Berlin University of Technology

Computer Vision & Remote Sensing

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Final Examination

Digital Image Processing

Winter term 2016/17

Name: . . . . **Student ID number:** . . . .

Auxiliary resources: none

A February 21, 2017

DO NOT OPEN THIS EXAMINATION SHEET UNTIL YOU ARE TOLD TO DO SO!

Write your **name** and **student ID** in the corresponding places at the top of this page **now**.

Books, notes, dictionaries, own empty sheets of paper, pocket calculators are **not allowed**.
Use only a pen. Everything written with a pencil will not be taken into account.

If you do not understand a question, please **ask**.
It will be to your advantage to read the entire examination before beginning to work.

The exam is to the largest part a **multiple choice** test, where the questions are divided into blocks.
For each question there is at least **one and at most four** correct answers.
The number of points *p* for a single correct answer are stated next to the question.
Please note, that there is a **penalty of *-p/2* points** for a wrong answer.
The minimal number of points for each block is 0 (i.e. no negative points for whole blocks).

	Which of the following numbers is even?				**2P**
	i) 2	**ii) 3**	**iii) 4**	**iv) 5**	
Example 1			**X** (correct +2P)		Result: 2P
Example 2		**X** (incorrect: -1P)	**X** (correct +2P)		Result: 1P
Example 3	**X** (correct +2P)		**X** (correct +2P)		Result: 4P

Notation:

Black = Gray level of 0
White = Gray level of 255

Lots of luck and do your best!

Question	i)	ii)	iii)	iv)
1.				
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Total: 55 points

Block I

1. Given an **optical camera** with square pixels, a principal distance of *200px*, no skew, and a principal point at *(10,10)*, which of the following is the correct **algebraic model** of the camera? 1P

i)	ii)	iii)	iv)
$\begin{bmatrix} 10 & 0 & 200 \\ 0 & 10 & 200 \\ 0 & 0 & 1 \end{bmatrix}$	$\begin{bmatrix} 200 & 0 & 10 \\ 0 & 200 & 10 \\ 0 & 0 & 1 \end{bmatrix}$	$\begin{bmatrix} 20 & 0 & 1 \\ 0 & 20 & 1 \\ 0 & 0 & 1 \end{bmatrix}$	$\begin{bmatrix} -10 & 0 & 200 \\ 0 & -10 & 200 \\ 0 & 0 & 1 \end{bmatrix}$

2. **Digitization and quantization** are two necessary steps while creating digital images from a continuous signal. Assume that a digitization with four and a quantization with eight samples were used to create an image. 1P

Which of the properties stated below has the **resulting image**?

i) Size of 4x4px and 8 gray levels	ii) Size of 8x8px and 4 gray levels	iii) Size of 4x4px and 4 gray levels	iv) Size of 8x8px and 8 gray levels

3. Measurement **noise in optical images** is commonly assumed as being 1P

i) homogeneous.	ii) Gaussian distributed.	iii) multiplicative.	iv) having the mean value of 1.

4. The so-called “**black level**” of an optical camera is 1P

i) the brightness level at which the camera still makes good images.
ii) the signal-to-noise-ratio obtained when taking images in darkness.
iii) an offset which leads to a positive pixel value even if no light was measured by this pixel.
iv) the smallest value of the final image.

Block II

5. Given the following **relative grayscale histogram** $h(g)$, provide the intensity values of **a possible image** in Figure 1. 1P

Please note that the full image range is from 0 to 255. The majority of the histogram values with $h(g) = 0$ is not shown.

g	h(g)
0	0.25
1	0.125
2	0
3	0.25
4	0.25
5	0.125

Figure 1

6. If **histogram equalization** is applied to the image of Question 5., which of 2P

the relative gray level histograms below belongs to the resulting image?

i)

g	0	51	153	204	255
h(g)	0.25	0.125	0.25	0.25	0.125

ii)

g	0	51	153	204	255
h(g)	1/6	1/6	1/6	1/6	1/6

iii)

g	63	95	159	223	255
h(g)	0.25	0.125	0.25	0.25	0.125

iv)

g	3	5	9	13	15
h(g)	0.25	0.125	0.25	0.25	0.125

7. The application of **histogram equalization** to an image A, resulted in the image B. If histogram equalization is applied to B, then the resulting image C will have — 1P

i) **more contrast** than image B.
ii) **less contrast** than image B.
iii) the **same contrast** as image B.
iv) the **same contrast** as image A.

