

Image Sensing and Digitization

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<http://www.fbmi.cvut.cz>

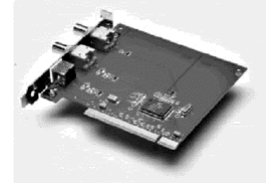
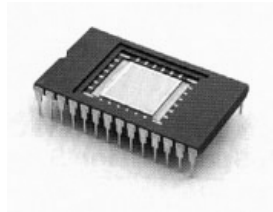


Image sensing devices I



Image sensing devices II

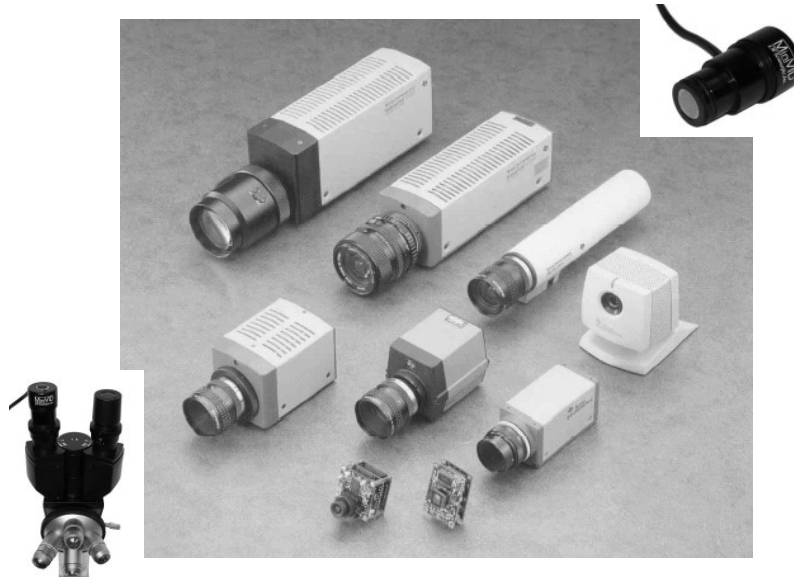
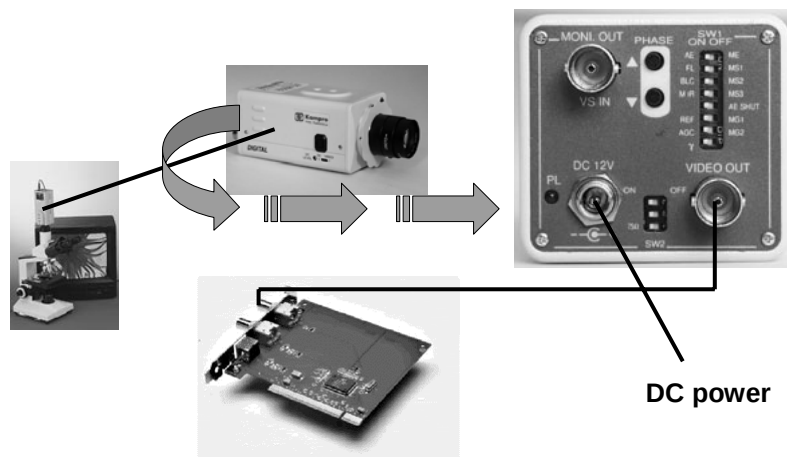


Image sensing devices III



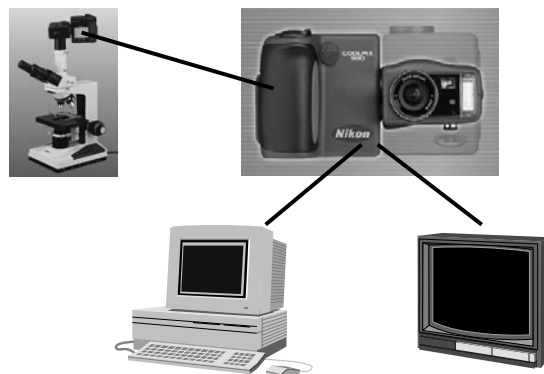
Possibilities, how to sense image (1)

- analogue TV videocamera + frame grabber



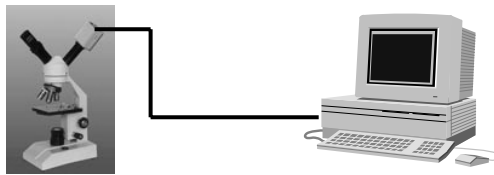
Possibilities, how to sense image (2)

- 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.

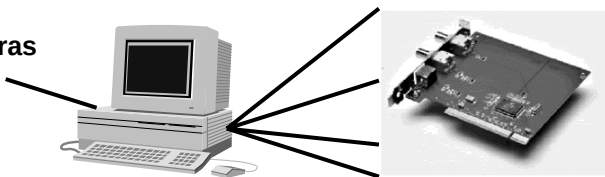
- 1.2 to 5.8 million pixels
- Outstanding image quality
- Color or monochrome
- High sensitivity
- COOLED CCD
- Long integration exposure
- Very easy to learn & operate



Computers possibilities

- standard PC with frame grabber (FG)

digital videocameras with IEEE 1394 (FireWire)



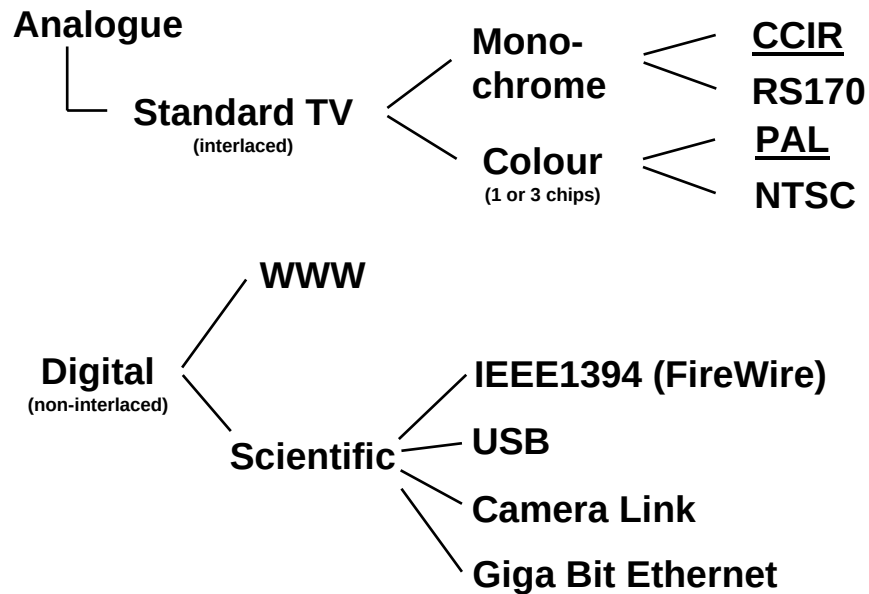
- laptops with FG (PCMCIA + ext. module)

standard TV camera



digital videocameras with IEEE 1394 (FireWire)

