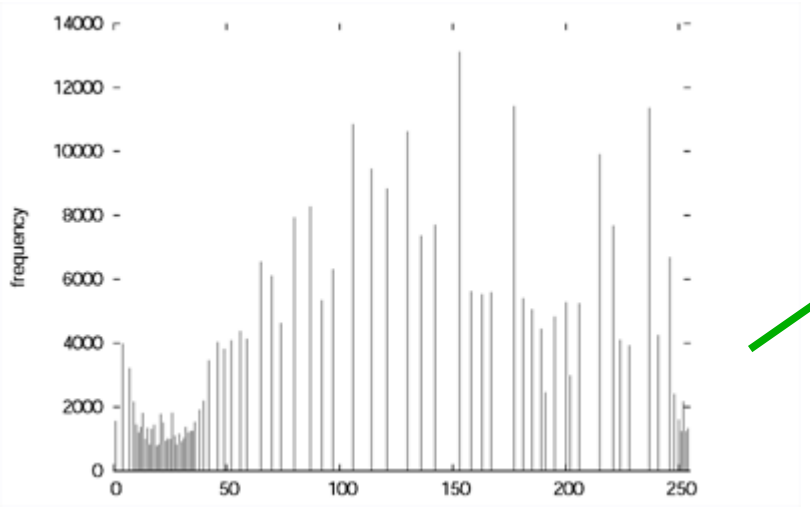
Luminance transformation

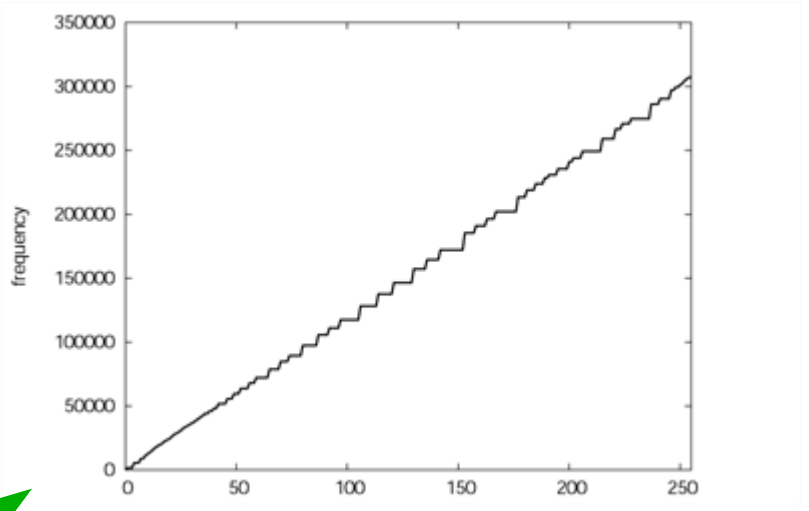






Result after equalisation





cumulative histogram

Colour operations

- Transformation **RGB → HSV**
- Changes to **saturation S**
- Changes to **hue H**
  - Change of object colours
  - Selective de-colourisation ...
- Reverse transformation **H'S'V' → R'G'B'**

HSV operations

HSV operations

Examples of colour operations

(algorithm: Miroslav Hrivík)

Examples of colour operations

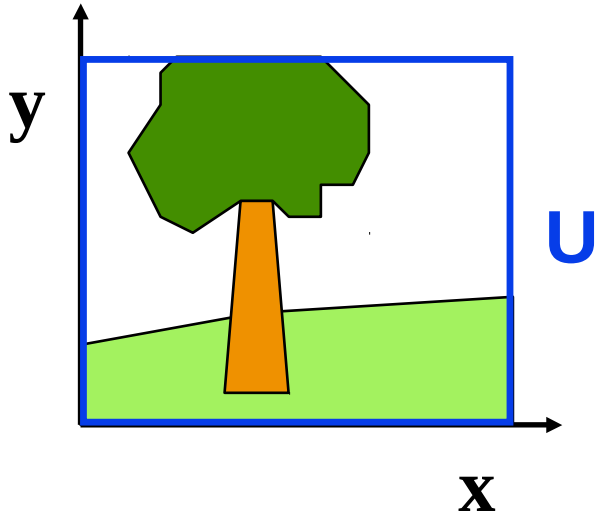
(photo & algorithm: David Marek)