Block III

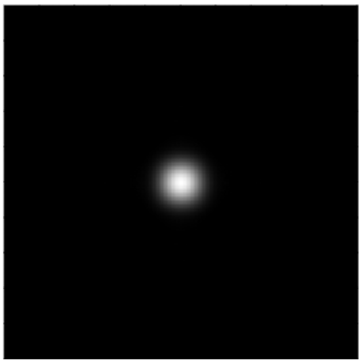
The following matrices represent kernels of **linear shift-invariant filters**.

i)	ii)	iii)	iv)
$\begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix}$	$\begin{bmatrix} 1 & 1 & 1 \\ 0 & 0 & 0 \\ -1 & -1 & -1 \end{bmatrix}$	$\begin{bmatrix} 1 & 2 & 1 \\ 2 & 4 & 2 \\ 1 & 2 & 1 \end{bmatrix}$	$\begin{bmatrix} 1 & 2 & 1 \\ 2 & -4 & 2 \\ 1 & 2 & 1 \end{bmatrix}$

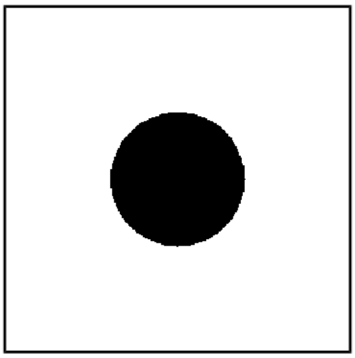
8. Which of the filters above can be applied as **separable filters**? — 1P

9. Which of the filters above can be applied by using **integral images**? — 1P

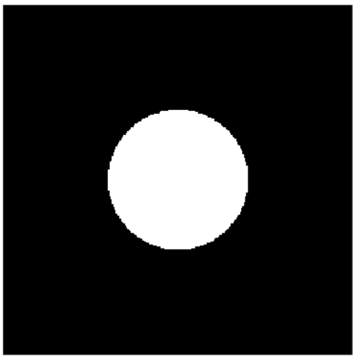
10. Which of the filters above is only a **low-pass filter**? — 1P



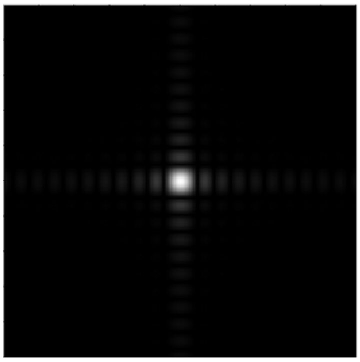
i)



ii)



iii)



iv)

The images above show the **amplitude of spectra** of different filters (where black means zero amplitude and white means positive amplitude).

11. Which of the spectra above belong to a **box filter**? 1P

12. Which of the spectra above belong to a **Gaussian filter**? 1P

13. Which of the spectra above belong to a ideal **high-pass filter**? 1P

14. Which of the spectra above belong to a rotation symmetric 2D **sinc function** in spatial domain? 1P

Block IV

15. The **frequency domain** representation F, G of two signals f, g are stated below. 2P

F	0.2 - 0.8i	0.3 - 0.4i	-2 + 1i	3	-2 - 1i	0.3 + 0.4i	0.2 + 0.8i
G	-0.1 + 0.6i	0.2 - 0.2i	-5 + 2i	9	-5 - 2i	0.2 + 0.2i	-0.1 - 0.6i

A **correlation** of f and g results in which of the following spectra?

i)	0.46 + 0.2i	-0.02 - 0.14i	8 - 9i	27	8 + 9i	-0.02 + 0.14i	0.46 - 0.2i
ii)	-0.6 - 0.32i	-0.07 - 0.24i	3 - 4i	9	3 + 4i	-0.07 + 0.24i	-0.6 + 0.32i
iii)	-0.35 - 0.12i	0 - 0.08i	21 - 20i	81	21 + 20i	0 + 0.08i	-0.35 + 0.12i
iv)	-0.5 - 0.04i	0.14 - 0.02i	12 - 1i	27	12 + 1i	0.14 + 0.02i	-0.5 + 0.04i

16. The **ringing effect** in the context of digital image processing is 1P

i) caused by **homogeneous** image regions.
ii) caused by **discontinuities** in the frequency spectrum of a low-pass filter.
iii) caused by **discontinuities** in the frequency spectrum of a high-pass filter.
iv) caused by **discontinuities** of the filter in spatial domain.