Sensing videocameras



Basic system configuration

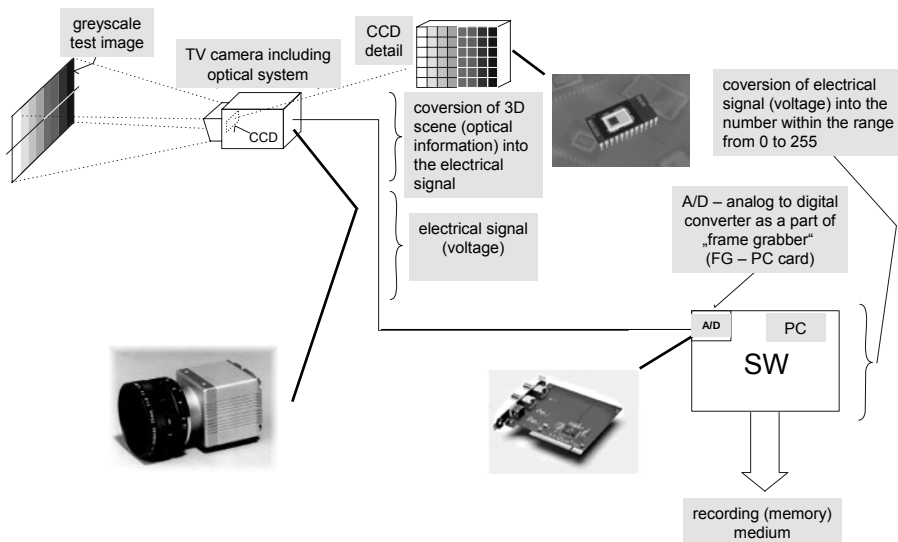
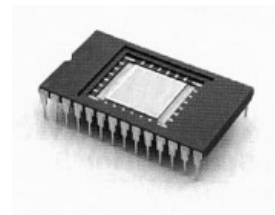
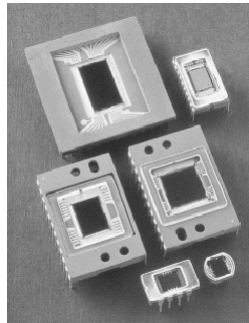
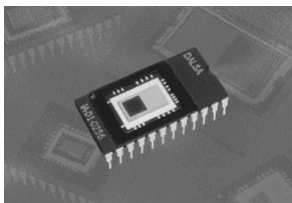
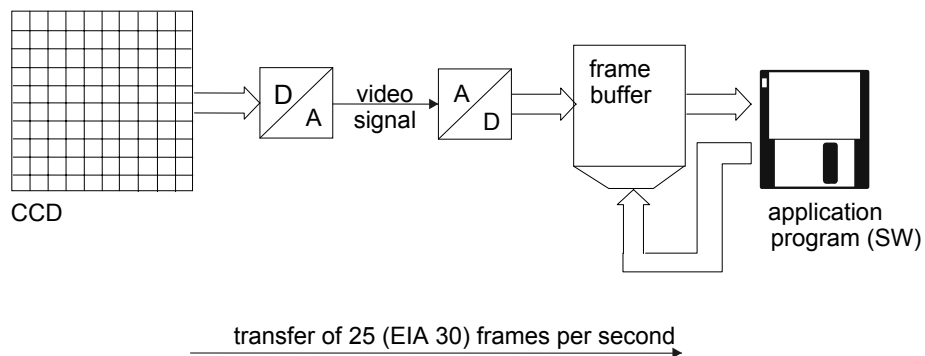


Image sensing elements

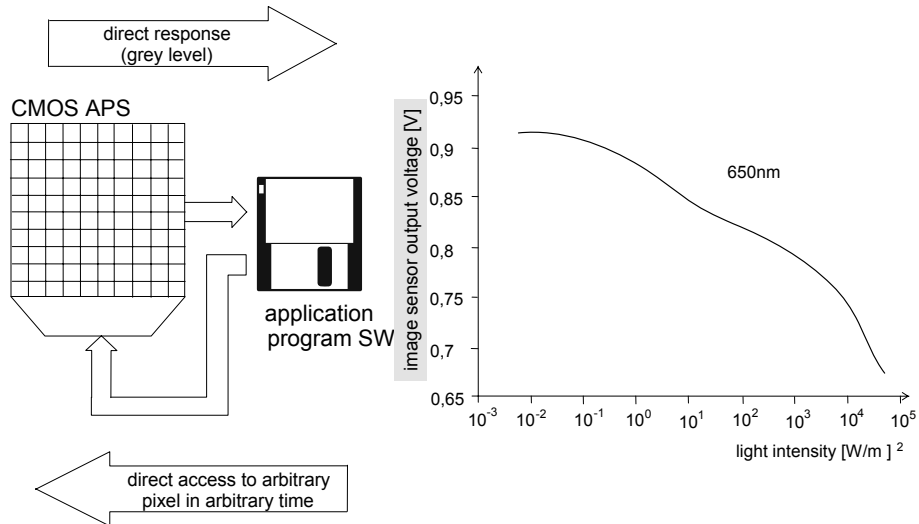
- vacuum tubes
- semiconductor
 - CCD
 - CID
 - CMOS
 - CIS



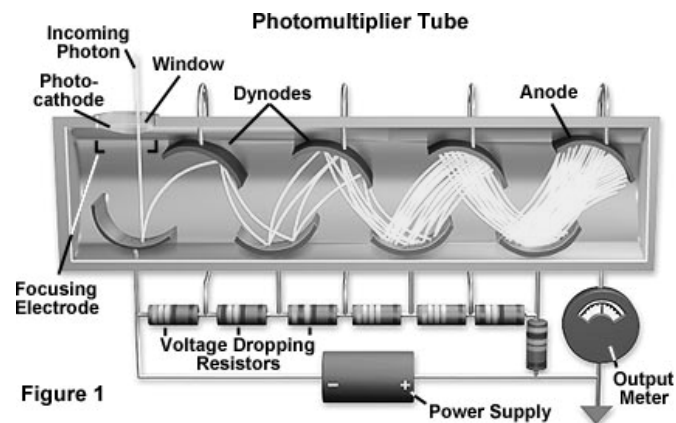
Basic system configuration with CCD image sensor



