Technical University of Denmark

Written exam, December 13, 2019

Course name: Image Analysis

Course number: 02502

Duration: 4 hours

Aids allowed: Alle aids allowed.

Weighting: All questions are equally weighted

Name:

Signature:

Desk no.:

Question	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Answer	5	4	1	4	2	1	2	5	5	2	4	1	4	3	5

Question	16	17	18	19	20	21	22	23	24	25
Answer	1	3	1	3	2	1	5	3	2	3

Possible answers to each question are numbered from 1 to 6. The chosen number of the answer must be entered in the table above. In case you enter an incorrect number in the table this may be corrected by "inking out" the wrong number and instead placing the correct number below. Should there be any doubts in connection with a correction, the question will be considered as not answered. ONLY THE FRONT PAGE IS TO BE HANDED-IN.

If you decide to make a blank hand-in or leave the examination prematurely the front page must in all circumstances be handed-in. Rough drafts, calculations and comments will not be included in the evaluation. Only numbers included in the above table will be registered.

A correct answer will be equivalent to 5 points. An incorrect answer will be equivalent to -1 points. Questions unanswered as well as answer number six (equivalent to "do not know") will not produce points. The final grade is determined by the examiners.

Please do not forget to state your name, signature, and desk number on the paper.

Exercise 19.1

You have made an algorithm that can locate neon fish in an aquarium. An expert has marked all neon fish in an image as seen in Figure 1 (left). The result of your algorithm is seen in Figure 1 (right). What is the true positive rate of your algorithm?

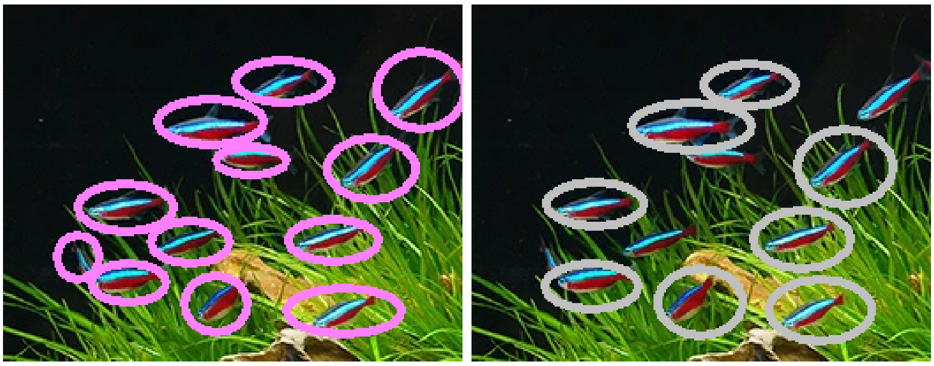

Figure 1: Image of aquarium with neon fish. Left: Expert markings are shown as ellipses. Right: Algorithm markings are shown as ellipses.

1. 77%
2. 92%
3. 81%
4. 55%
5. 67%
6. Do not know

Exercise 19.2

On the image (I) seen in Figure 2 the operation

$$(\mathrm{I} \bullet \mathrm{SE2}) \oplus \mathrm{SE1} - \mathrm{I},$$

is performed, where SE1 og SE2 are seen in Figure 3. How many foreground pixels are there in the resulting image?

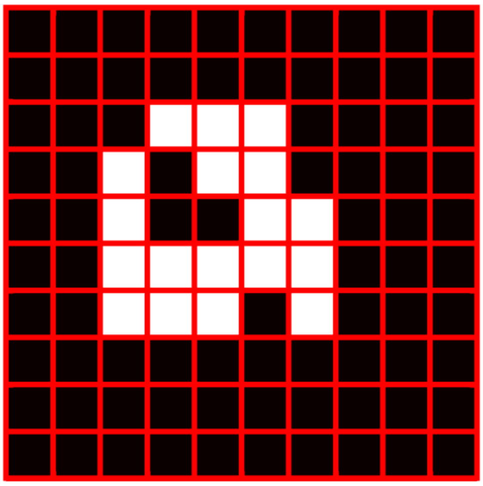

Figure 2: Binary image I. White pixels are foreground (1) and black pixels are background (0).