17. In the following a,b are real-valued constants and s, f, g are continuous signals in time domain with the frequency representations S, F, G, respectively. A convolution is denoted by $\otimes$, $\cdot$ means component-wise multiplication, and * means complex conjugation. 1P

Which of the following **relations** are true?

i) $s=f+a \Leftrightarrow S=F+a$	ii) $s=af+bg \Leftrightarrow S=aF+bG$	iii) $f(t)\in\mathbb{R} \Rightarrow F(-\mu)=F(\mu)^*$	iv) $s=f\otimes g \Leftrightarrow S=F\cdot G$

Block V

18. The **amplitude spectrum** of a **one-dimensional degradation** function **(discrete, 7 elements)** is shown in Figure 2. Which of the following spectra belongs to the **clipped inverse filter** with a threshold value of T=0.5? 2P

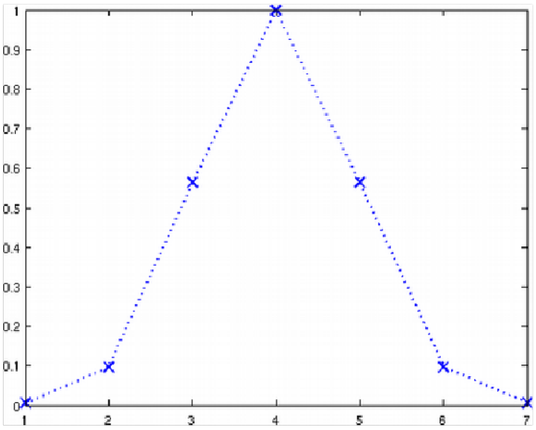
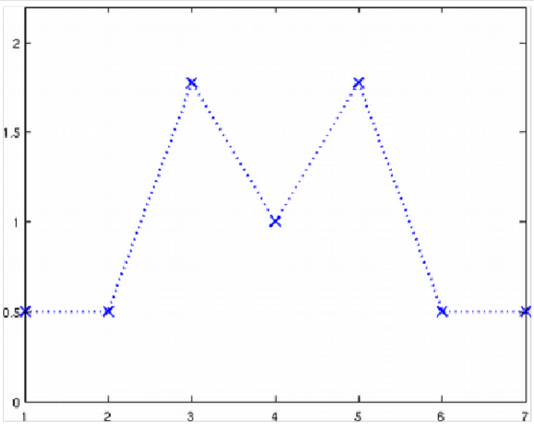
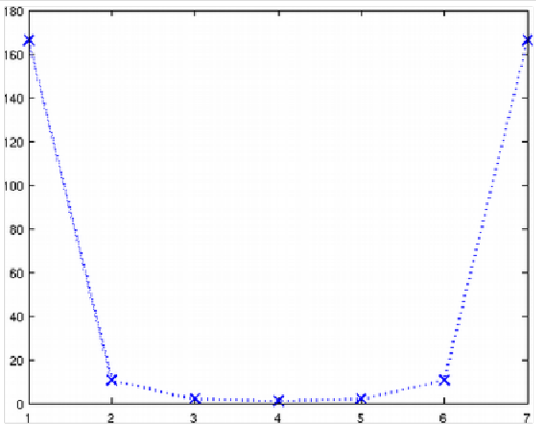