Basic system configuration with CMOS image sensor

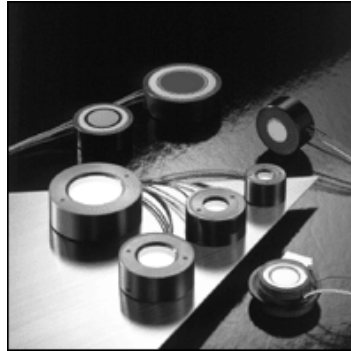


PMT („photomultiplier tube“) (adopted from <http://micro.magnet.fsu.edu>)



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

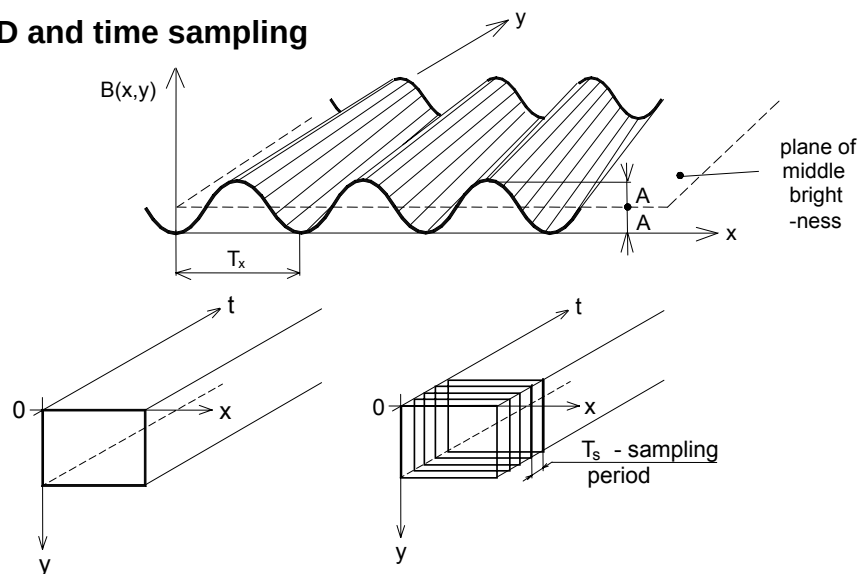


Image digitization (sampling) II

- spatial sampling

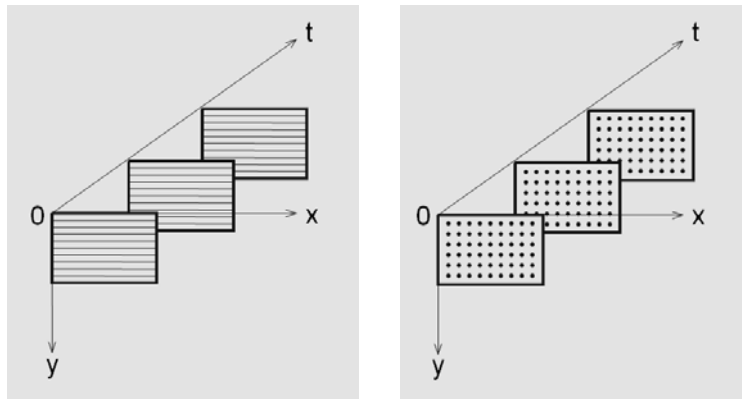
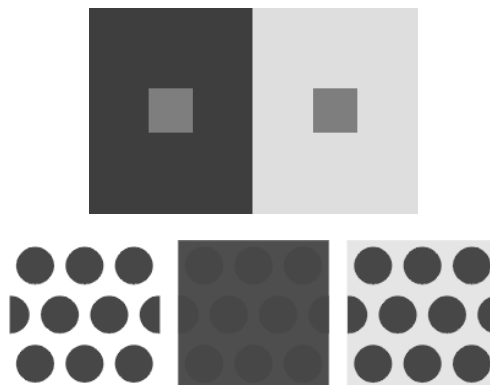


Image digitization (sampling) III

- level digitization (quantization)

- brightness and contrast perception



Fundamentals of Digital Image Processing

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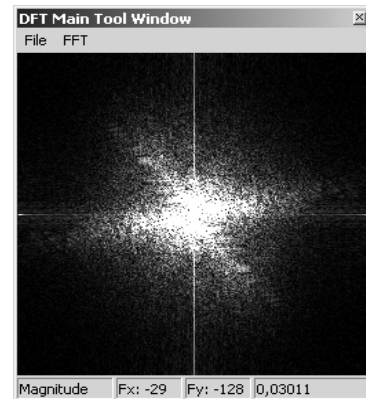


Image as two-dimensional matrix

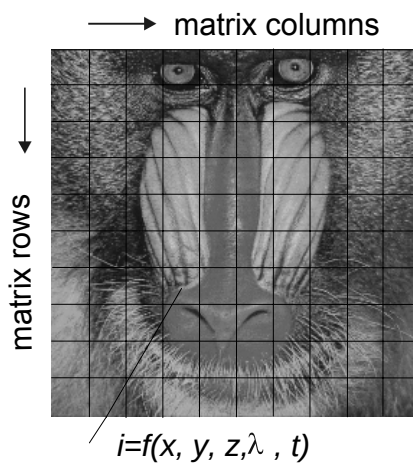
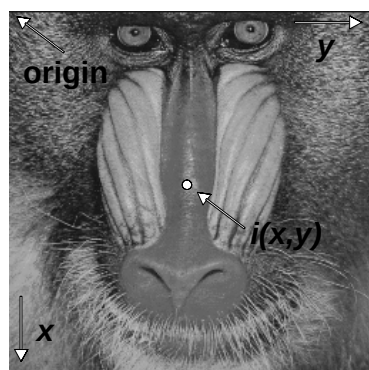