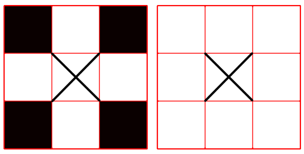

Figure 3: Left: SE1, Right: SE2. White pixels are foreground (1) and black pixels are background (0). The center is marked with a cross.

1. 17
2. 15
3. 27
4. 22
5. 29
6. Do not know

Exercise 19.3

The point $(x, y) = (10, 30)$ is transformed using a homography with the parameter vector $\vec{d} = [3, 1, 4, 2, 7, 6, 2, 1]^T$. What is the resulting point (x', y')?

1. (1.25, 4.63)
2. (3.11, 2.12)
3. (5.65, 3.79)
4. (1.53, 1.08)
5. (2.33, 2.98)
6. Do not know

Exercise 19.4

The point $(x, y) = (33, 97)$ is rotated using a rotation matrix (rotating counter clockwise) with $\theta = 8°$. The closest four pixels to the transformed point and their pixel values are:

x	y	value
19	100	143
20	100	98
19	101	197
20	101	213

What is the interpolated value using bilinear interpolation (rounded to an integer) in the point?

1. 111
2. 164
3. 191
4. 177
5. 202
6. Do not know

Exercise 19.5

A camera without lens distortions has been used to take a movie of a flying bird. The bird is moving with a constant speed. The bird's path is parallel to the camera's horizontal axis and orthogonal to the optical axis of the camera. The movie has been taken with a distance of 20 meters from the optical center to the path of the bird. The field-of-view of the camera is 28°. The time from the bird is appearing in the left side of the image to it touches the right side of the image is 2 seconds. How fast is the bird flying?

1. 3 m/s
2. 5 m/s
3. 7 m/s
4. 8 m/s
5. 2 m/s
6. Do not know

Exercise 19.6

A BLOB analysis using 4-connectivity is performed on the image seen in Figure 4. It is a 0-based (x,y) coordinate system with origin in the upper left corner. The largest BLOB is kept and the resulting image is coded using binary run-length coding. The code is:

1. $[5; (3, 3)], [6; (1, 1)], [6; (3, 4)], [7; (1, 4)], [8; (1, 1)]$
2. $[4; (3, 3)], [6; (1, 2)], [7; (3, 4)], [7; (1, 4)], [8; (1, 1)]$
3. $[5; (2, 3)], [6; (1, 1)], [6; (3, 4)], [8; (1, 5)], [8; (1, 1)]$
4. $[4; (3, 3)], [6; (1, 2)], [6; (3, 5)], [7; (1, 4)], [8; (1, 3)]$
5. $[5; (2, 3)], [6; (1, 1)], [6; (3, 4)], [7; (2, 4)], [8; (2, 3)]$
6. Do not know

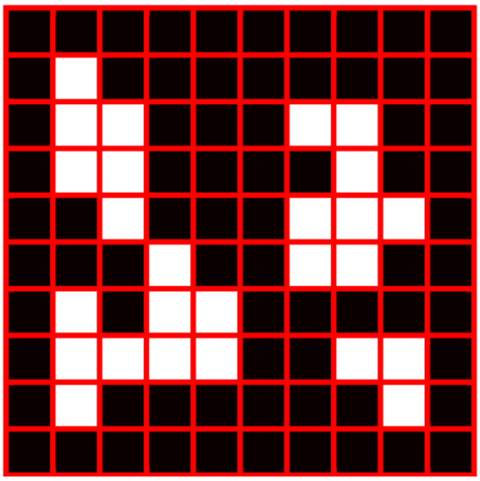

Figure 4: Binary image I. White pixels are foreground (1) and black pixels are background (0).