Mathematical Definition of Images

„image function”

$$f: \quad U \subset R^2 \rightarrow R^n$$

$$f: \quad \lfloor x, y \rfloor \rightarrow \lfloor a_1, a_2, \ldots a_n \rfloor$$



Point location in the plane

Image attributes (colour, transparency)

Convolution

- „Weighted Moving Average“
  - Weight function **g**
- Close connection with the **Fourier transform**
  - Spectral domain
  - Filters like „low pass“ etc.

$$(f * g)(x) = \int_{-\infty}^{\infty} f(t) \cdot g(x-t)\, dt$$

1D version

Discrete Convolution

- „Weighted moving average“ of a series (table)
  - Series (table) of weights **g**
- Associated with the D**iscrete Fourier Transform (DFT)**

$$(f * g)[n] = \sum_{m=-\infty}^{\infty} f[m] \cdot g[n-m]$$

1D version

Convolution Effects

- Low pass filter (only positive values of **g**)
  - Blurring
  - Noise reduction
- High pass filter (positive and negative values, sum **0**)
  - Edge detection
  - Image sharpening
- Complex spectral filters
- Other effects („emboss“, …)

Image blurring

original

Gauss

1	2	1
2	4	2
1	2	1

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Edge detection („high-pass“)

original

Sobel (2 directions)

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

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

Image Sharpening

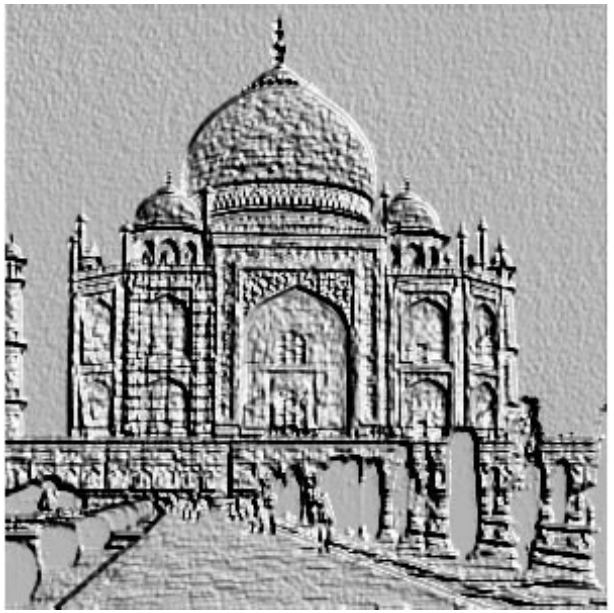
Laplacian

0	-1	0
-1	4	-1
0	-1	0

Added to image

0	-1	0
-1	5	-1
0	-1	0

„Emboss“ effect



emboss

original

-1	0	0
0	1	0
0	0	0

Non-uniform blur

original

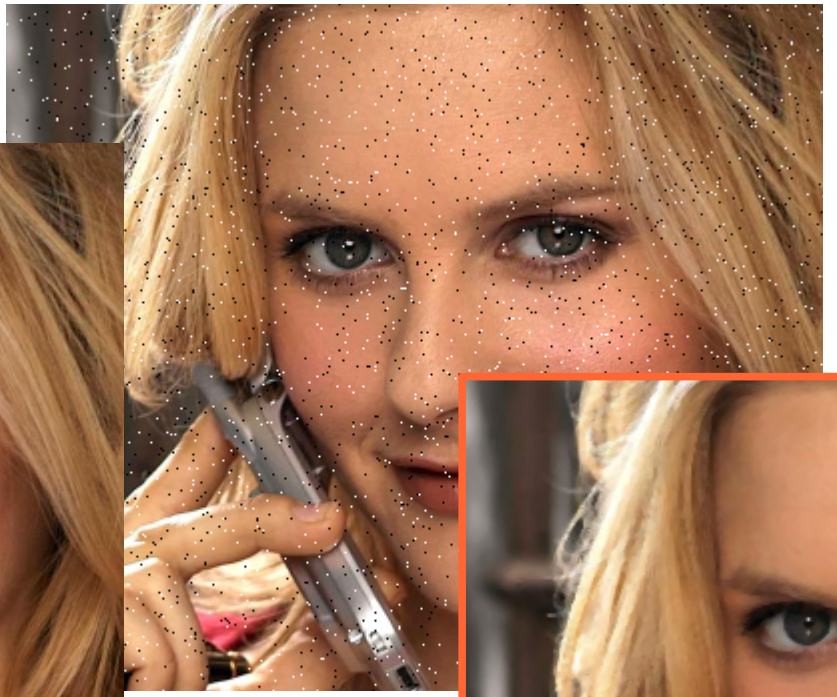
Radial blur
(1D blur)