Image as 3D relief

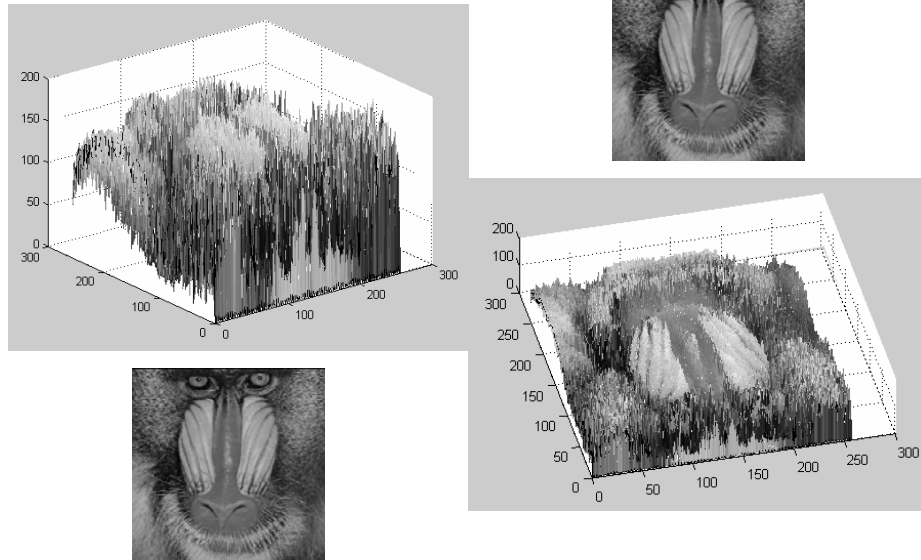


Image resolution and number of grey levels

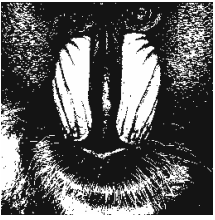
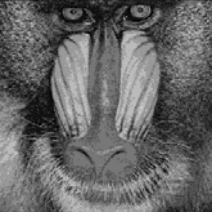
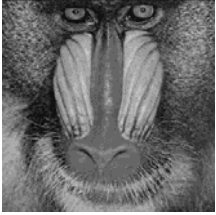
Image resolution		Different number of grey levels	
256 x 256 pixels		2 grey levels	4 grey levels
			
128 x 128 pixels		8 grey levels	16 grey levels
			

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

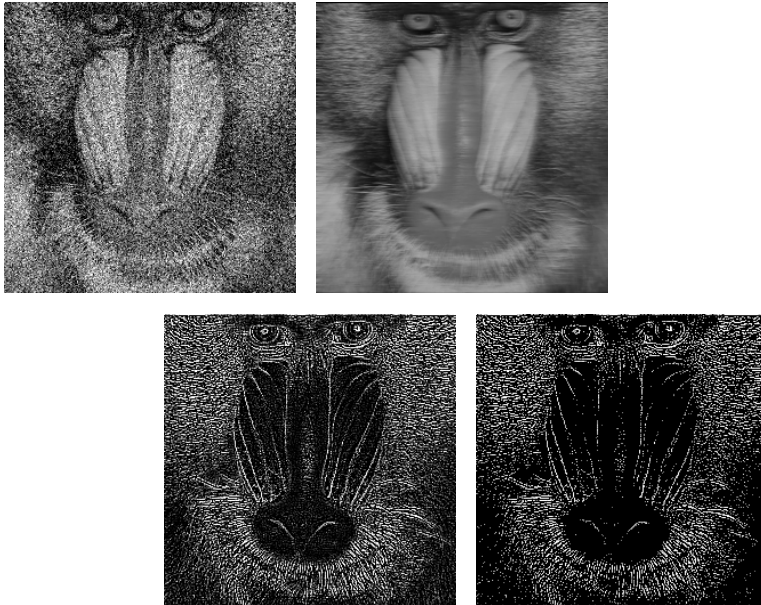


Image operations and pixel neighbourhood

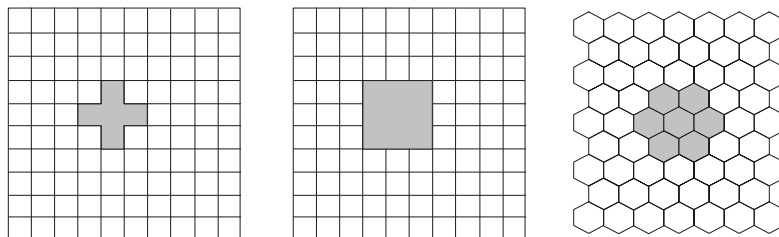
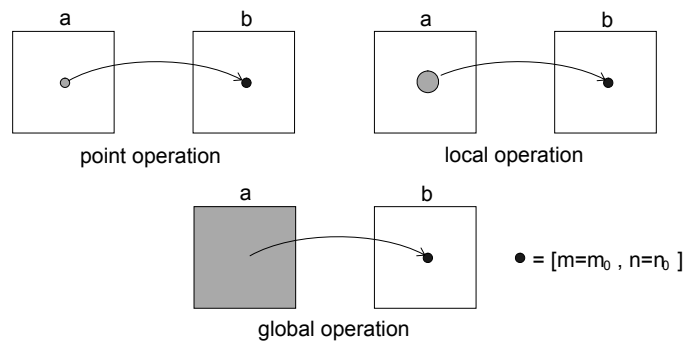


Image arithmetic operations I

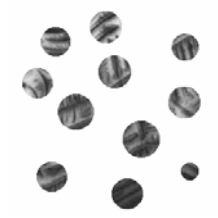
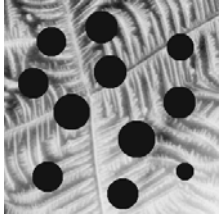
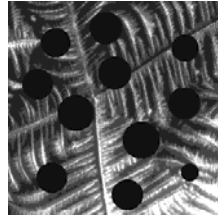
Arithmetic operation between grey level image ("a") and BW ("b") images and greylevel images, (255 (1) corresponds to white, 0 (0) corresponds to black)		
↕ grey level image "a" ↕	↕ binary (BW) image "b" ↕	↕ $ADD(a,b) = a + b$ ↕
		
↕ $SUB(a,b) = a - b$ ↕	↕ $MULT(a,b) = a \cdot b$ ↕	↕ $DIV(a,b) = a / b$ ↕
		

Image arithmetic operations II

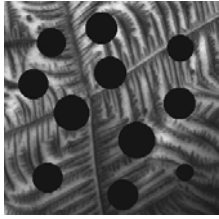
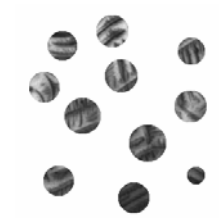
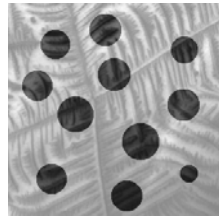
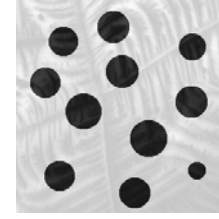
Arithmetic operations between grey level ("a") and BW ("b") images and between grey level images, (255 (1) corresponds to white, 0 (0) corresponds to black)		
↕ $MIN(a,b)$ ↕	↕ $MAX(a,b)$ ↕	↕ $AVE(a,b) = \text{average}$ ↕
		