Exercise 19.7

A BLOB analysis using 8-connectivity is performed on the image seen in Figure 5. It is a 0-based (x,y) coordinate system with origin in the upper left corner. The largest BLOB is kept and the resulting image is coded using binary chain coding. The code is:

1. $(1, 1)(7647264435247123222)$
2. $(1, 1)(7667764445227123322)$
3. $(1, 1)(5647761452371213\,22)$
4. $(1, 1)(6367264445427125312)$
5. $(1, 1)(7647762452251231\,22)$
6. Do not know

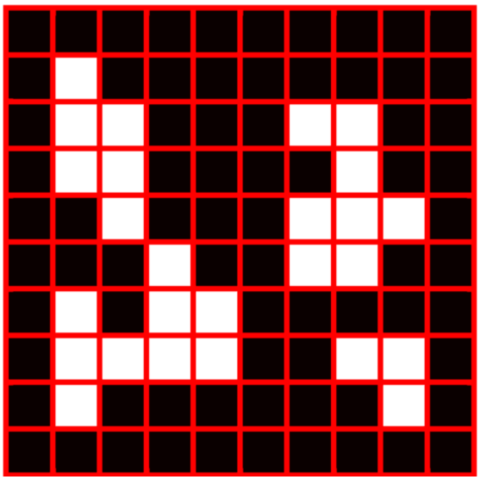

Figure 5: Binary image I. White pixels are foreground (1) and black pixels are background (0).

Exercise 19.8

The RGB values in the image seen in Figure 6 are converted to HSI values. A new image is created by using the I values (rounded to nearest integer). A linear gray level mapping is performed on the new image. The resulting image has a minimum pixel value of 20 and a maximum pixel value of 180. What is the result in the center pixel?

1. 201
2. 172
3. 197
4. 165
5. 180
6. Do not know

R: 18 G: 10 B: 45	R: 25 G: 75 B: 70	R: 25 G: 90 B: 155
R: 170 G: 30 B: 10	R: 10 G: 150 B: 220	R: 250 G: 10 B: 70
R: 140 G: 20 B: 0	R: 0 G: 20 B: 160	R: 10 G: 20 B: 45

Figure 6: RGB image

Exercise 19.9

A logarithmic mapping is applied to the image in Figure 7. All pixel values are then rounded to the nearest integer. An optimal path from the top to the bottom of the image is computed using dynamic programming. What is the total cost of the optimal path?

1. 489
2. 513
3. 876
4. 678
5. 740
6. Do not know

193	180	98	112	125
189	8	177	97	114
100	71	81	195	165
167	12	242	203	181
44	25	9	48	192

Figure 7: Grayscale image.

Exercise 19.10

The RGB values in the image seen in Figure 8 are color thresholded using the threshold values: $R_{\text{min}} = 40$, $R_{\text{max}} = 80$, $G_{\text{min}} = 110$, $G_{\text{max}} = 130$, $B_{\text{min}} = 205$, $B_{\text{max}} = 215$. The RGB values satisfying these conditions are set as foreground and the rest to background. The original RGB value of the pixels that are identified as foreground are now converted to HSI values. What is the sum of the S values of these pixels?

1. 1.15
2. 1.025
3. 2.085
4. 1.08
5. 0.07
6. Do not know

R: 120 G: 110 B: 50	R: 60 G: 120 B: 210	R: 35 G: 170 B: 15
R: 30 G: 50 B: 60	R: 70 G: 125 B: 214	R: 60 G: 120 B: 70
R: 75 G: 20 B: 220	R: 10 G: 30 B: 160	R: 35 G: 50 B: 45

Figure 8: RGB image

Exercise 19.11

The gradient magnitude has been computed in the marked pixel in Figure 9 to be 155.7. The gradient in the x and y direction are approximated using a horizontal and a vertical Prewitt filter. What is the value of the pixel that is blanked out (rounded to the nearest integer)?

