Image Sensing and Digitization

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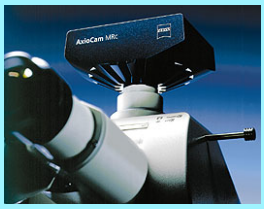
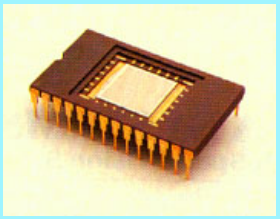




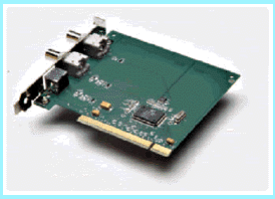


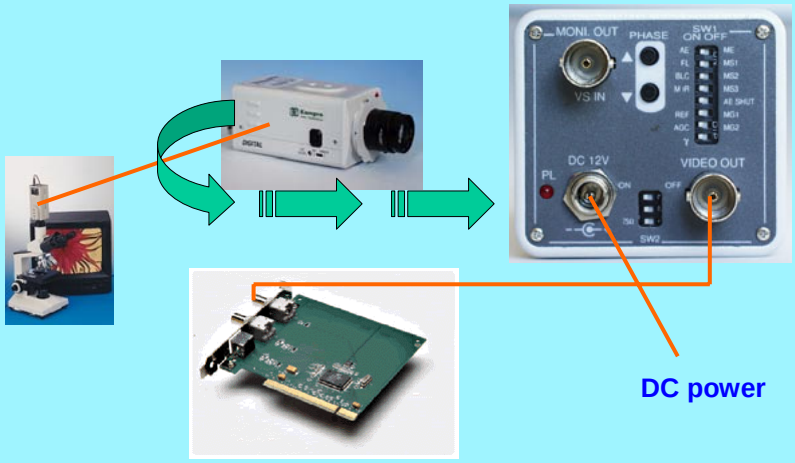
Image sensing devices I

Image sensing devices II

Image sensing devices III

Possibilities, how to sense image (1)

- analogue TV videocamera + frame grabber

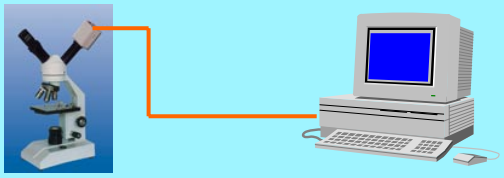


Possibilities, how to sense image (2)

- digital still camera (DSC)

Possibilities, how to sense image (3)

- digital videocameras for microscopy with different interface



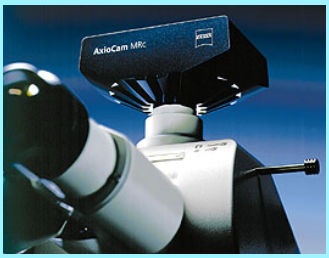
Possibilities, how to sense image (4)

- specialized microscope, USB digital microscope

http://www.theproscope.com

Possibilities, how to sense image (5)

- specialized complex systems



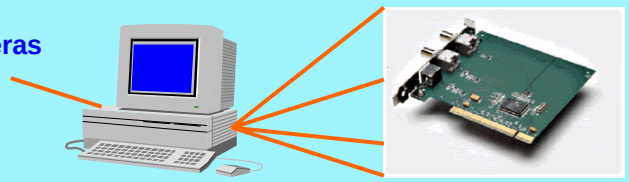
High-resolution digital camera systems for microscopy.

- 1.2 to 5.8 million pixels
- Outstanding image quality
- Color or monochrome
- High sensitivity
- COOLED CCD
- Long integration exposure
- Very easy to learn & operate

Computers possibilities

- standard PC with frame grabber (FG)

digital videocameras with IEEE 1394 (FireWire)



- laptops with FG (PCMCIA + ext. module)

standard TV camera

digital videocameras with IEEE 1394 (FireWire)

Sensing videocameras

- **Analogue**
  - **Standard TV** (interlaced)
    - **Mono-chrome**
      - **CCIR**
      - **RS170**
    - **Colour** (1 or 3 chips)
      - **PAL**
      - **NTSC**
- **Digital** (non-interlaced)
  - **WWW**
  - **Scientific**
    - **IEEE1394 (FireWire)**
    - **USB**
    - **Camera Link**
    - **Giga Bit Ethernet**

Basic system configuration

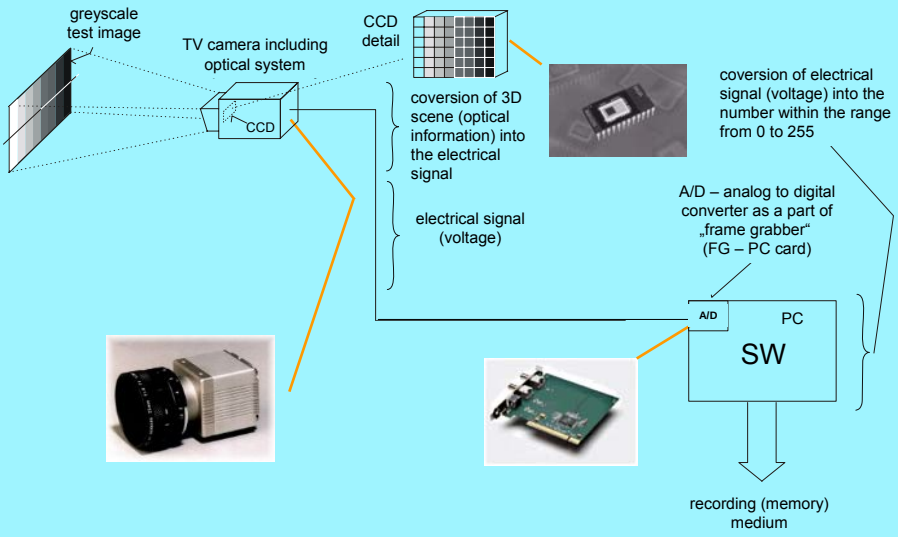
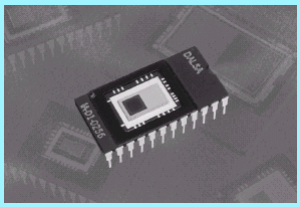
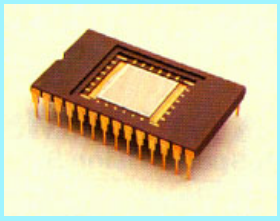


