Digital Image Processing

Image Enhancement 2
Spatial Filtering

From:
Digital Image Processing, Chapter 3
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Contents

In This lecture we will look more at spatial filtering techniques:

- *Negative transform*
- *Log transform*
- *Power law transform*
- *Image morphological filters*
  - Erosion
  - Dilation

Image Negatives

- Are obtained by using the transformation function s=T(r).
- [0,L-1] the range of gray levels

  $s = L\text{-}1\text{-}r$

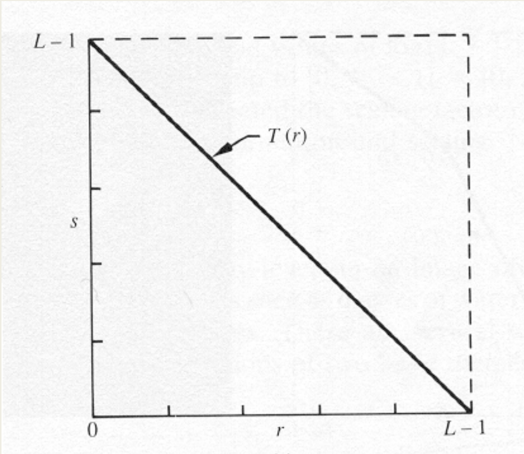

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Image Negatives

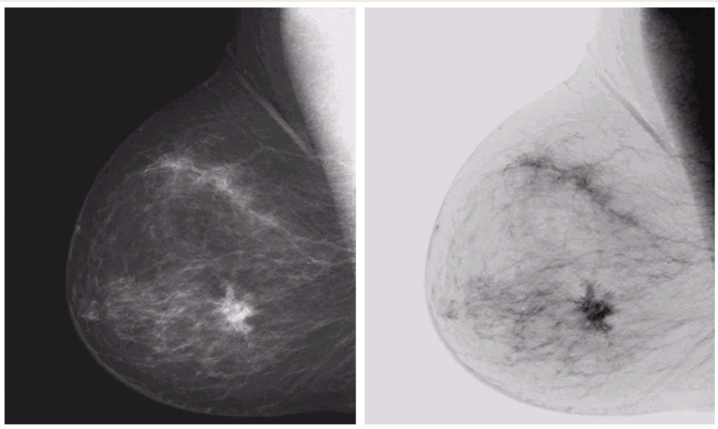

FIGURE 3.4 (a) Original digital mammogram. (b) Negative image obtained using the negative transformation in Eq. (3.2-1). (Courtesy of G.E. Medical Systems.)

- Digital equivalent of obtaining a photographic negative
- Useful for enhancing white or gray detail embedded in a large, predominantly dark region.

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$s = L-1-r, \quad L=256$

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51
52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77
78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103
104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129
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229	228	227	226	225	224	223	222	221	220	219	218	217	216	215	214	213	212	211	210	209	208	207	206	205	204
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73	72	71	70	69	68	67	66	65	64	63	62	61	60	59	58	57	56	55	54	53	52	51	50	49	48
47	46	45	44	43	42	41	40	39	38	37	36	35	34	33	32	31	30	29	28	27	26	25	24	23	22
21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0				

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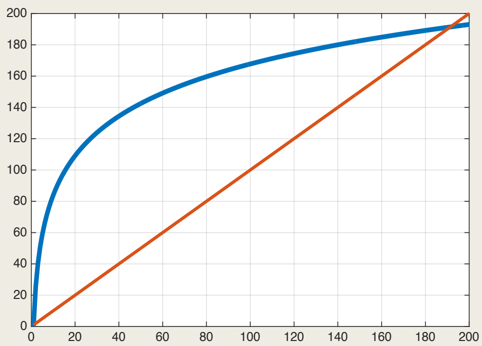
Log Transformations

