Berlin University of Technology

Computer Vision &
Remote Sensing

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Final Examination

Digital Image Processing

Winter term 2017/18

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

Auxiliary resources: none

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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, and 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 in most parts a **multiple choice** test.
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, while by giving no answer points are neither gained nor lost (i.e. no penalty for not giving an answer).
The minimal number of points for each question is 0 (i.e. no negative points for whole questions).

	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
Example 4		**X** (incorrect: -1P)			Result: 0P

Notation:

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

Lots of luck and do your best!

Please use this table to denote your answers by making a cross (“X”) in the column corresponding to your answer. If you want to correct a falsely given answer, strike the line through and use the empty rows at the end of the table.

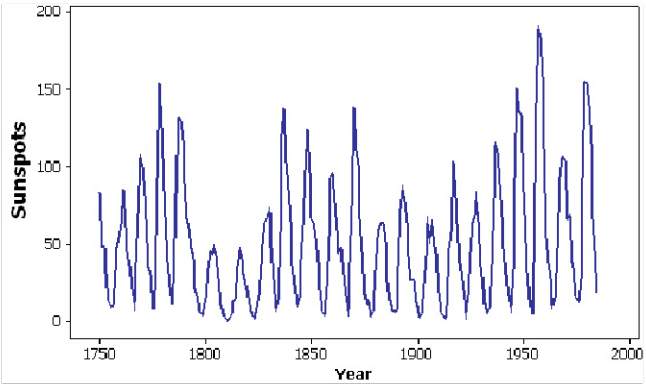
Question	i)	ii)	iii)	iv)
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10.				
11.				
12.				
13.				
14.				
15.				
16.				
17.				
18.				
19.				
20.				
21.				
22.				
23.				
24.				

Total: 45 points

Block 1

1. In the following a single sample ***x*** of four large datasets ***X*** is given. 1P
Which of those is an example for **structured data**?

i)



ii)

"*I find your lack of faith disturbing.*"
iii)

Age	*Gender*	*Country*	*Income*
32	female	German	32K

iv)

2. Which of the following statements about "**semantic segmentation"** is true? 1P

Semantic segmentation aims to …
i) … group pixels that have a **similar texture**.
ii) … estimate the **location of objects** in an image.
iii) … group pixels that belong to the **same object**.
iv) … estimate **bounding boxes** around objects.

3. Which of the following statements about "**bottom-up processing"** is true? 1P

Bottom-up processing …
i) … is **model driven**.
ii) … starts with **low-level image operations**.
iii) … is **data driven**.
iv) … **projects a model** into the image and performs a matching operation.

Block 2

4. Given two images *f,g* of same size, which of the following statements is the **convolution theorem**? 2P

Note: FFT and IFFT denote the forward and inverse form of the Fourier Transformation, convolution is denoted by $\otimes$ while $\cdot$ means point-wise multiplication and * complex conjugation.

i) $(f \otimes g)(x) = \int f(\tau) \cdot g(x-\tau) d\tau$	ii) $f \otimes g = IFFT(FFT(f) \cdot FFT(g))$
iii) $f \cdot g = IFFT(FFT(f) \otimes FFT(g))$	iv) $f \otimes g = IFFT(FFT(f) \cdot FFT(g)^*)$

5. 1P

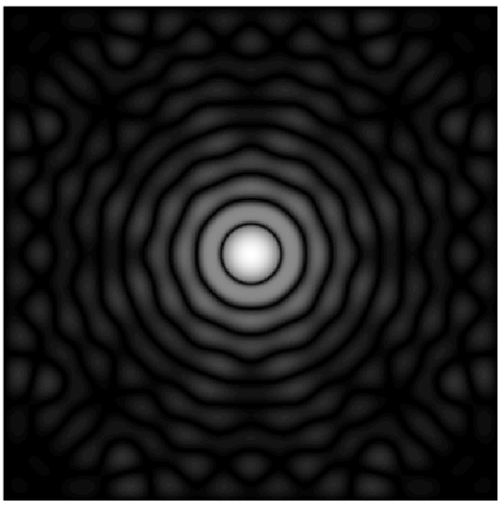
Which of the images below is the result of applying an **ideal high-pass filter** to the picture above?

i)