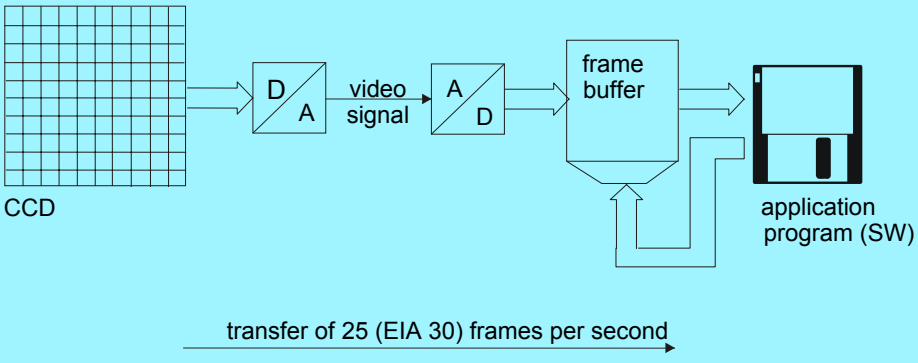
Image sensing elements

- vacuum tubes
- semiconductor
  - CCD
  - CID
  - CMOS
  - CIS

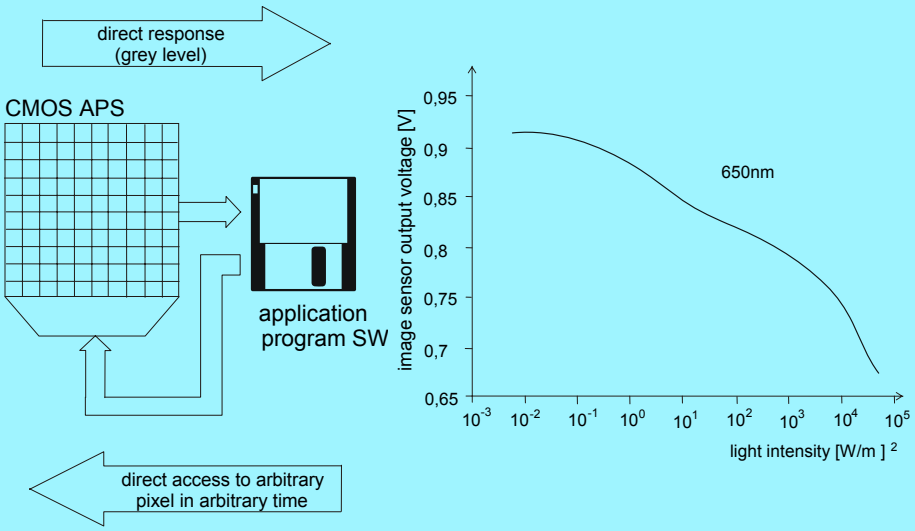




Basic system configuration with CCD image sensor

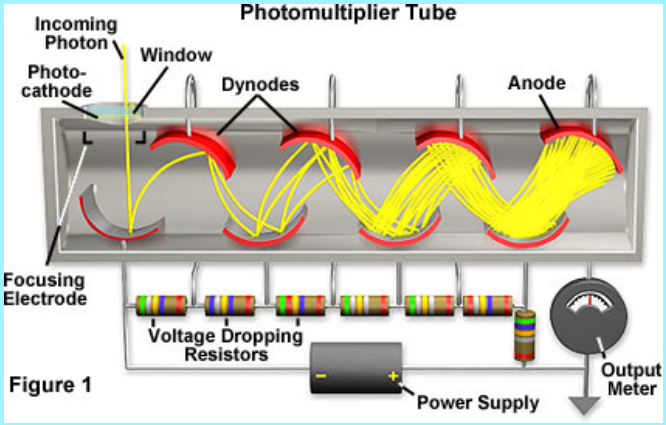


Basic system configuration with CMOS image sensor



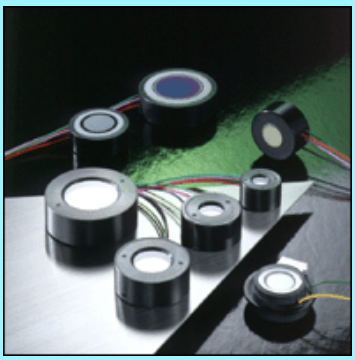
PMT („photomultiplier tube“)

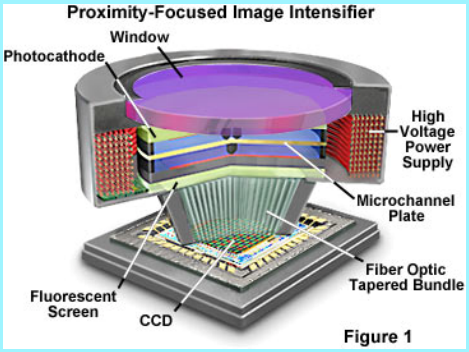
(adopted from http://micro.magnet.fsu.edu)