Non-linear fitlers („rank filters“)

- **Windowed filtering** (as with convolution)
- Pixel ranking in the window, according to :
  - **median** – noise reduction, artistic effects, …
  - **minimum** – „erosion“
  - **maximum** – „dilatation“
- Various **window shapes**
  - square
  - circle
  - cross (preserves sharp corners)

Median for Noise Reduction

Original



“Salt & Pepper”

Median 3×3

Median: Image Repair

Dilation and Erosion

Dilation

Erosion

Noise suppression

- Advanced techniques seek to **preserve edges**
  - Direct frequency reduction does not work
- Variants of **median filtering**
- **Anisotropic filtering**
  - Smudging on image contours (along the gradient of the image function)
- Filtering with a **rotating mask**
  - The pixel neighbourhood is considered
  - Average with minimal variance

Artistic filters

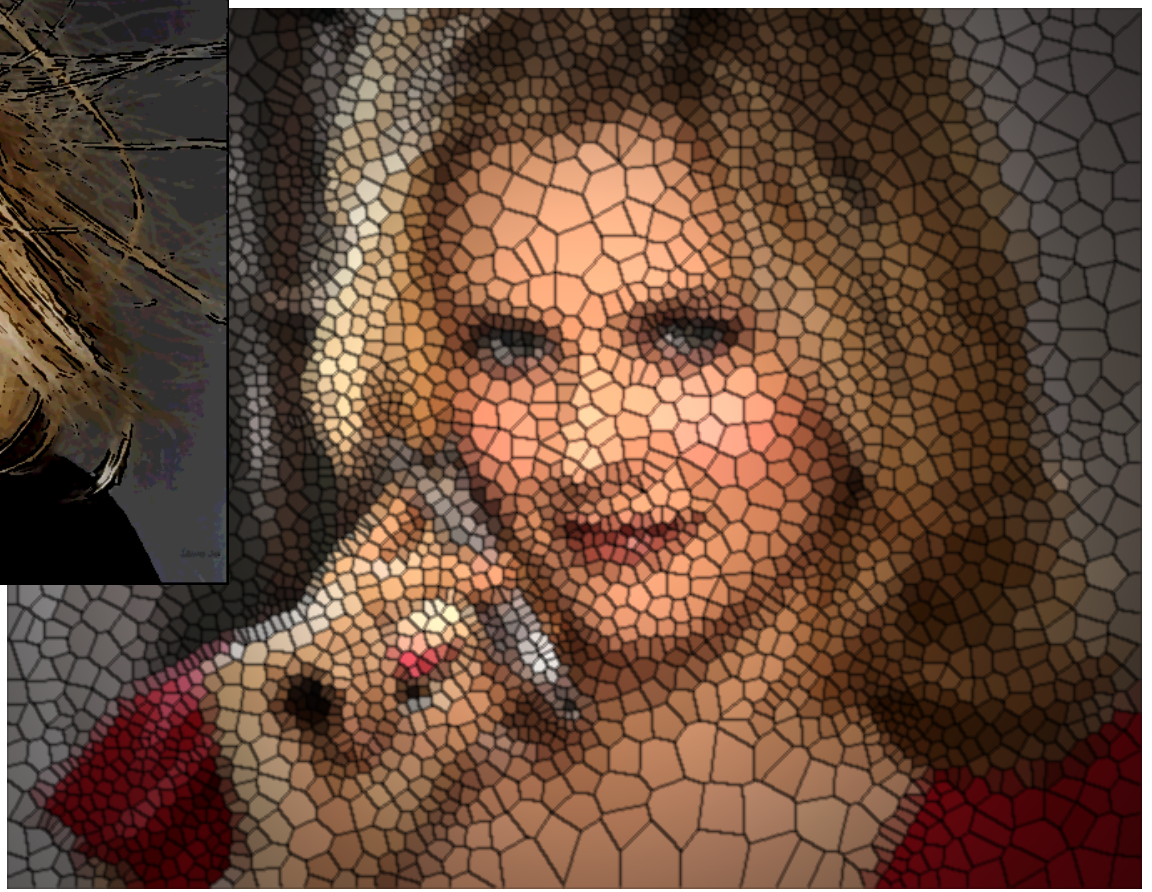
- Imitation of **painter/illustrator techniques**
- **Simulated strokes** of brushes / crayons etc.
- Effects of type „**mosaic**“, stained glass, ...
- **NPR** (non-photorealistc) **effects**
  - Edge highlighting
  - Filling object interiors
  - Area accretion (segmentation)
  - ...