↕ $OVERLAY(a,b)$ ↕	↕ $WEIGHT(25\% a, 75\% b) = 25\% a + 75\% b$ ↕	↕ $WEIGHT(50\% a, 50\% b) = 50\% a + 50\% b$ ↕
		

Image logical (binary) operations I

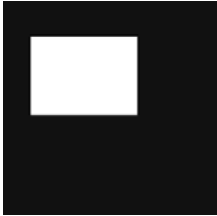
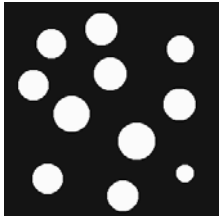
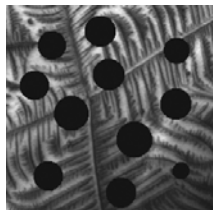
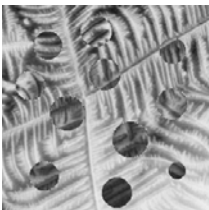
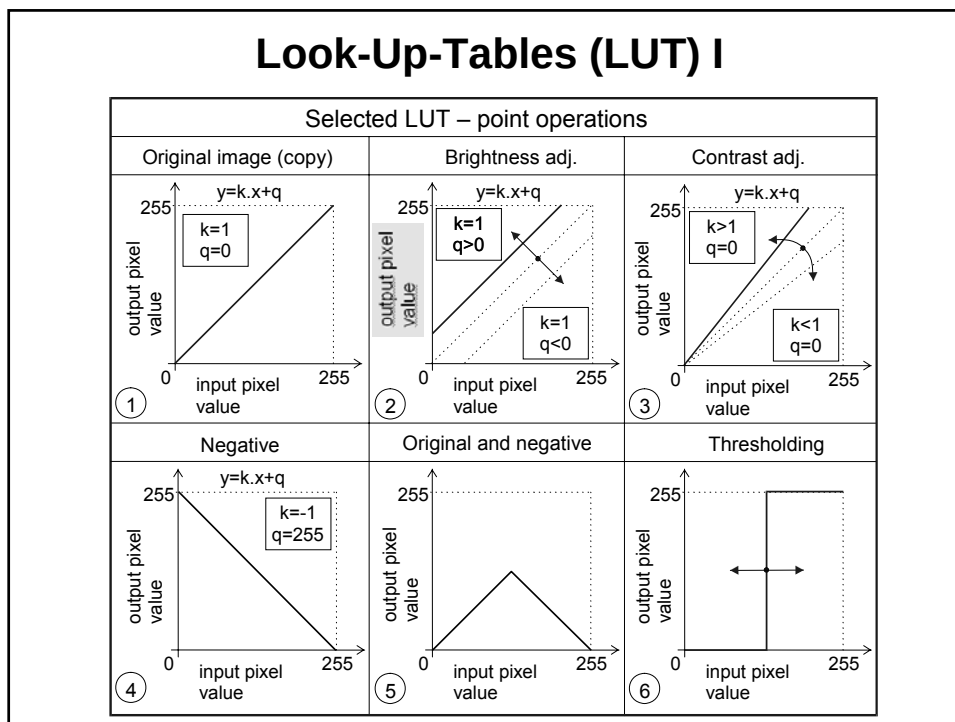
Logical operations between binary (BW) images (binary point operations) and between grey level ("a") and BW ("b") images (binary value 1 - white, binary value 0 - black)		
binary (BW) image "a"	binary (BW) image "b"	$\text{NOT}(a) = \bar{a}$
		
$\text{NOT}(b) = \bar{b}$	$\text{OR}(a,b) = a + b$	$\text{AND}(a,b) = a \cdot b$
		

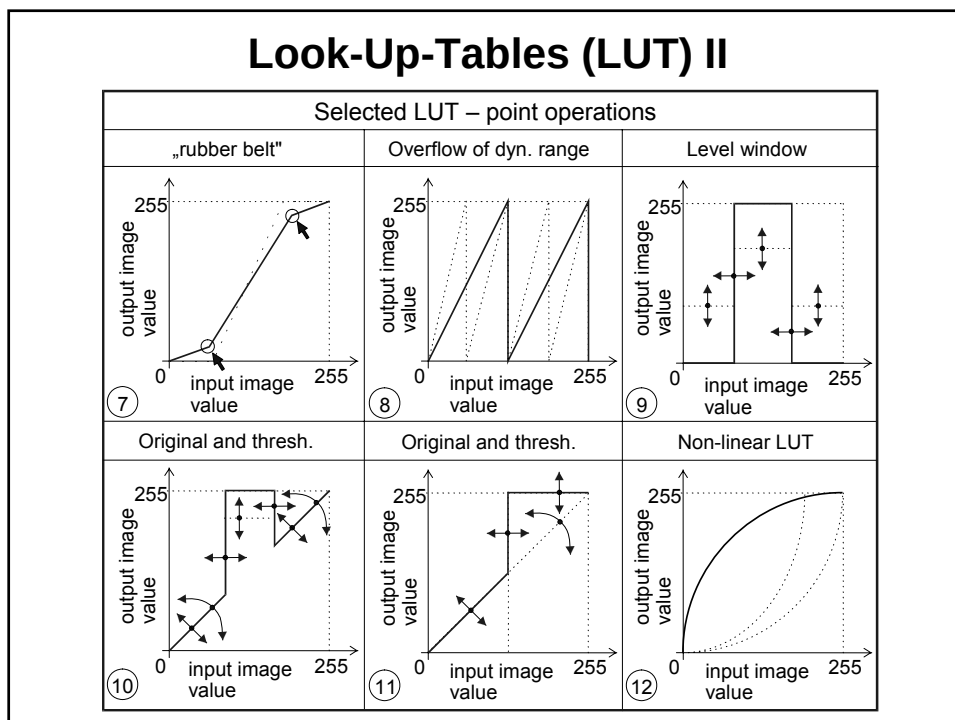
Image logical (binary) operations II

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)		
$\text{XOR}(a,b) = a \oplus b = a \cdot \bar{b} + \bar{a} \cdot b$	$\text{SUB}(a,b) = a \setminus b = a - b = a \cdot \bar{b}$	$\text{OR}(a,b) = a + b$
		
$\text{AND}(a,b) = a \cdot b$	$\text{XOR}(a,b) = a \oplus b = a \cdot \bar{b} + \bar{a} \cdot b$	$\text{SUB}(a,b) = a \setminus b = a - b = a \cdot \bar{b}$
		