PMT are used in confocal microscopes

II („image intensifiers“) - ICCD





adopted from http://micro.magnet.fsu.edu

Image digitization (sampling) I

- 2D and time sampling

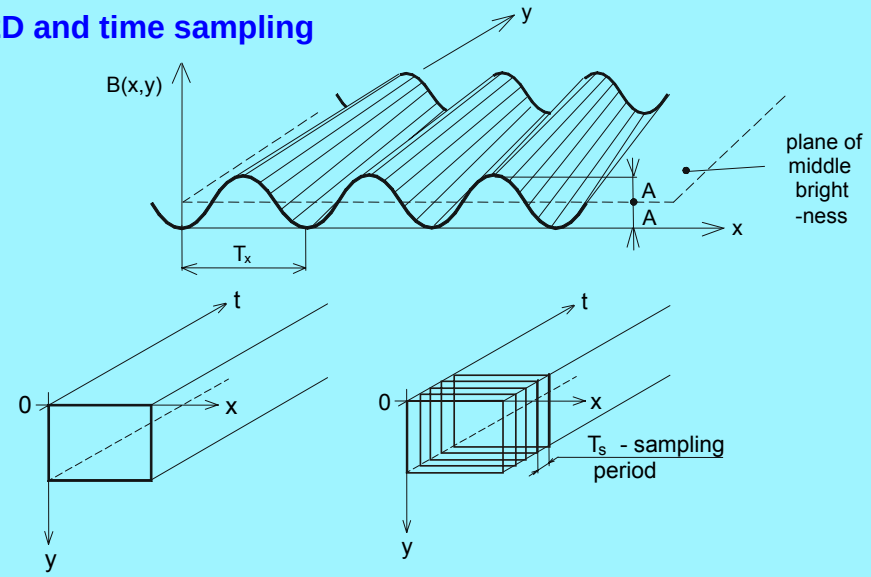


Image digitization (sampling) II

- spatial sampling

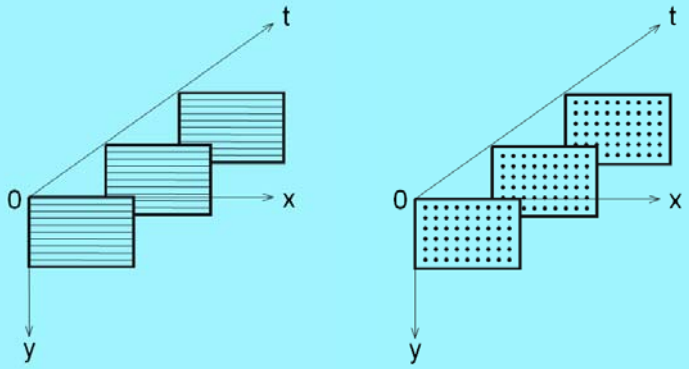
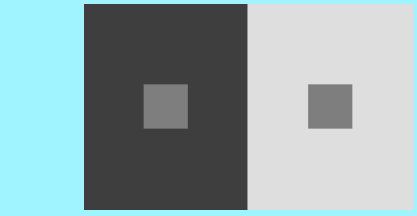
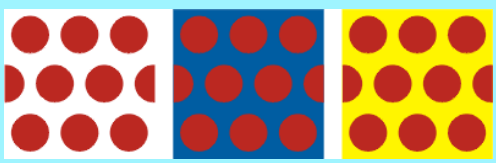


Image digitization (sampling) III

- level digitization (quantization)
  - brightness and contrast perception





Fundamentals of Digital Image Processing

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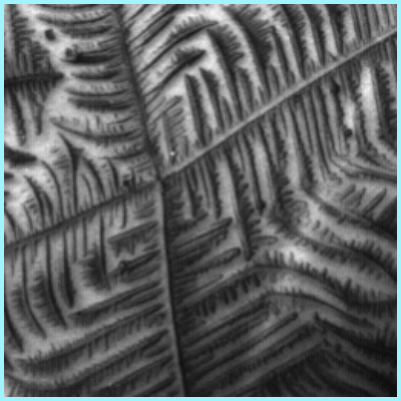


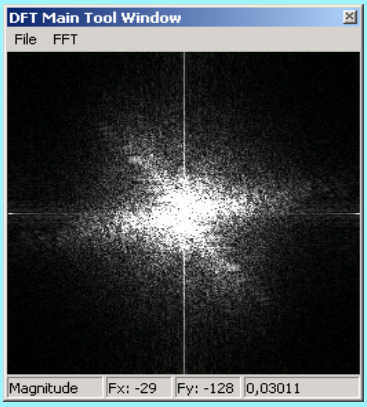
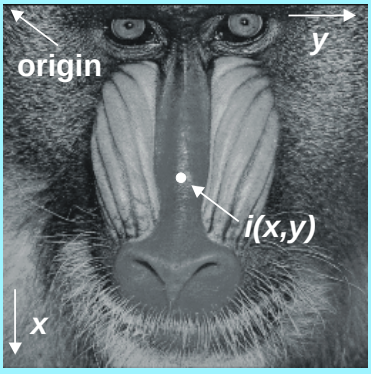


Image as two-dimensional matrix



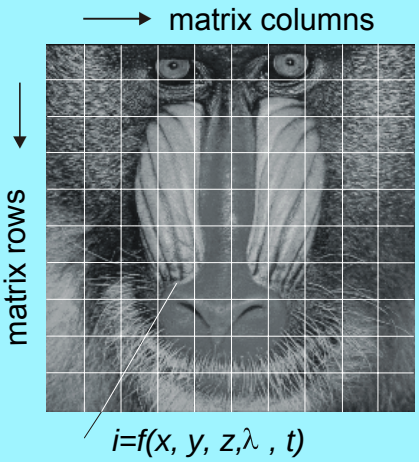
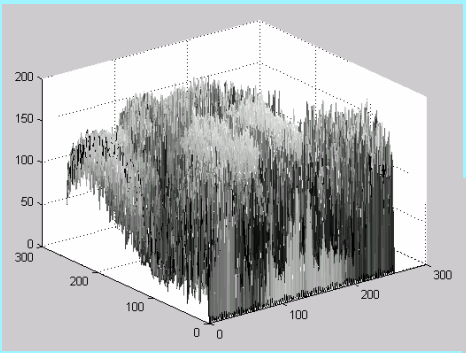


Image as 3D relief



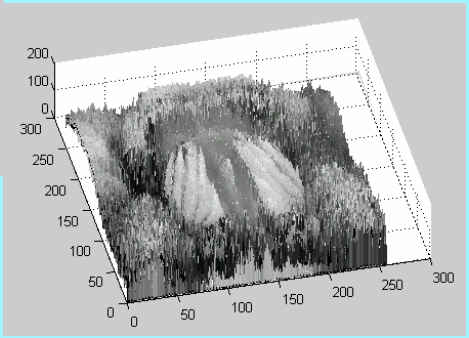


Image resolution and number of grey levels

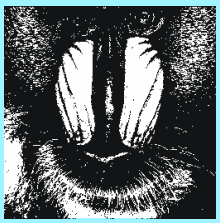
Image resolution	Different number of grey levels	
256 x 256 pixels	2 grey levels	4 grey levels
		
128 x 128 pixels	8 grey levels	16 grey levels
		

Image resolution and number of grey levels

Image resolution	Different number of grey levels	
64 x 64 pixels	32 grey levels	64 grey levels
		
32 x 32 pixels	128 grey levels	256 grey levels
		

Image processing steps

- image preprocessing (image enhancement)
- segmentation
- object description (analysis)
- image understanding