$$s = c\,\log(1+r)$$

c: constant

Compresses the dynamic range of images with large variations in pixel values



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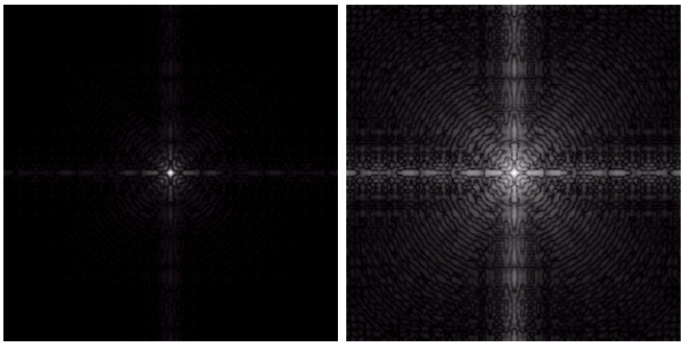
Log Transformations



a b

FIGURE 3.5
(a) Fourier spectrum.
(b) Result of applying the log transformation given in Eq. (3.2-2) with $c = 1$.

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$s = c \log(1+r)$, c=1

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51
52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77
78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103
104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129
130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153	154	155
156	157	158	159	160	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180	181
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234	235	236	237	238	239	240	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255				
0	32	51	64	74	82	89	96	101	106	110	114	118	121	125	128	130	133	135	138	140	142	144	146	148	150
152	153	155	156	158	159	161	162	163	165	166	167	168	170	171	172	173	174	175	176	177	178	179	180	181	182
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246	246	246	246	247	247	247	247	247	248	248	248	248	248	249	249	249	249	249	250	250	250	250	250	251	251
251	251	251	252	252	252	252	252	253	253	253	253	253	254	254	254	254	254	254	255	255	255				

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Power-Law Transformations

$$s = cr^{\gamma}$$

C, γ : positive constants

- Gamma correction

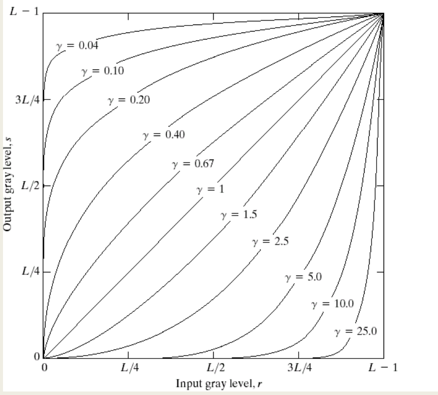

FIGURE 3.6 Plots of the equation $s = cr^{\gamma}$ for various values of γ ($c = 1$ in all cases).

- A family of possible transformation curves obtained simply by varying γ.
- The curves generated with values of γ >1 have exactly the opposite effect as those generated with values of γ < 1.

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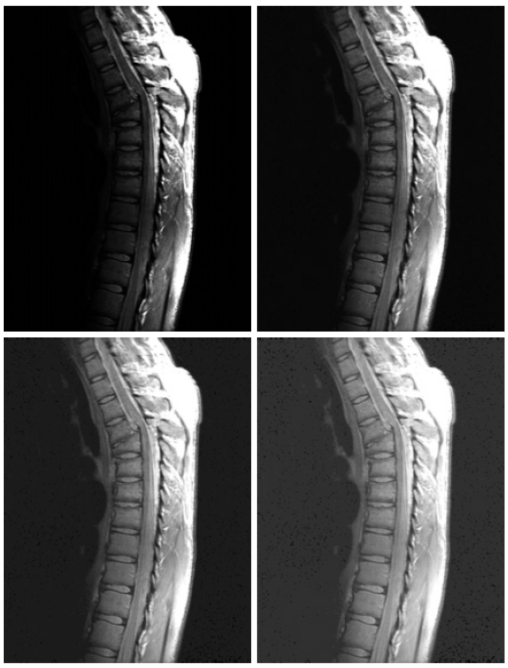
Power-Law Transformations



a b
c d

FIGURE 3.8 (a) Magnetic resonance (MR) image of a fractured human spine. (b)–(d) Results of applying the transformation in Eq. (3.2-3) with $c = 1$ and $\gamma = 0.6, 0.4,$ and 0.3, respectively. (Original image for this example courtesy of Dr. David R. Pickens, Department of Radiology and Radiological Sciences, Vanderbilt University Medical Center.)