Look-Up-Tables (LUT) I



Look-Up-Tables (LUT) II



LUT implementation and application

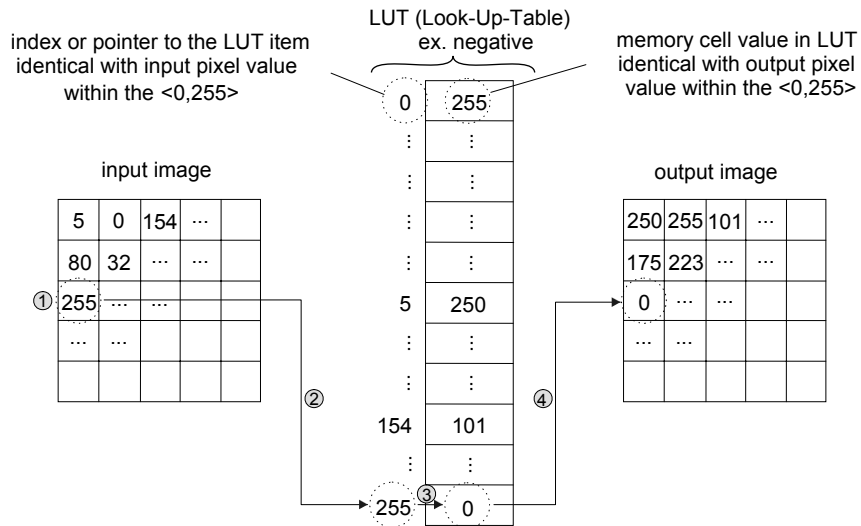


Image histograms I

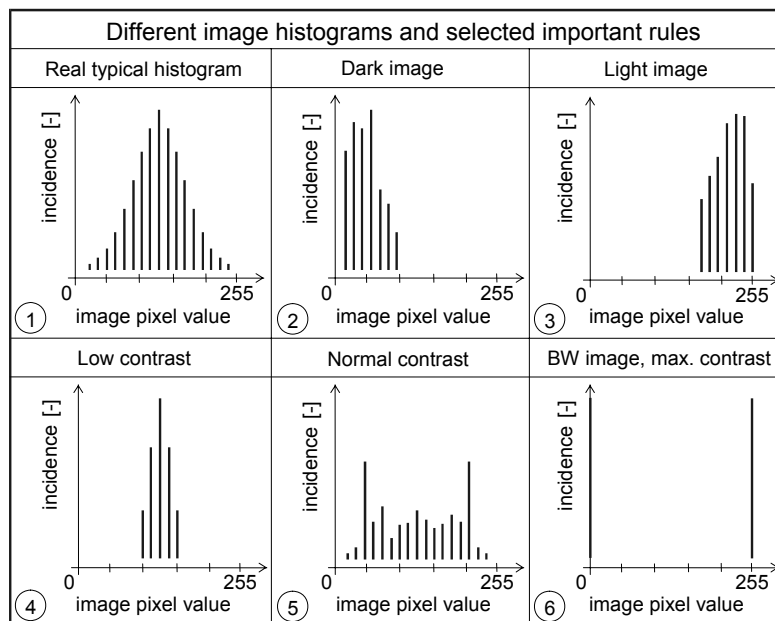
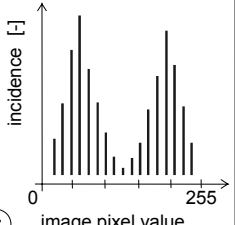
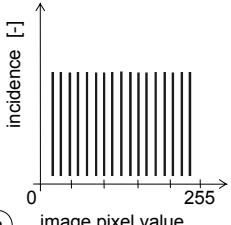
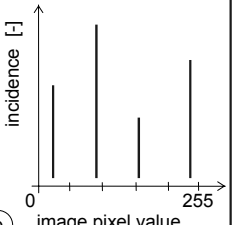
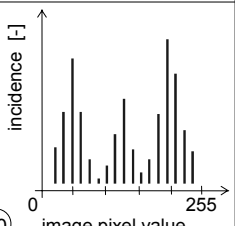
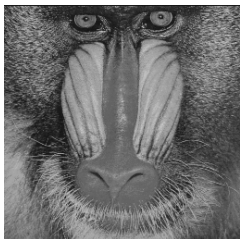
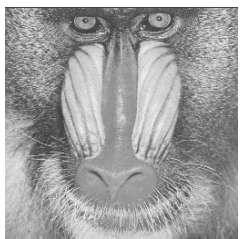


Image histograms II

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	⑪ 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.	⑫ 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.

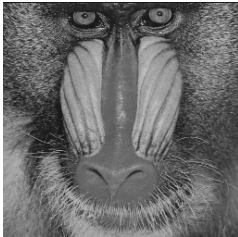
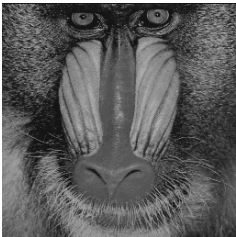
Aspects of constant addition to image I

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)	<table><tr><td>56</td><td>53</td><td>48</td><td>49</td><td>101</td></tr><tr><td>38</td><td>22</td><td>69</td><td>16</td><td>36</td></tr><tr><td>76</td><td>84</td><td>196</td><td>27</td><td>21</td></tr><tr><td>22</td><td>18</td><td>109</td><td>14</td><td>16</td></tr><tr><td>74</td><td>27</td><td>14</td><td>8</td><td>22</td></tr></table>	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	<table><tr><td>106</td><td>103</td><td>98</td><td>99</td><td>151</td></tr><tr><td>88</td><td>72</td><td>119</td><td>66</td><td>86</td></tr><tr><td>126</td><td>134</td><td>246</td><td>77</td><td>71</td></tr><tr><td>72</td><td>68</td><td>159</td><td>64</td><td>66</td></tr><tr><td>124</td><td>77</td><td>64</td><td>58</td><td>72</td></tr></table>	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
56	53	48	49	101																																																
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72	68	159	64	66																																																
124	77	64	58	72																																																

Aspects of constant addition to image II

Operat. $\Rightarrow$	Constant addition to the orig. image (brightness incr.)	
$\Downarrow$ Subject	Before the operation (input)	After the operation (output)
LUT		
Histogram		

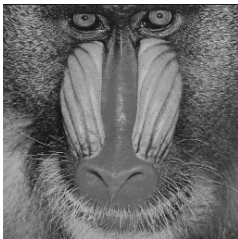
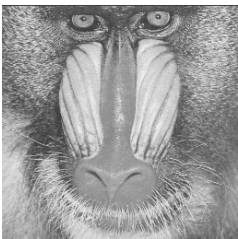
Aspects of constant subtraction from image I