Examples of image operations

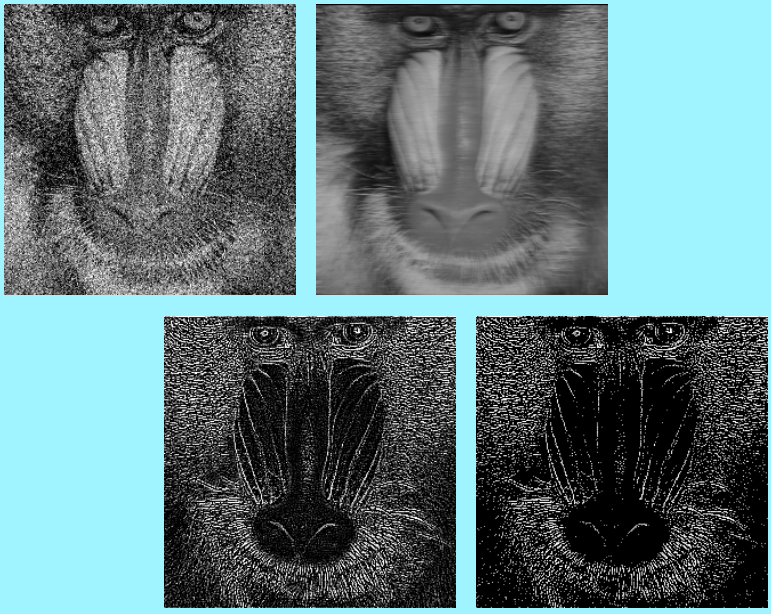


Image operations and pixel neighbourhood

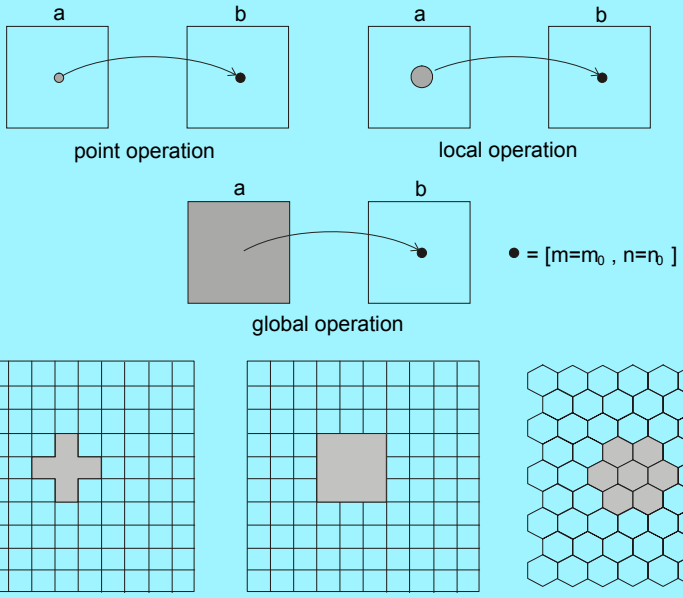


Image arithmetic operations I

Arithmetic operation between grey level image ("a") and BW ("b") images and greylevel images, (255 (1) corresponds to white, 0 (0) corresponds to black)

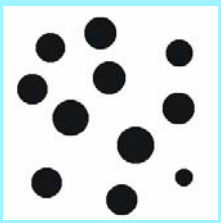
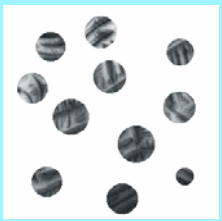
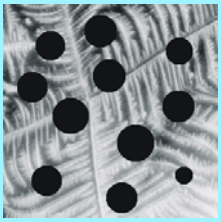
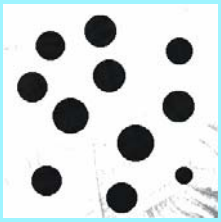
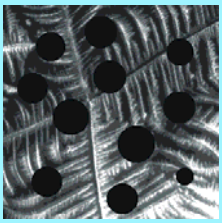
grey level image "a"	binary (BW) image "b"	ADD(a,b) = a + b
		
SUB(a,b) = a - b	**MULT(a,b) = a• b**	**DIV(a,b) = a / b**
		

Image arithmetic operations II

Arithmetic operations between grey level ("a") and BW ("b") images and between grey level images, (255 (1) corresponds to white, 0 (0) corresponds to black)

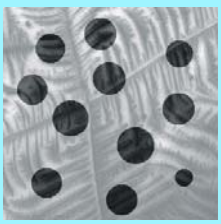
MIN(a,b)	MAX(a,b)	AVE(a,b) = average
		
OVERLAY(a,b)	**WEIGHT(25% a, 75% b) = 25% a + 75% b**	**WEIGHT(50% a, 50% b) = 50% a + 50% b**
		

Image logical (binary) operations I

Logical operations between binary (BW) images (binary point operations) and between grey level ("a") and BW ("b") images (binary value 1 - white, binary value 0 - black)

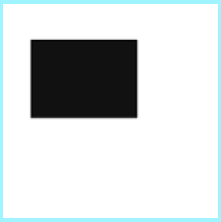
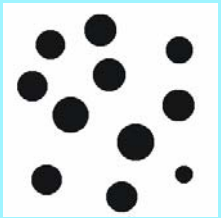
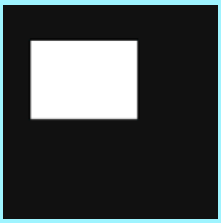
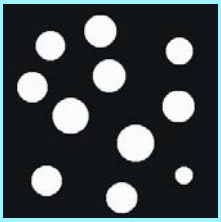
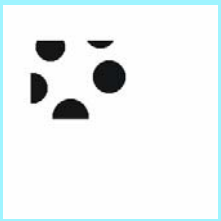
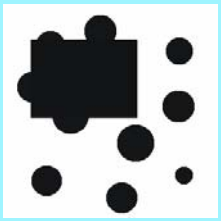
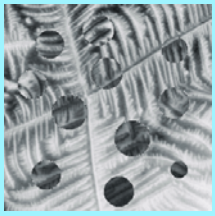
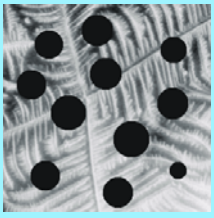
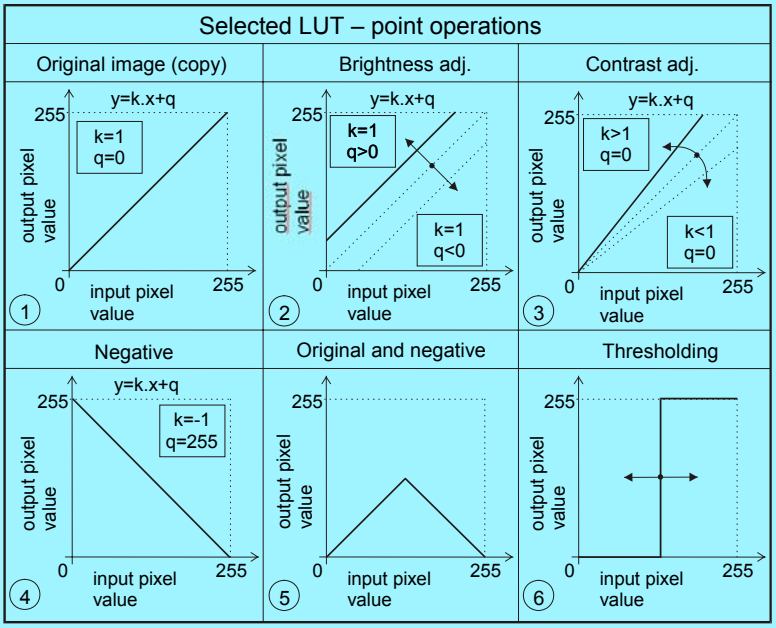
binary (BW) image "a"	binary (BW) image "b"	NOT(a) = $\bar{a}$
		