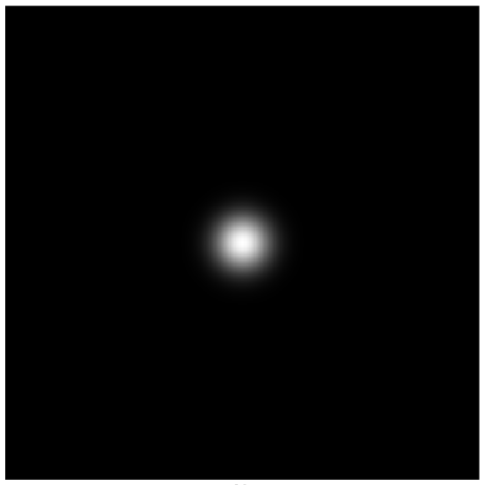
ii)

iii)

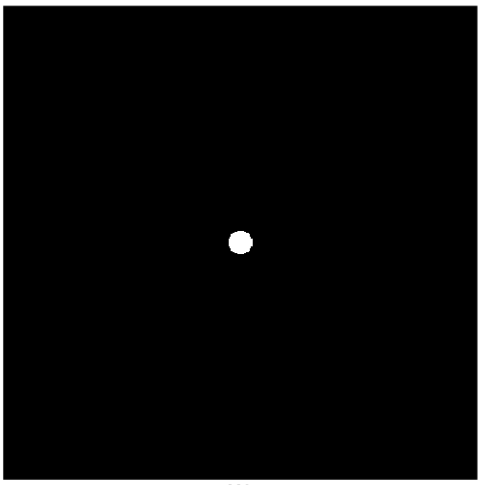
iv)

6.  1P

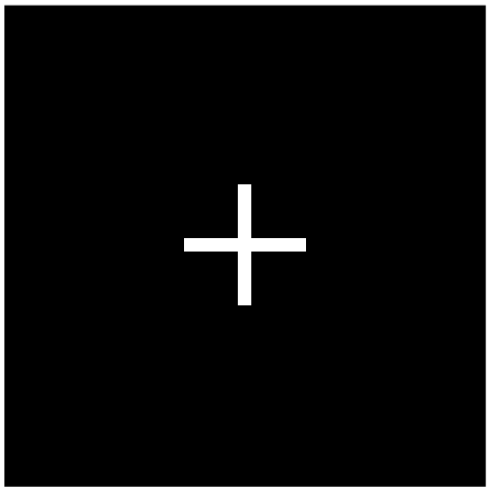
The image above shows the magnitude of the **frequency spectrum** of which of the following images?



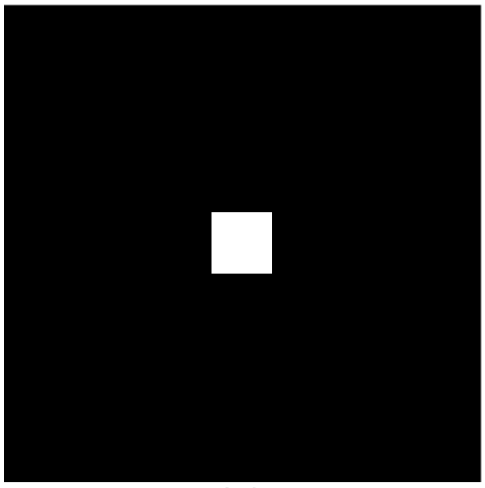
i)



ii)



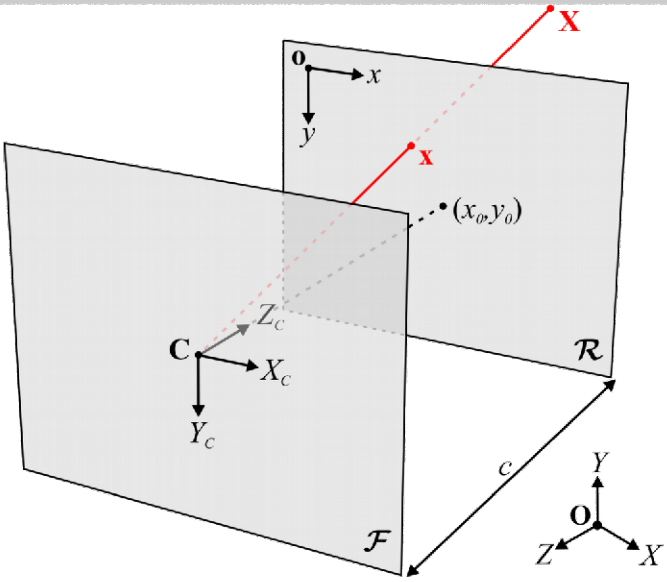
iii)



iv)