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Power-Law Transformations

a b
c d

FIGURE 3.9 (a) Aerial image. (b)–(d) Results of applying the transformation in Eq. (3.2-3) with $c = 1$ and $\gamma = 3.0, 4.0,$ and 5.0, respectively. (Original image for this example courtesy of NASA.)

$$s = cr^{\gamma}, \ \ \gamma = 0.4, \quad c = 1$$

0.4																									
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51
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104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129
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234	235	236	237	238	239	240	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255				
0	28	37	43	48	53	57	61	64	67	70	73	75	78	80	82	84	86	88	90	92	94	96	97	99	101
102	104	105	107	108	110	111	113	114	115	117	118	119	120	122	123	124	125	126	127	129	130	131	132	133	134
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12

$$s = cr^{\gamma}, \;\; \gamma = 0.8, \;\; c = 1$$

0.8																									
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
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156	157	158	159	160	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180	181
182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207
208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233
234	235	236	237	238	239	240	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255				
0	3	5	7	9	11	13	14	16	18	19	21	22	24	25	26	28	29	31	32	33	35	36	37	39	40
41	42	44	45	46	47	48	50	51	52	53	54	56	57	58	59	60	61	63	64	65	66	67	68	69	70
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217	217	218	219	220	221	222	222	223	224	225	226	227	227	228	229	230	231	232	232	233	234	235	236	236	237
238	239	240	240	241	242	243	244	245	245	246	247	248	249	249	250	251	252	253	253	254	255				

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$$s = cr^{\gamma}, \;\; \gamma = 1, \;\; c = 1$$

1																									
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51
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0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
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$$s = cr^{\gamma}, \;\; \gamma = 1.5, \;\; c = 1$$

1.5																									
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51
52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77
78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103
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130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153	154	155
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234	235	236	237	238	239	240	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255				
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224	226	227	228	230	231	233	234	236	237	239	240	242	243	245	246	248	249	251	252	254	255				

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$$s = cr^{\gamma}, \;\; \gamma = 2, \;\; c = 1$$

2																									
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51
52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77
78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103
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156	157	158	159	160	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180	181
182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207
208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233
234	235	236	237	238	239	240	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255				
0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	2	2	2	2	2	2
3	3	3	3	4	4	4	4	5	5	5	5	6	6	6	7	7	7	8	8	8	9	9	9	10	10
11	11	11	12	12	13	13	14	14	15	15	16	16	17	17	18	18	19	19	20	20	21	21	22	23	23
24	24	25	26	26	27	28	28	29	30	30	31	32	32	33	34	35	35	36	37	38	38	39	40	41	42
42	43	44	45	46	47	47	48	49	50	51	52	53	54	55	56	56	57	58	59	60	61	62	63	64	65
66	67	68	69	70	71	73	74	75	76	77	78	79	80	81	82	84	85	86	87	88	89	91	92	93	94
95	97	98	99	100	102	103	104	105	107	108	109	111	112	113	115	116	117	119	120	121	123	124	126	127	128
130	131	133	134	136	137	139	140	142	143	145	146	148	149	151	152	154	155	157	158	160	162	163	165	166	168
170	171	173	175	176	178	180	181	183	185	186	188	190	192	193	195	197	199	200	202	204	206	207	209	211	213
215	217	218	220	222	224	226	228	230	232	233	235	237	239	241	243	245	247	249	251	253	255				

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$$s = cr^{\gamma}, \ \ \gamma = 3, \ \ c = 1$$