NOT(b) = $\bar{b}$	**OR(a,b) = a + b**	**AND(a,b) = a•b**
		

Image logical (binary) operations II

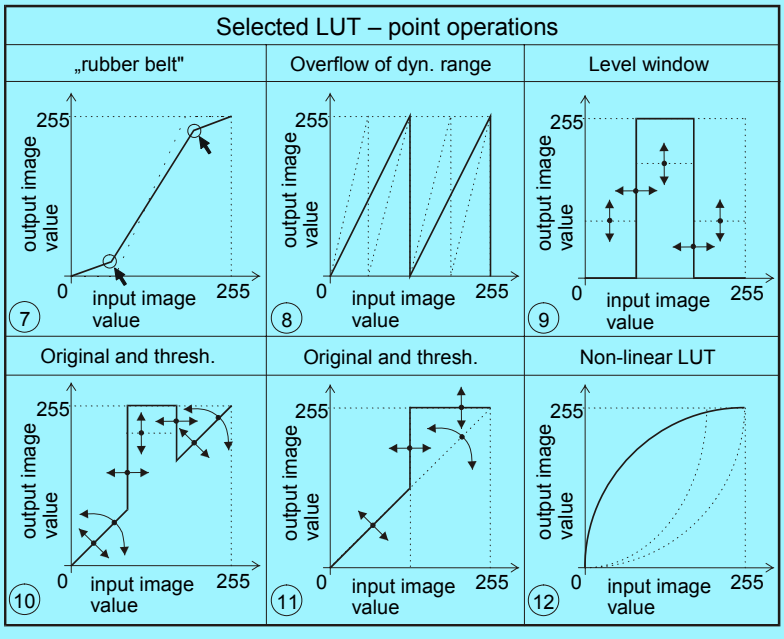
Logical operations between binary (BW) images (binary point operation) and between grey level ("a") and BW ("b") images (binary value 1 - white, binary value 0 - black)

XOR(a,b) = a⊕b = a•$\bar{b}$ + $\bar{a}$•b	SUB(a,b) = a \ b = a - b = a•$\bar{b}$	OR(a,b) = a + b
		
AND(a,b) = a b	**XOR(a,b) = a⊕b = a•$\bar{b}$ + $\bar{a}$•b**	**SUB(a,b) = a \ b = a - b = a•$\bar{b}$**
		

Look-Up-Tables (LUT) I



Look-Up-Tables (LUT) II



LUT implementation and application

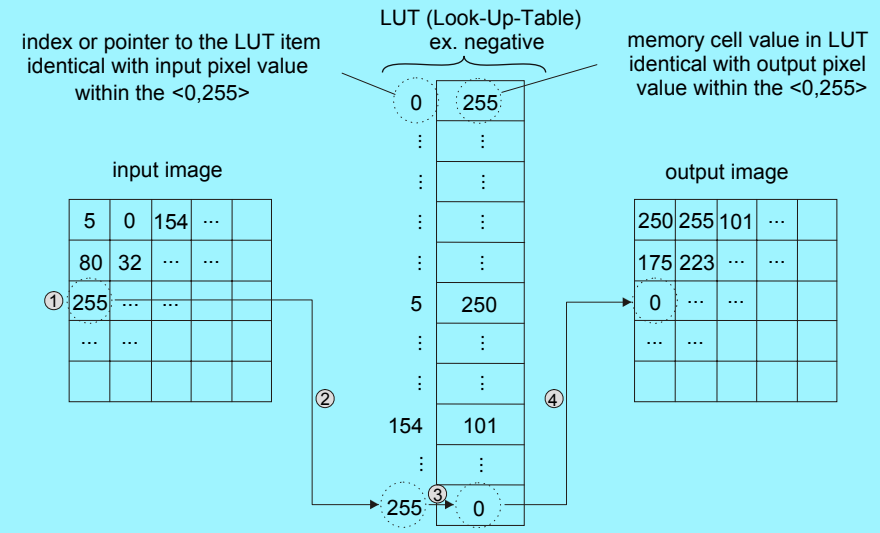


Image histograms I

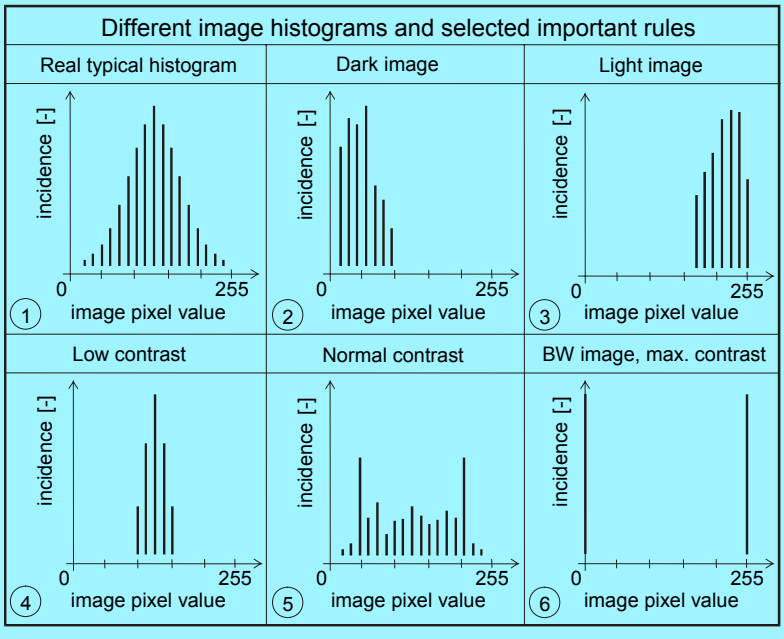
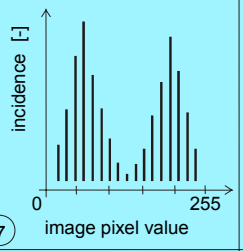
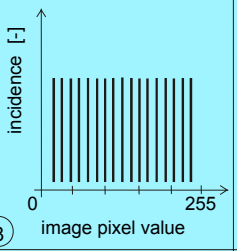
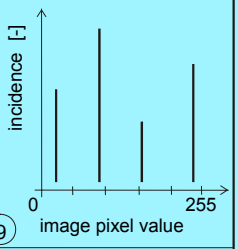
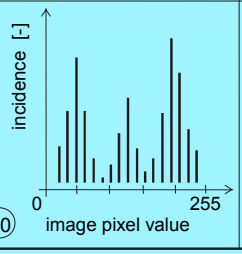