1. 98
2. 132
3. 245
4. 151
5. 24
6. Do not know

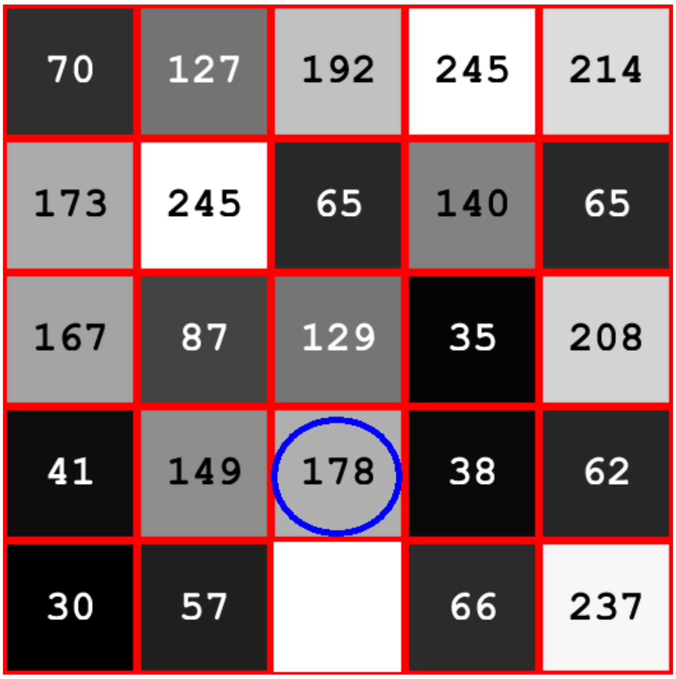

Figure 9: Grayscale image

Exercise 19.12

An optimal path from the top to the bottom of the image seen in Figure 10 is computed using dynamic programming. A Matlab matrix coordinate system is used. What is the value in the backtracing image at position (4,6)?

1. 5
2. 7
3. 1
4. 3
5. 2
6. Do not know

208	244	108	173	34	112	181	245
231	246	234	193	12	97	192	87
32	40	202	189	25	195	70	149
233	248	245	14	210	203	173	57
161	244	167	17	177	48	167	192
25	124	9	44	81	125	41	65
71	204	34	180	242	114	30	129
139	36	238	8	9	165	127	178

Figure 10: Grayscale image.

Exercise 19.13

Your camera has a CCD chip that measures 5.4 x 4.2 mm. The images taken with the camera have dimensions 6480 x 5040 pixels. It can be assumed that $b = f$. You have captured a sharp photo of a coffee cup from a distance of 1.2 meters. The cup is 8 cm high. On the image, the cup is 600 pixels high. What is the focal length of your camera?

1. 5.6 mm
2. 6.6 mm
3. 7.1 mm
4. 7.5 mm
5. 8.1 mm
6. Do not know

Exercise 19.14

A filter is applied to the image in Figure 11 (left) using correlation. The kernel (filter) is seen Figure 11 (right), where the marked pixel is the center of the kernel. The coefficients of the kernel should be normalized. It can be assumed that pixels outside the border of the image have value 0 (zero padding). The resulting pixel values are rounded to the nearest integer. What is the result in the marked pixel?

1. 76
2. 254
3. 154
4. 123
5. 206
6. Do not know

208	244	108	173	71	112	181	245
231	246	234	193	12	97	192	87
32	40	202	189	25	195	70	149
233	248	245	100	210	203	173	57
161	244	167	167	177	48	167	192
25	124	9	44	81	125	41	65
71	204	217	180	242	114	30	129
139	36	238	8	9	165	127	178

227	66	237	121	234
245	214	89	90	73
140	65	50	212	193
35	208	64	149	192
38	62	157	140	97

Figure 11: Left: Grayscale image. Right: Filter

Exercise 19.15

A BLOB analysis using 8-connectivity has been performed on the image seen in Figure 12 and the five found BLOBs have been marked with numbers. The BLOB features *area* and *compactness* have been computed for the five BLOBs. A reference BLOB has an area of 10 pixels and a compactness of 0.5. The Euclidean distance in feature space has been computed between the five BLOBs and the reference BLOB. Which of the five BLOBs has the minimum distance?