Operat. $\Rightarrow$	Constant subtraction from image (brightness decreases.)																																																			
$\Downarrow$ Subject	Before the operation (input)	After the operation (output)																																																		
Image																																																				
Image data (small detail of the left eye)	<table><tr><td>56</td><td>53</td><td>48</td><td>49</td><td>101</td></tr><tr><td>38</td><td>22</td><td>69</td><td>16</td><td>36</td></tr><tr><td>76</td><td>84</td><td>196</td><td>27</td><td>21</td></tr><tr><td>22</td><td>18</td><td>109</td><td>14</td><td>16</td></tr><tr><td>74</td><td>27</td><td>14</td><td>8</td><td>22</td></tr></table>	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	<table><tr><td>36</td><td>33</td><td>28</td><td>29</td><td>81</td></tr><tr><td>18</td><td>2</td><td>49</td><td>0</td><td>16</td></tr><tr><td>56</td><td>64</td><td>176</td><td>7</td><td>1</td></tr><tr><td>2</td><td>0</td><td>89</td><td>0</td><td>0</td></tr><tr><td>54</td><td>7</td><td>0</td><td>0</td><td>2</td></tr></table>	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
56	53	48	49	101																																																
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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 decreases.)	
↓ Subject	Before the operation (input)	After the operation (output)
LUT	$y=k.x+q$ $k=1$ $q=0$	$y=k.x+q$ $k=1$ $q=-20$
Histogram	incidence [-] 0 255 image pixel value	incidence [-] 0 255 image pixel value result of underflow range $<0,255>$

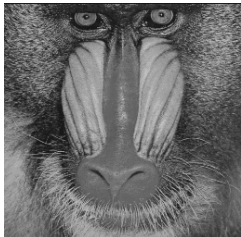
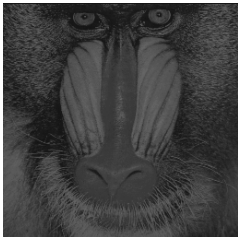
Aspects of image multiplication by constant I

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)	<table><tr><td>56</td><td>53</td><td>48</td><td>49</td><td>101</td></tr><tr><td>38</td><td>22</td><td>69</td><td>16</td><td>36</td></tr><tr><td>76</td><td>84</td><td>196</td><td>27</td><td>21</td></tr><tr><td>22</td><td>18</td><td>109</td><td>14</td><td>16</td></tr><tr><td>74</td><td>27</td><td>14</td><td>8</td><td>22</td></tr></table>	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	<table><tr><td>80</td><td>76</td><td>69</td><td>70</td><td>145</td></tr><tr><td>54</td><td>31</td><td>99</td><td>23</td><td>51</td></tr><tr><td>109</td><td>120</td><td>255</td><td>39</td><td>30</td></tr><tr><td>31</td><td>26</td><td>156</td><td>20</td><td>23</td></tr><tr><td>106</td><td>39</td><td>20</td><td>11</td><td>31</td></tr></table>	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
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Aspects of image multiplication by constant II

Operat. $\Rightarrow$	Image multiplication by constant (contrast increasing)	
$\downarrow$ Subject	Before the operation (input)	After the operation (output)
LUT		
Histogram		

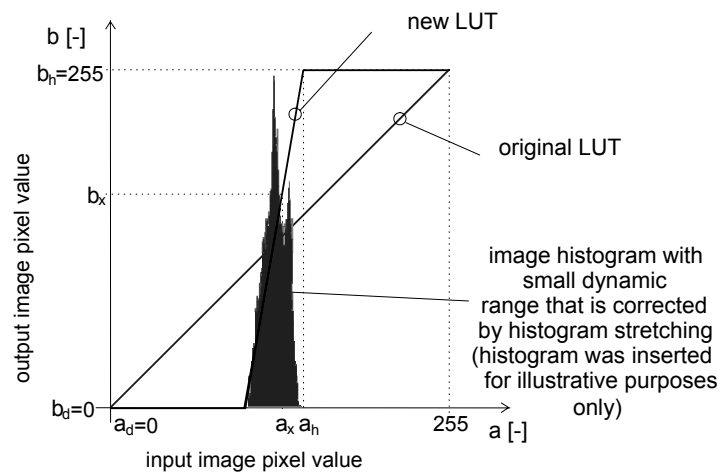
Aspects of image division by constant I

Operat. $\Rightarrow$	Image division by constant (contrast decreasing)																																																			
$\Downarrow$ Subject	Before the operation (input)	After the operation (output)																																																		
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Aspects of image division by constant II

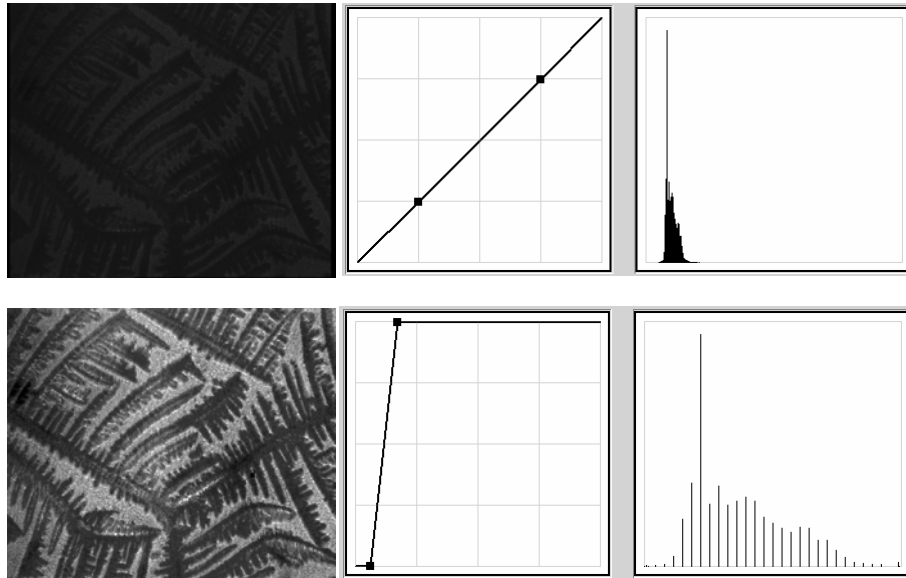
Operat. $\Rightarrow$	Image division by constant (contrast decreasing)	
$\downarrow$ Subject	Before the operation (input)	After the operation (output)
LUT	$y=k.x+q$ $k=1$ $q=0$	$y=k.x+q$ $k=0,51$ $q=0$
Histogram	incidence [-] 0 255 image pixel value	incidence [-] 0 255 image pixel value