Example – artistic filter

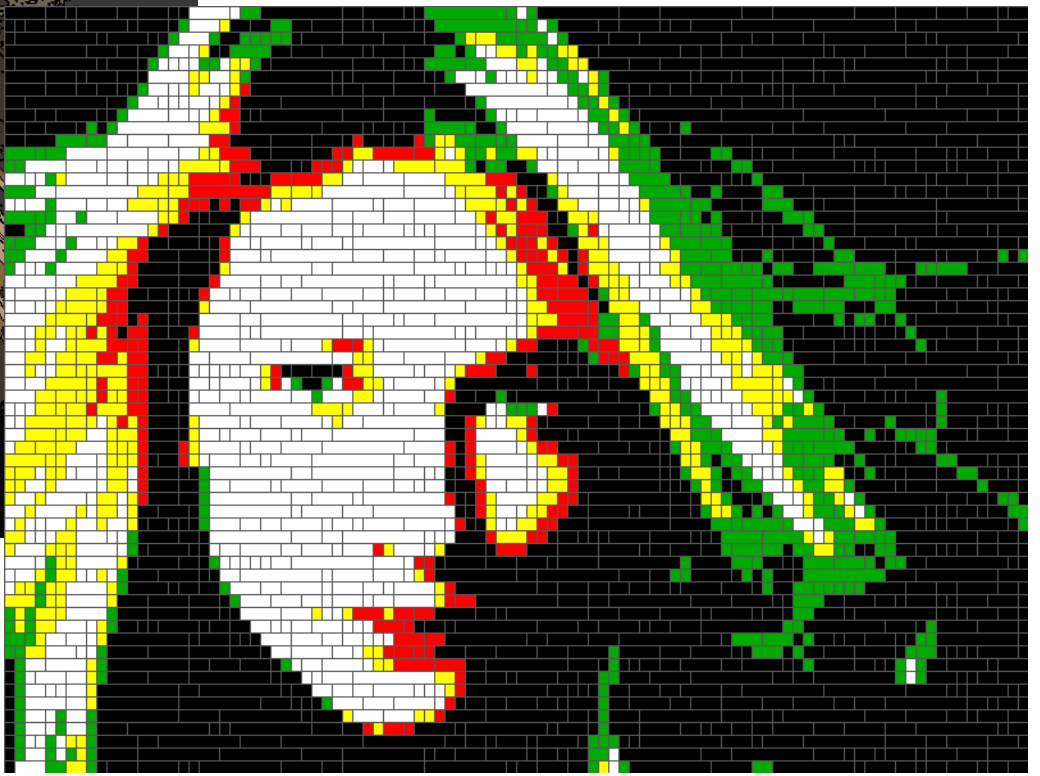
original

drawing

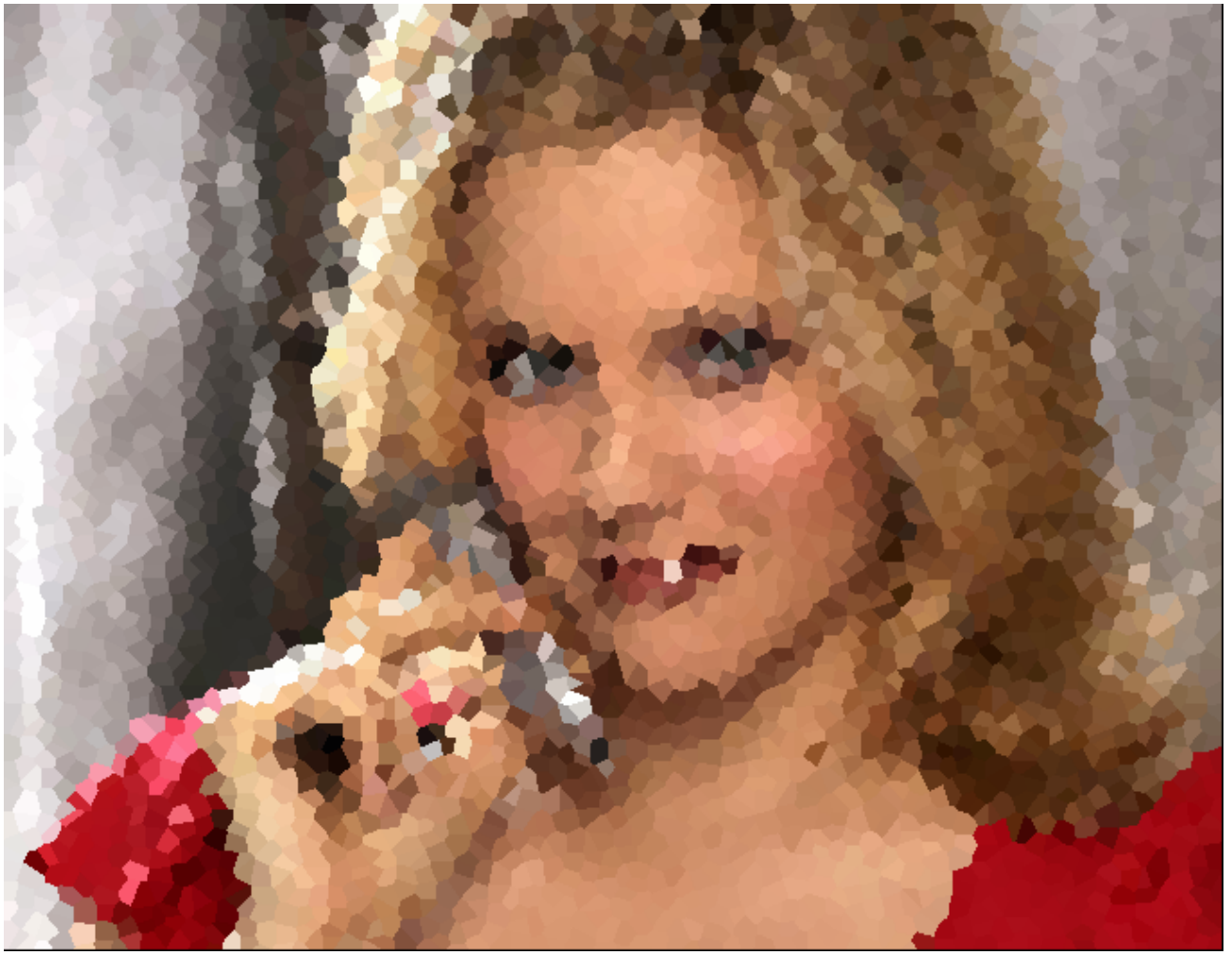
Examples – NPR filters



Examples – NPR filters



Example - mosaic



Literature

- Pratt W. K.: ***Digital Image Processing: PIKS Inside***, 3rd Edition, Wiley-Interscience, 2001
- Gonzales R. C, Woods R. E.: ***Digital Image Processing***, 3rd Edition, Prentice Hall, 2007