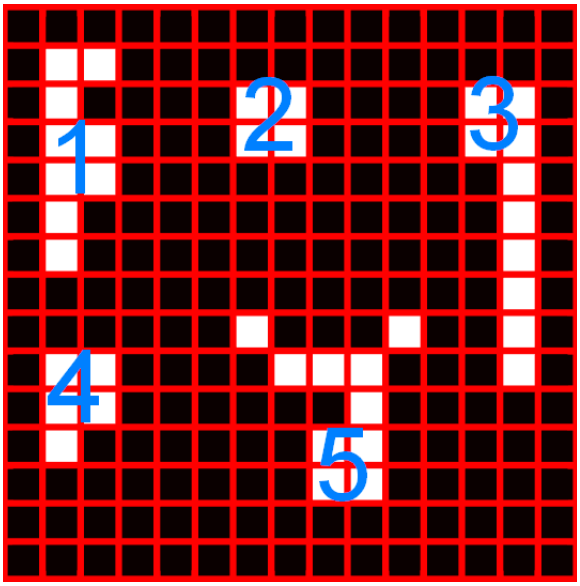

Figure 12: Binary image I. White pixels are foreground (1) and black pixels are background (0).

1. 1
2. 2
3. 3
4. 4
5. 5
6. Do not know

Exercise 19.16

In order to make a pixel classification, an expert has annotated areas in an image containing skin, melanoma and background. The original image contains pixel values between 0 and 255. The annotated pixel values are shown in Table 1. What are the class ranges for a minimum distance classifier using these annotated values?

1. $[0, 117], [118, 194], [195, 255]$
2. $[0, 115], [116, 189], [190, 255]$
3. $[0, 98], [100, 108], [109, 255]$
4. $[0, 121], [122, 201], [202, 255]$
5. $[0, 87], [88, 198], [199, 255]$
6. Do not know

Class	Pixel values
Background	210, 208, 209, 213
Skin	178, 181, 178, 179
Melanoma	56, 57, 57, 58

Table 1: Pixel values in the areas annotated by the expert.

Exercise 19.17

In order to make a pixel classification, an expert has annotated areas in an image containing houses, signs, people, trees and bushes. The original image contains pixel values between 0 and 255. The annotated pixel values are shown in Table 2. Using the annotated data for house, people and tree a parametric classifier is made. What are the class ranges for this parametric classifier?

1. $[0, 85], [86, 103], [103, 255]$
2. $[0, 87], [88, 107], [108, 255]$
3. $[0, 82], [83, 103], [104, 255]$
4. $[0, 75], [75, 101], [103, 255]$
5. $[0, 84], [85, 107], [108, 255]$
6. Do not know

Class	Pixel values
House	75, 76, 77
Sign	223, 221, 224
People	89, 91, 91
Tree	135, 138, 141
Bush	94, 95, 99

Table 2: Pixel values in the areas annotated by the expert.

Exercise 19.18

In order to make a pixel classification, an expert has annotated areas in an image containing houses, signs, people, trees and bushes. The original image contains pixel values between 0 and 255. The annotated pixel values are shown in Table 2. Using the annotated data, a minimum distance classifier is created and is used on the image in Figure 13. The pixels identified as people are set to foreground (1) and the rest are set to (0). A morphological erosion with SE1 from Figure 3 is performed on the image. How many foreground pixels remain?

1. 1
2. 2
3. 3
4. 4
5. 5
6. Do not know

208	244	108	173	71	112	181	245
231	246	234	193	12	97	192	13
32	40	87	189	25	195	70	149
233	89	92	91	210	203	173	57
161	244	90	167	177	48	167	192
25	124	84	180	179	125	41	65
71	88	83	85	242	114	30	129
139	36	238	8	9	165	127	178

Figure 13: Grayscale image.

Exercise 19.19

A 5 x 5 image is filled with values given by the *gray level run length* code: 4, 6, 1, 7, 3, 10, 6, 120, 2, 210, 4, 75, 5, 150. It is a 0-based (x,y) coordinate system with origin in the upper left corner. A template matching is performed using the template seen in Figure 14. What is the normalized cross correlation in the pixel at position $(2, 1)$?