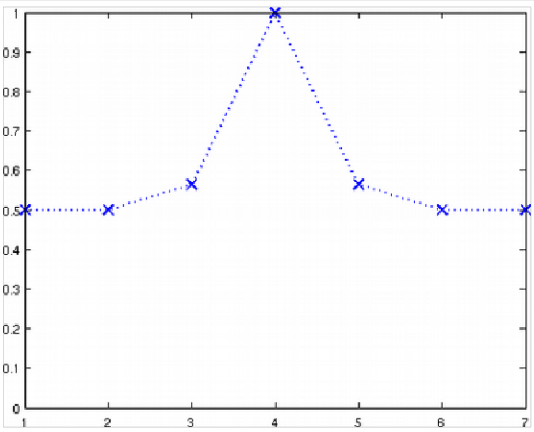
Figure 2



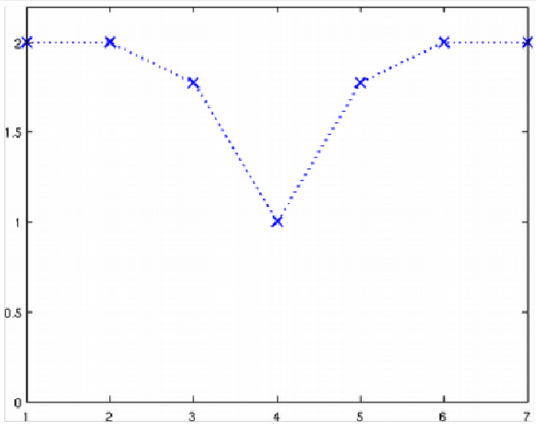
i)



ii)



iii)



iv)

19. Assume that a measured signal s can be modelled as $s=h\otimes o+n$, where s and o are the measured and original signal, respectively, h is a linear shift-invariant filter which can be modelled as convolution $\otimes$, and n is a random noise term. Assuming the k-th component H_k of the spectrum H of h is $H_k=4-3i$, and $SNR=2$. What is the corresponding k-th element of the spectrum of the **Wiener Filter** M_k ? 2P

i) $M_k=\frac{4-3i}{5.25}$	ii) $M_k=\frac{4-3i}{25.25}$	iii) $M_k=\frac{4+3i}{5.25}$	iv) $M_k=\frac{4+3i}{25.25}$

Block VI

20. The **optimal thresholding** method is initialized with $F_0=\{15,15,30,64\}$ and $B_0=\{91,91\}$. The **threshold** T_2 of the 2nd iteration is 3P

i) $T_2 = 51$	ii) $T_2 = 61$	iii) $T_2 = 53$	iv) $T_2 = 77.5$

21. A color image is given in Lab color space. The information of the i-th pixel is given as L_i, a_i, b_i (denoting the corresponding color values) and x_i, y_i (denoting the spatial pixel positions). **SLIC** initializes the cluster centers c_i as 1P

i) $c_i = (L_i, a_i, b_i, x_i, y_i)$	ii) $c_i = (L_i, a_i, b_i)$	iii) $c_i = (x_i, y_i)$	iv) SLIC doesn't use clustering.

22. The internal energy of an **active contour** 1P

i) controls the **elasticity** of the curve.
ii) controls the **stiffness** of the curve.
iii) ensures that the curve fits to the **image content**.
iv) includes user-defined higher level **knowledge**.

23. 3P

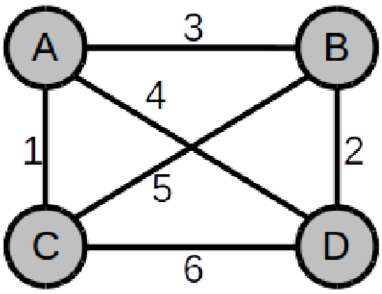


Figure 3

Figure 3 shows a **weighted undirected graph** with four nodes (represented by circles, A-D) and six edges with corresponding weights. What is the value of the **Normalized Cut** that divides the given graph into the two subgraphs consisting of A,C and B,D?

i) 18	ii) $180 / 220$	iii) $189 / 110$	iv) $180 / 200$

Block VII

24. The **structure tensor** A_p of a pixel p in a homogeneous neighborhood N with a constant gray level value v_i of $v_i = 1$ for all $i \in N$ is 1P

i) $A_p=\begin{bmatrix}1 & 1\\1 & 1\end{bmatrix}$	ii) $A_p=\begin{bmatrix}0 & 0\\0 & 0\end{bmatrix}$	iii) $A_p=\begin{bmatrix}1 & 0\\0 & 1\end{bmatrix}$	iv) A_p = 1

25. The **eigenvalues of a structure tensor** are $\lambda_1 = 10, \lambda_2 = 2$. The corresponding image region most likely corresponds to 1P

i) an homogeneous area.	ii) an edge.	iii) a corner.	iv) a blob.