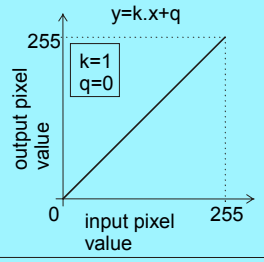
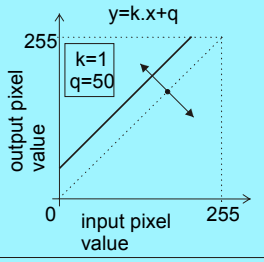
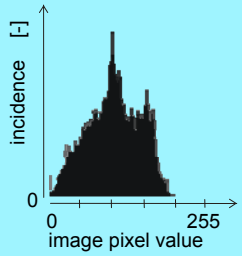
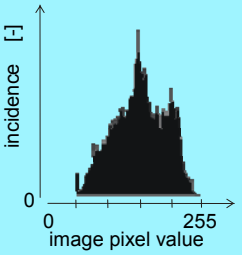
Image histograms II

Different image histograms and selected important rules		
Bimodal histogram	Ideal unreal histogram	4 grey levels in image
 (7)	 (8)	 (9)
Trimodal histogram	Rule No.1 and 2	Rule No. 3 and 4
 (10)	1. Histogram has no relationship to the position of pixel within the image. 2. There is possible to determine an area, that is related to the grey level. (11)	3. Sum of all incidences is equal to number of pixels within the image. 4. Before the histogram computation there is required to reset 1D array where are saved histogram incidences. (12)

Aspects of constant addition to image I

Operat. ⇨	Constant addition to orig. image (brightness increasing)	
⇩ **Subject**	Before the operation (input)	After the operation (output)
Image		
Image data (small detail of the left eye)	56 53 48 49 101 38 22 69 16 36 76 84 196 27 21 22 18 109 14 16 74 27 14 8 22	106 103 98 99 151 88 72 119 66 86 126 134 246 77 71 72 68 159 64 66 124 77 64 58 72

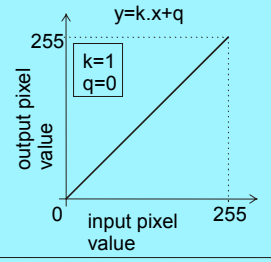
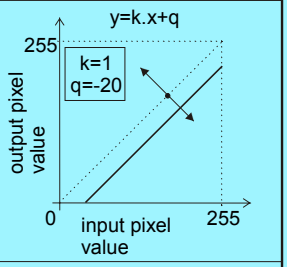
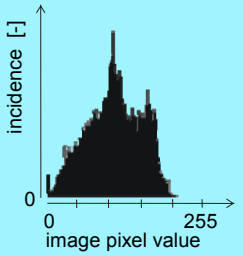
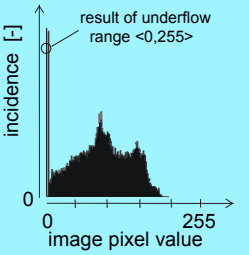
Aspects of constant addition to image II

Operat. ⇨	Constant addition to the orig. image (brightness incr.)	
⇩ Subject	Before the operation (input)	After the operation (output)
LUT		
Histogram		

Aspects of constant subtraction from image I

Operat. ⇨	Constant subtraction from image (brightness decreas.)	
⇩ Subject	Before the operation (input)	After the operation (output)
Image		
Image data (small detail of the left eye)	56 53 48 49 101 38 22 69 16 36 76 84 196 27 21 22 18 109 14 16 74 27 14 8 22	36 33 28 29 81 18 2 49 0 16 56 64 176 7 1 2 0 89 0 0 54 7 0 0 2

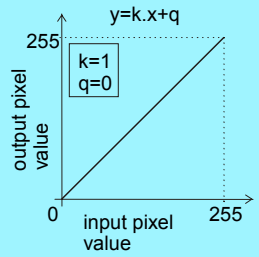
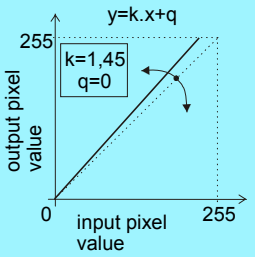
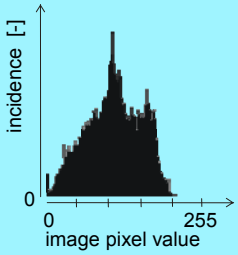
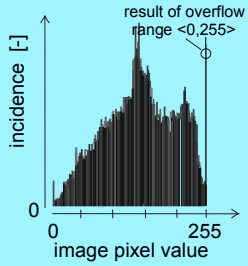
Aspects of constant subtraction from image II

Operat. ⇨	Constant subtraction from image (brightness decreas.)	
⇩ Subject	Before the operation (input)	After the operation (output)
LUT		
Histogram		

Aspects of image multiplication by constant I

Operat. ⇨	Image multiplication by constant (contrast increasing)	
⇩ Subject	Before the operation (input)	After the operation (output)
Image		
Image data (small detail of the left eye)	56 53 48 49 101 38 22 69 16 36 76 84 196 27 21 22 18 109 14 16 74 27 14 8 22	80 76 69 70 145 54 31 99 23 51 109 120 255 39 30 31 26 156 20 23 106 39 20 11 31

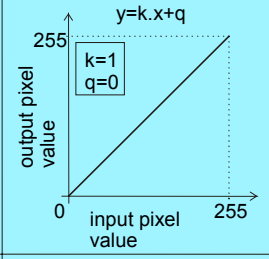
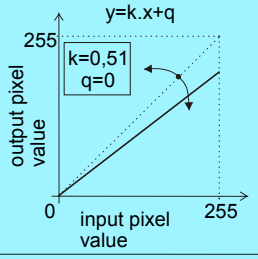
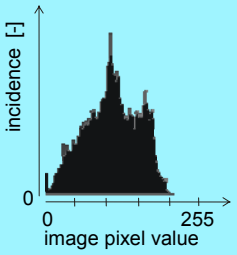
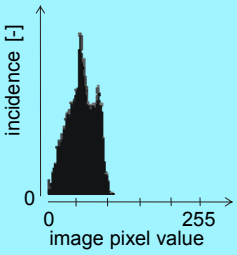
Aspects of image multiplication by constant II