208	233	71
231	161	139
32	25	244

Figure 14: Template

1. 0.34
2. 0.76
3. 0.49
4. 0.58
5. 0.67
6. Do not know

Exercise 19.20

To be able to do an image registration between a reference image and a template image, two sets of corresponding landmarks have been placed in the two images. The landmarks can be seen in the table below.

Landmarks in reference	x	y	Landmarks in template	x	y
a_1	7	6	b_1	3	6
a_2	8	3	b_2	9	4
a_3	3	2	b_3	7	3

Initially, the landmarks from the template are transformed using the transformation matrix:

$$\begin{bmatrix} 2.7 & 0.2 \\ 0.1 & 3.1 \end{bmatrix} \tag{1}$$

After the transformation, the squared distance objective function F is computed. The result is:

1. 1017.1
2. 906.5
3. 867.2
4. 734.3
5. 541.4
6. Do not know

Exercise 19.21

You need to paint a wall and want to compute how many liters of paint you need. You have taken a sharp photo of the wall from a distance of 35 meters. Your camera has a focal length of 28 mm and a CCD chip that measures 5.2 x 3.6 mm. The images taken with the camera have dimensions 5720 x 3960 pixels. It can be assumed that $b = f$. The size of the wall in the image is 4400 x 2640 pixels. One liter paint covers 7 m^2. How many liters of paint do you need (rounded up to nearest deciliter)?

1. 2.2 liters
2. 1.3 liters
3. 1.7 liters
4. 3.1 liters
5. 3.4 liters
6. Do not know

Exercise 19.22

To be able to do an image registration between a reference image and a template image, two sets of corresponding landmarks have been placed in the two images. The landmarks can be seen in the table below.

Landmarks in reference	x	y	Landmarks in template	x	y
a_1	7	6	b_1	3	6
a_2	8	3	b_2	9	4
a_3	3	2	b_3	7	3

The optimal translation that brings landmarks from the reference image over in the template image is found. It is:

1. (0.25, 1.05)
2. (0.98, -0.10)
3. (0.78, 1.07)
4. (-0.2, 0.54)
5. (0.33, 0.67)
6. Do not know

Exercise 19.23

To be able to do an image registration between a reference image and a template image, two sets of corresponding landmarks have been placed in the two images. The landmarks can be seen in the table below.

Landmarks in reference	x	y	Landmarks in template	x	y
a_1	2	5	b_1	2	9
a_2	7	6	b_2	1	5
a_3	1	3	b_3	8	4

The landmarks from the reference can be moved using a translation transformation. What is the minimal value of the the squared distance objective function F that can be achieved using this transformation?

1. 120.1
2. 134.6
3. 97.3
4. 88.2
5. 177.2
6. Do not know

Exercise 19.24

A 3x3 maximum rank filter is applied to the image in Figure 15 followed by a gamma mapping with $\gamma = 1.37$. All pixel values are then rounded to integers. What is the result in the marked pixel?

1. 127
2. 243
3. 187
4. 254
5. 201
6. Do not know

208	25	40	36	167
231	71	248	108	9
32	139	244	234	217
233	244	124	202	238
161	246	204	245	173

Figure 15: Grayscale image.

Exercise 19.25

The image seen in Figure 16 is filtered using a $3x3$ min-rank filter. The resulting image is then filtered using a vertical $3x3$ Sobel filter. What is the result in the marked pixel?

1. 15
2. 207
3. 85
4. 196
5. 117
6. Do not know

208	244	108	173	71	112	181	245
231	246	234	193	12	97	192	87
32	40	202	189	25	195	70	149
233	248	245	100	210	203	173	57
161	244	167	167	177	48	167	192
25	124	9	44	81	125	41	65
71	204	217	180	242	114	30	129
139	36	238	8	9	165	127	178

Figure 16: Grayscale image.