3																									
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51
52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77
78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103
104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129
130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153	154	155
156	157	158	159	160	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180	181
182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207
208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233
234	235	236	237	238	239	240	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255				
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2
2	2	2	3	3	3	3	3	3	3	4	4	4	4	4	5	5	5	5	6	6	6	6	6	7	7
7	8	8	8	8	9	9	9	10	10	10	11	11	12	12	12	13	13	14	14	14	15	15	16	16	17
17	18	18	19	19	20	20	21	22	22	23	23	24	25	25	26	27	27	28	29	29	30	31	32	32	33
34	35	35	36	37	38	39	40	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57
58	60	61	62	63	64	65	67	68	69	70	72	73	74	76	77	78	80	81	82	84	85	87	88	90	91
93	94	96	97	99	101	102	104	105	107	109	111	112	114	116	118	119	121	123	125	127	129	131	132	134	136
138	140	142	144	147	149	151	153	155	157	159	162	164	166	168	171	173	175	178	180	182	185	187	190	192	195
197	200	202	205	207	210	213	215	218	221	223	226	229	232	235	237	240	243	246	249	252	255				

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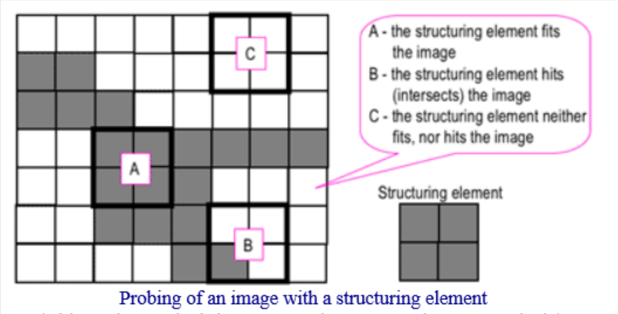
Morphological Image Processing

- **Morphological image processing** is a collection of non-linear operations related to the shape or morphology of features in an image.
- Morphological operations rely only on the relative ordering of pixel values, not on their numerical values, and therefore are especially suited to the processing of binary images.
- Morphological operations can also be applied to greyscale images such that their light transfer functions are unknown and therefore their absolute pixel values are of no or minor interest.

Morphological Image Processing

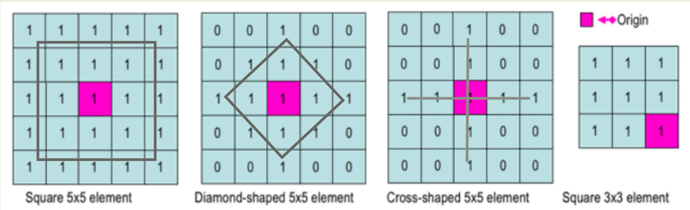
- Morphological techniques probe an image with a small shape or template called a **structuring element**.
- The structuring element is positioned at all possible locations in the image and it is compared with the corresponding neighbourhood of pixels.
- Some operations test whether the element "fits" within the neighbourhood, while others test whether it "hits" or intersects the neighbourhood:



Probing of an image with a structuring element
(white and grey pixels have zero and non-zero values, respectively).

Morphological Image Processing

- The **structuring element** is a small binary image, i.e. a small matrix of pixels, each with a value of zero or one:
  - *The matrix dimensions specify the size of the structuring element.*
  - *The pattern of ones and zeros specifies the shape of the structuring element.*
  - *An origin of the structuring element is usually one of its pixels, although generally the origin can be outside the structuring element.*



Examples of simple structuring elements.

Morphological Image Processing

- A common practice is to have odd dimensions of the structuring matrix and the origin defined as the centre of the matrix.
- When a structuring element is placed in a binary image, each of its pixels is associated with the corresponding pixel of the neighbourhood under the structuring element.
- The structuring element is said to **fit** the image if, for each of its pixels set to 1, the corresponding image pixel is also 1.
- Similarly, a structuring element is said to **hit**, or intersect, an image if, at least for one of its pixels set to 1 the corresponding image pixel is also 1.

		A	B	C
fit	s_1	yes	no	no
	s_2	yes	yes	no
hit	s_1	yes	yes	yes
	s_2	yes	yes	no

Fitting and hitting of a binary image with structuring elements s_1 and s_2.