Operat. ⇨	Image multiplication by constant (contrast increasing)	
⇩ Subject	Before the operation (input)	After the operation (output)
LUT		
Histogram		

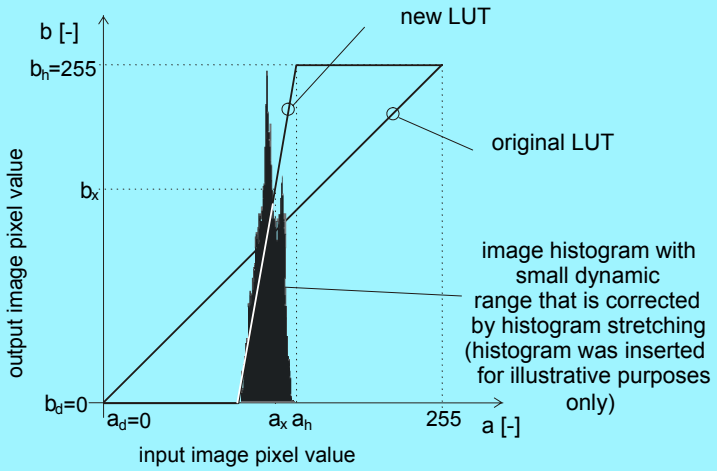
Aspects of image division by constant I

Operat. ⇨	Image division by constant (contrast decreasing)	
⇩ Subject	Before the operation (input)	After the operation (output)
Image		
Image data (small detail of the left eye)	56 53 48 49 101 38 22 69 16 36 76 84 196 27 21 22 18 109 14 16 74 27 14 8 22	29 27 25 25 52 19 11 35 8 18 39 43 101 14 11 11 9 56 7 8 38 14 7 4 11

Aspects of image division by constant II

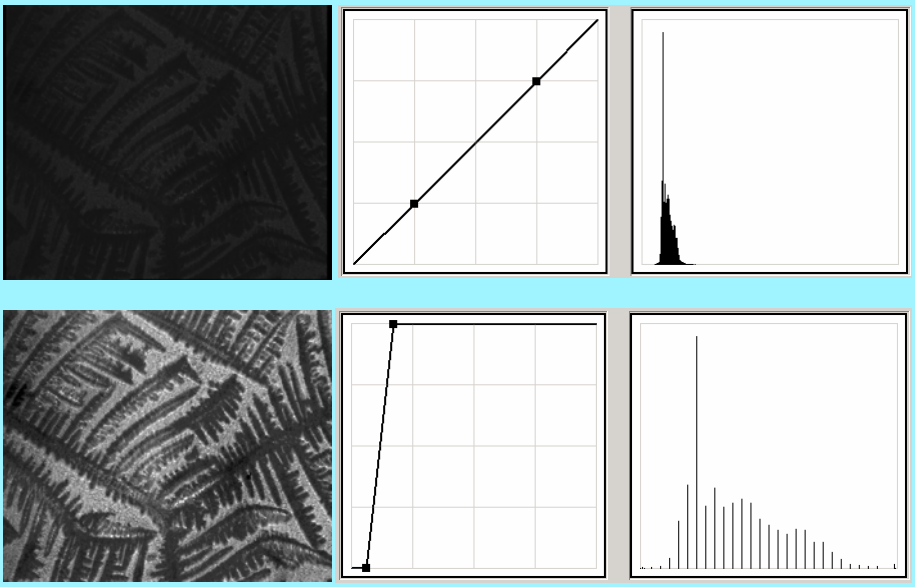
Operat. ⇨	Image division by constant (contrast decreasing)	
⇩ Subject	Before the operation (input)	After the operation (output)
LUT		
Histogram		

Histogram stretching I

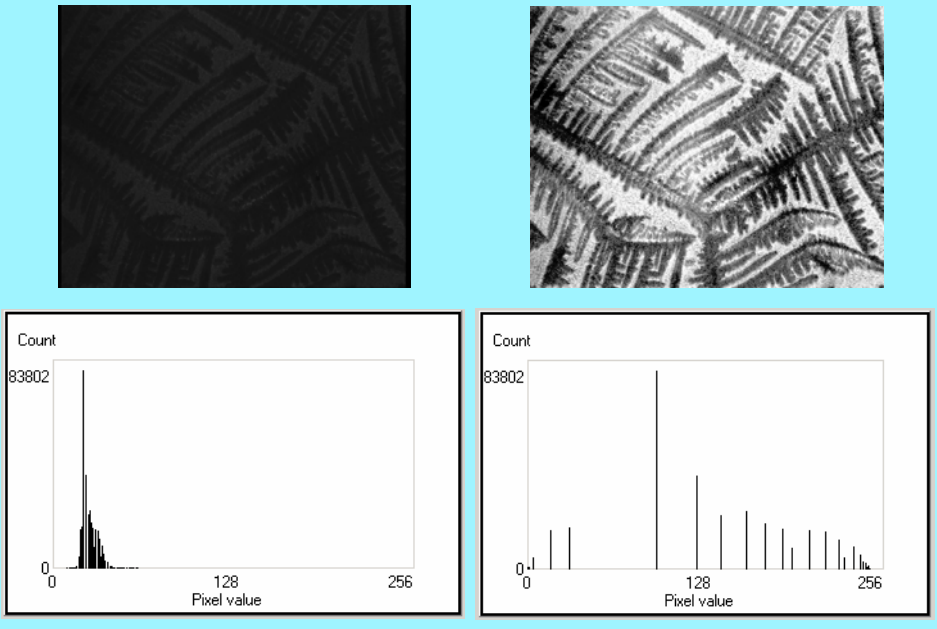


$$b_x = (a_x - a_d) * \left[\frac{(b_h - b_d)}{(a_h - a_d)} \right] + b_d$$

Histogram stretching II



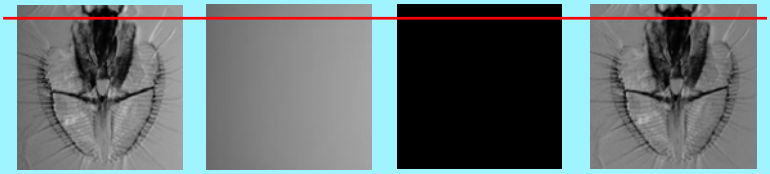
Histogram equalization



„Flat-field“ correction

$$I_{corr}(x,y) = \frac{I_{orig}(x,y) - I_{dark}(x,y)}{I_{empty}(x,y) - I_{dark}(x,y)} K$$