Histogram stretching I

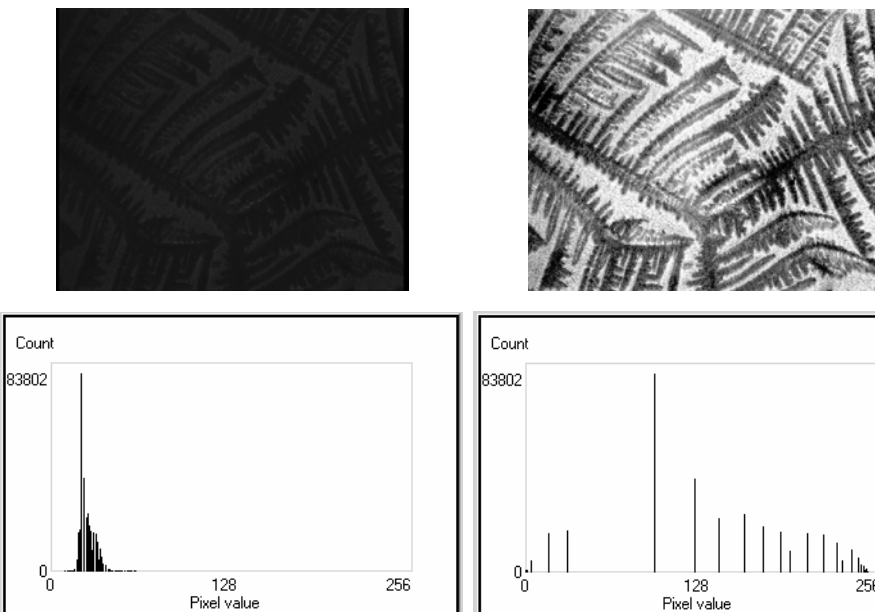


$$b_x = (a_x - a_d) * \left[\frac{(b_h - b_d)}{(a_h - a_d)} \right] + b_d$$

Histogram stretching II

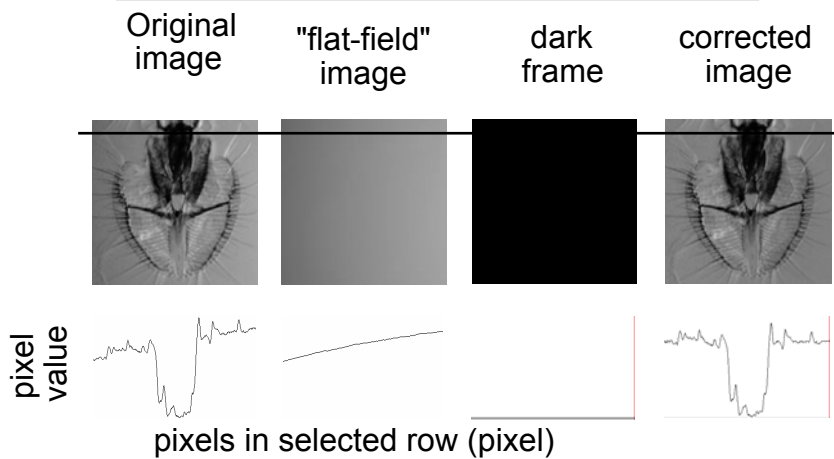


Histogram equalization



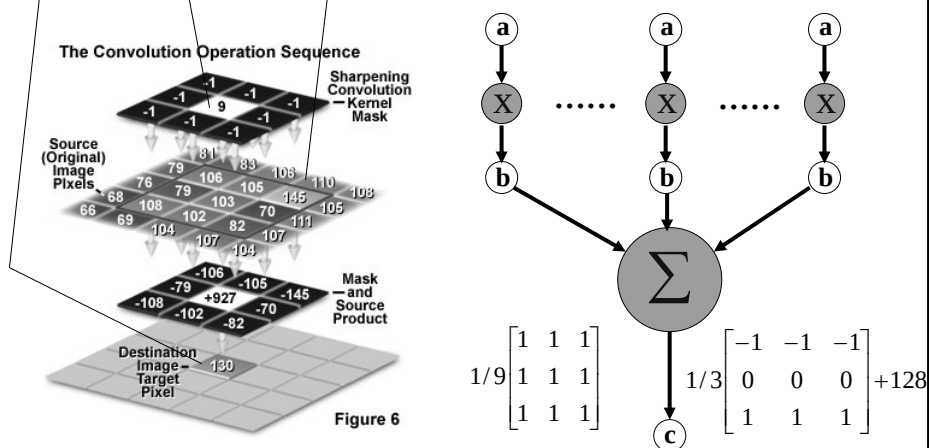
„Flat-field“ correction

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

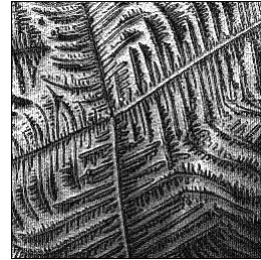
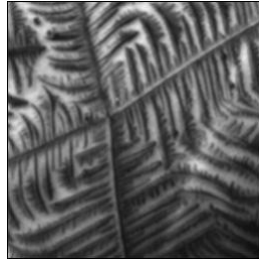


2D convolution filtration

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



2D convolution filtration - examples



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

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

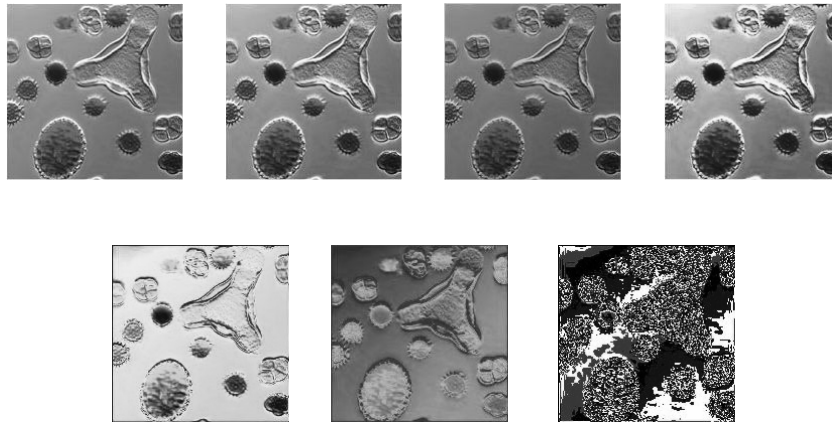
Median filtration



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

$\uparrow$
 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