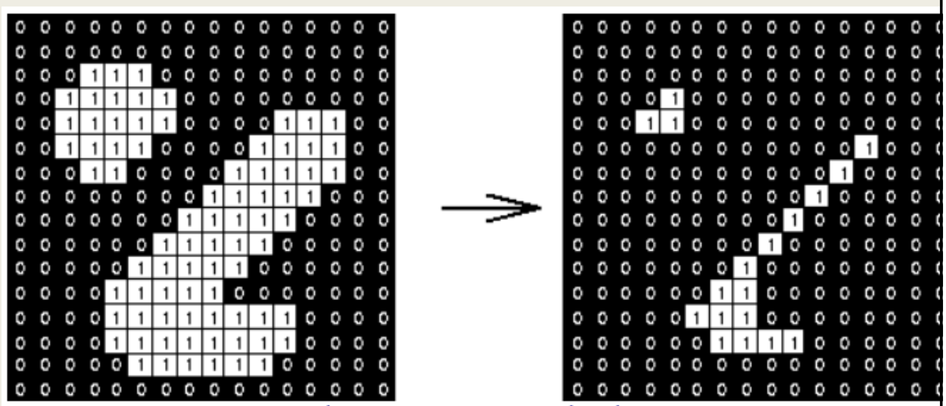
Erosion and dilation

- The erosion of a binary image f by a structuring element produces a new binary image with ones in all locations (x,y) of a structuring element's origin at which that structuring element s **fits** the input image f, i.e. g(x,y) = 1 is s fits f and 0 otherwise, repeating for all pixel coordinates (x,y).
- The erosion of a binary image:

Greyscale image | Binary image by thresholding | Erosion: a 2×2 square structuring element

- Erosion with small (e.g. 2×2 - 5×5) square structuring elements shrinks an image by stripping away a layer of pixels from both the inner and outer boundaries of regions. The holes and gaps between different regions become larger, and small details are eliminated:

Erosion and dilation



Erosion: a 3×3 square structuring element

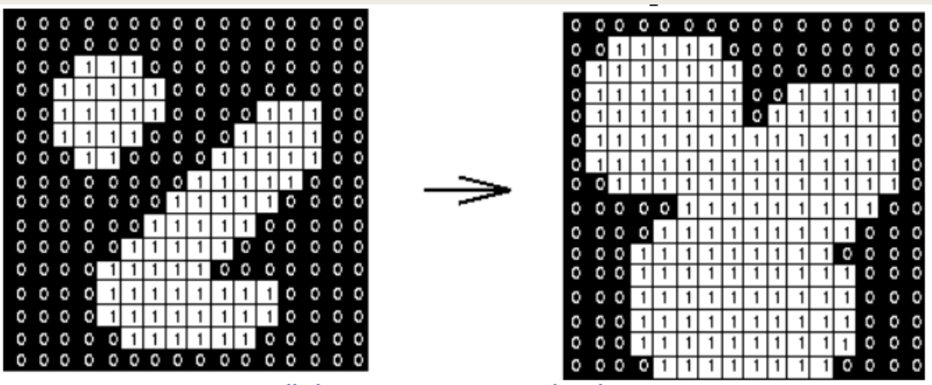
Erosion and dilation

- The dilation of an image f by a structuring element s produces a new binary image with ones in all locations (x,y) of a structuring element's origin at which that structuring element s hits the the input image f, i.e. g(x,y) = 1 if s **hits** f and 0 otherwise, repeating for all pixel coordinates (x,y).
- Dilation has the opposite effect to erosion -- it adds a layer of pixels to both the inner and outer boundaries of regions.
- The dilation of a binary image:

Binary image   Dilation: a 2×2 square structuring element

- The holes enclosed by a single region and gaps between different regions become smaller, and small intrusions into boundaries of a region are filled in.