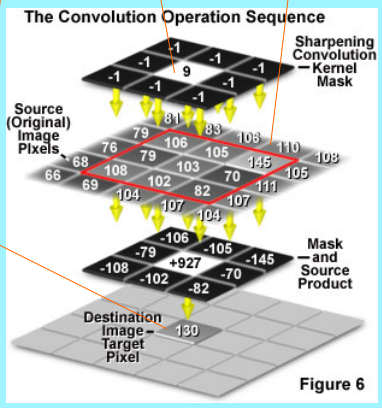
Original image | "flat-field" image | dark frame | corrected image

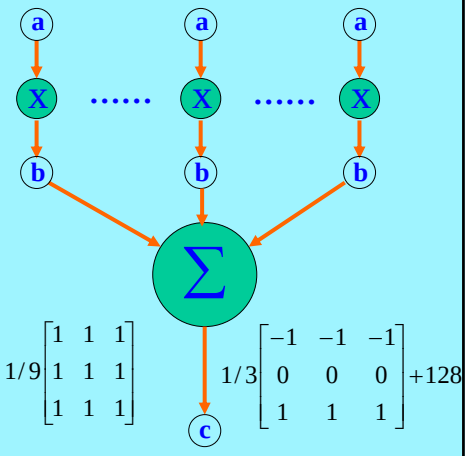


(images adopted from http://micro.magnet.fsu.edu)

2D convolution filtration

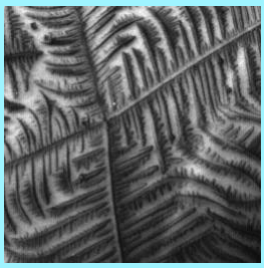
$$c(m,n) = a(m,n) \otimes b(m,n) = \sum_{j=-\infty}^{\infty} \sum_{k=-\infty}^{\infty} a(j,k) b(m-j, n-k)$$

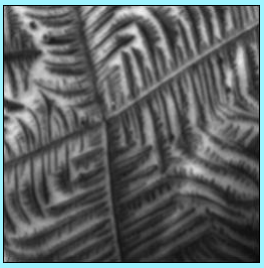


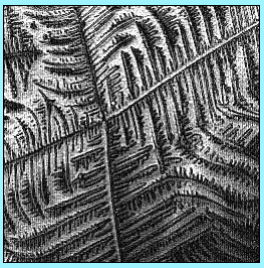


adopted from http://micro.magnet.fsu.edu

2D convolution filtration - examples

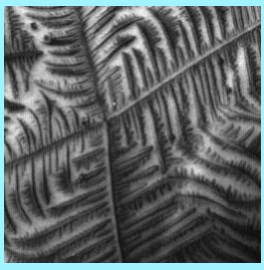


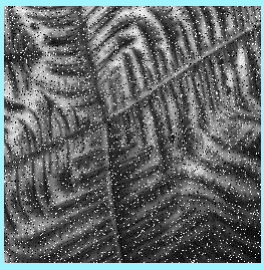




$$\frac{1}{9}\begin{bmatrix}1 & 1 & 1\\ 1 & 1 & 1\\ 1 & 1 & 1\end{bmatrix} \qquad \begin{bmatrix}-1 & -1 & -1\\ -1 & 9 & -1\\ -1 & -1 & -1\end{bmatrix}$$

Median filtration

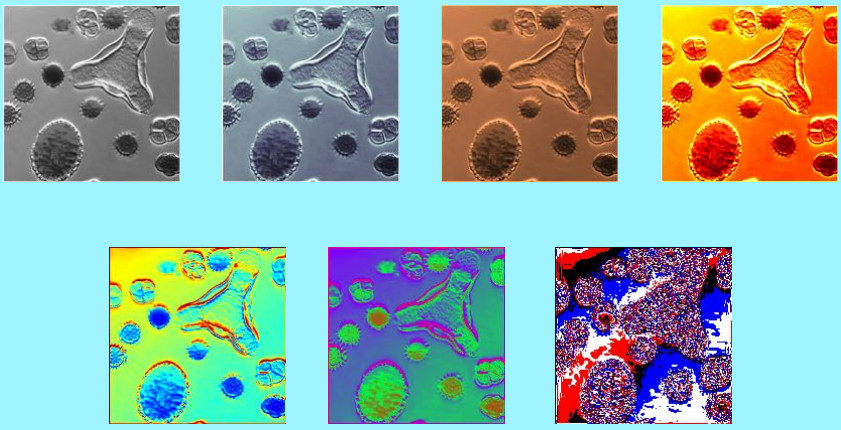




$$\begin{bmatrix}10 & 0 & 89\\ 255 & 56 & 131\\ 0 & 178 & 255\end{bmatrix} \rightarrow [0 \quad 0 \quad 10 \quad 56 \quad 89 \quad 131 \quad 178 \quad 255 \quad 255]$$

MEDIAN

Pseudo-colours



Overview of SW for image processing in Microscopy I

LUCIA

- http://www.lim.cz

QuickPHOTO MICRO

- http://www.quickphoto.cz, http://www.olympus.cz

UCSF, Jain Lab (free)

- http://www.jainlab.org

Morphometrics (free)

- http://life.bio.sunysb.edu/morph

Overview of SW for image processing in Microscopy II

The Visualization Toolkit - VTK (free)

- http://www.kitware.com

CorelDraw

- http://www.corel.com

Photoshop

- http://www.adobe.com

Matlab (versus Maple, MathCad)

- http://www.mathworks.com, http://www.humusoft.cz

SW (free, public domain)

MIPS (MS Windows) - educational

- http://webzam.fbmi.cvut.cz/hozman

Image Magick (MS Windows, Linux, Unix)

- http://www.imagemagick.org

XFig (Linux, Unix)

- http://www.xfig.org

WWW page with useful links

http://webzam.fbmi.cvut.cz/hozman

- free download of educational SW MIPS (Microscopy Image Processing Software, with Menu in English and help in Czech)
- free download of lecture (PDF file in Czech),
- free download of presentation (PDF and PPT in English),
- useful links to the image processing topics

Thank you for your attention