26. Given the eigenvalues above in Question 25., the **roundness** q of the **Förstner point detector** is 2P

i) $q = 5/3$	ii) $q = 5/9$	iii) $q = 5/36$	iv) $q = 20/3$

27. If there are two **dominant gradient orientations** in the neighborhood of a keypoint candidate, **SIFT** 1P

i) creates **one keypoint** with the strongest of the two orientations.
ii) creates **one keypoint** with the average of the two orientations.
iii) creates **two keypoints** at the same position each with one of the two orientations.
iv) creates **no keypoint** because it would be ambiguous.

28. **SURF** is method to detect and describe keypoints in images. Which of the following statements is true with respect to the **detection part** of SURF? 1P

i) SURF detects keypoints based on the **Hessian matrix**.
ii) SURF applies **integral images** to compute an approximation of the necessary image derivatives.
iii) SURF scales the filter kernel instead of using an image **scale space**.
iv) SURF is **slower** than SIFT.

Block VIII

29. 3P

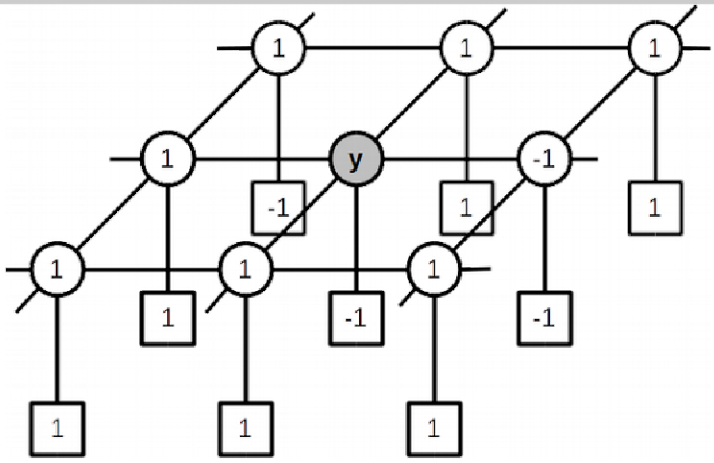


Figure 4

Figure 4 shows a **Markov Random Field** defined over a binary image (i.e. pixel values of *-1* or *1*), where **measurement nodes** x_i are represented as squares and ***label nodes*** y_i as circles. The **unary and pairwise potentials** are defined as below. What is the **energy of** $y=1$?

$$\psi^U(y_i, x_i) = -2 x_i y_i \qquad \psi^P(y_i, y_j) = -3 y_i y_j$$

i) *2*	ii) *-6*	iii) *-4*	iv) *-2*

30. Morphological operators for binary images such as **opening** (○) and **closing** (●) are defined for grayscale images, too. The **top-hat transform** g of a grayscale image f by using a structuring element b is given by 1P

i) $g=(f \circ b) \bullet b$	ii) $g=(f \bullet b) \circ b$	iii) $g=f-f \circ b$	iv) $g=f \bullet b-f$

31. 1P

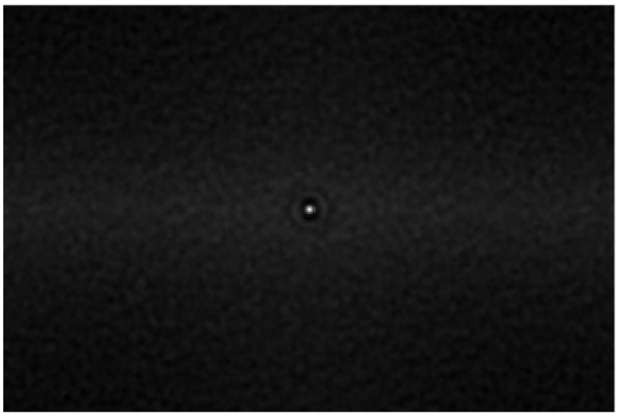


Figure 5

The **autocorrelation texture description** in Figure 5 was computed from a given image. In relation to the image size, the corresponding texture is

i) coarse.	ii) fine.	iii) regular.	iv) random.