Erosion and dilation



Dilation: a 3×3 square structuring element

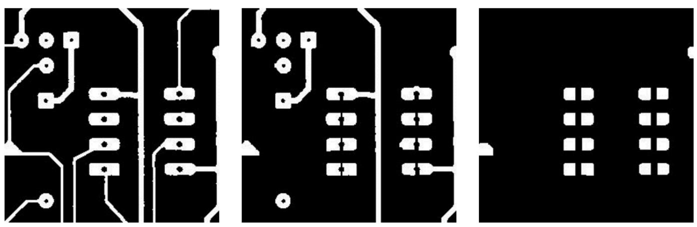
Compound operations

The **opening** of an image f by a structuring element s is an erosion followed by a dilation:

Binary image Opening: a 2×2 square structuring element

http://documents.wolfram.com/applications/digitalimage/UsersGuide/Morphology/ImageProcessing6.3.html

Opening is so called because it can open up a gap between objects connected by a thin bridge of pixels. Any regions that have survived the erosion are restored to their original size by the dilation:



Binary image f $f \circ s$ (5×5 square) $f \circ s$ (9×9 square)

Results of opening with a square structuring element (www.mmorph.com/html/morph/mmopen.html/).

Compound operations

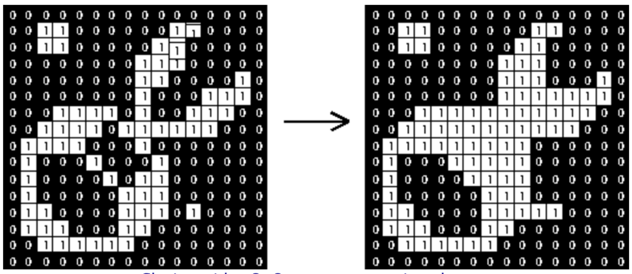
The **closing** of an image f by a structuring element s is a dilation followed by an erosion:

Binary image

Closing: a 2×2 square structuring element

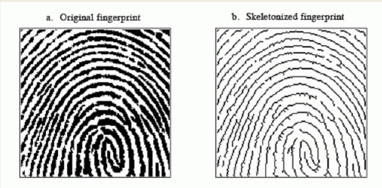
http://documents.wolfram.com/applications/digitalimage/UsersGuide/Morphology/ImageProcessing6.3.html

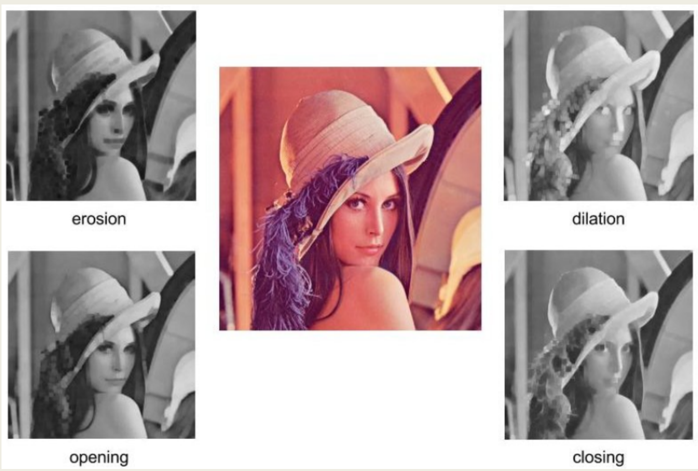
Closing is so called because it can fill holes in the regions while keeping the initial region sizes.



Closing with a 3×3 square structuring element (www.cs.princeton.edu/~pshilane/class/mosaic/).

Examples of Erosion and dilation





Exercise time

In today's lecture we have explored different filters

Using the given images, apply image negative, Log transform, and Power law.

To apply the above you need to know the following.

- Any of the above transforms will take the image to small values or well above 255.
- This means you need to scale the values between 0..255
- To perform the scaling you need to multiply each transformed value by 255 and divide the result by (max-min) of all the transformed values.
- You need to get the size of the image using [r,c]=size(image).

Try to apply the transform to a square part at the middle of the image
Enjoy…

http://uk.mathworks.com/help/images/morphology-fundamentals-dilation-and-erosion.html