Block 3

7.



$$K=\begin{bmatrix} 8446 & 0 & 4344 \\ 0 & 8446 & 2896 \\ 0 & 0 & 1 \end{bmatrix}$$

The figure above illustrates a standard **pinhole camera** system. Please assign the correct names to the following variables as defined in the figure. **This is not a multiple-choice question. Please use the table below.** 4P

C	
c	
(x_0, y_0)	
R	

8. The matrix above (next to the figure showing the camera system) states the **calibration matrix *K*** of a standard pinhole camera model. Please assign the correct values to the following variables as defined in the figure above. **This is not a multiple-choice question. Please use the table below.** 4P

c (in pixel)	
(x_0, y_0)	
Skew factor	
Aspect ratio	

9. Given a common optical camera, which of the following statements is a common assumption regarding the relationship between a true image f_T, the measured image f_M, and the **noise term** n? 1P

i) Image noise is **homogeneous**.

ii) The average of n over all image positions (x, y) is **zero**.

iii) Image noise is **additive**.

iv) $f_M(x, y) = f_T(x, y) \cdot n(x, y)$

Block 4

10. The magnitude of the Fourier spectrum *H* of a degradation filter *h* is given as 2P

$$|H|=[5,20,60,120,200,250,200,120,60,20,5]$$

Which of the following magnitudes of a spectrum *Q* belongs to the **clipped inverse filter** *q* (with a threshold *T = 30*) that can be used to restore the original signal if it was distorted by filter *h*.

i) $|Q|=[1/5,1/20,1/60,1/120,1/200,1/250,1/200,1/120,1/60,1/20,1/5]$

ii) $|Q|=[30,30,1/60,1/120,1/200,1/250,1/200,1/120,1/60,30,30]$

iii) $|Q|=[1/30,1/30,1/60,1/120,1/200,1/250,1/200,1/120,1/60,1/30,1/30]$

iv) $|Q|=[0,0,1/60,1/120,1/200,1/250,1/200,1/120,1/60,0,0]$

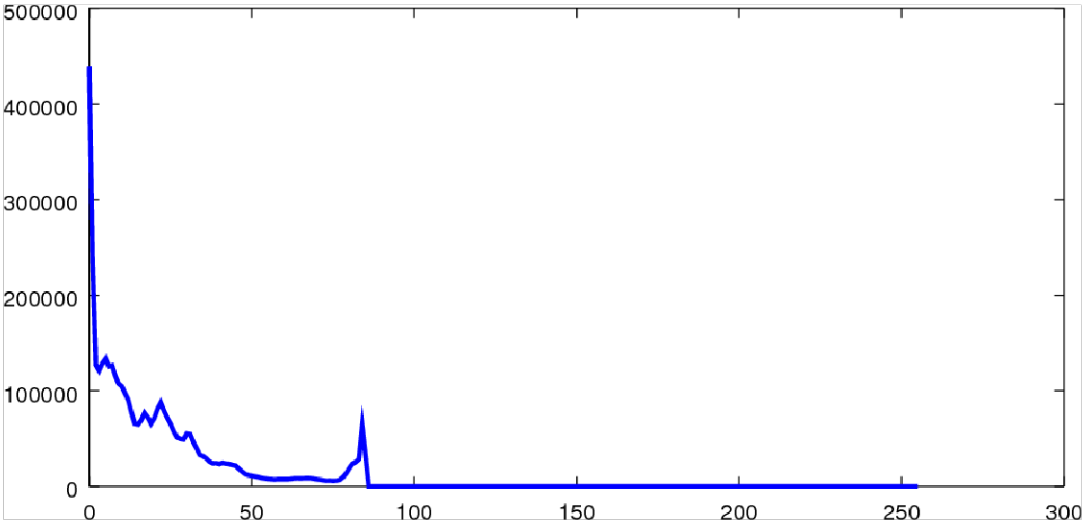
11. Which is the signal model that the **inverse filter** assumes (⊗ denotes convolution and *s, o, h,* and *n* denote the measured and original image, a filter and a noise term, respectively)? 1P

i) $s=h\otimes(o+n)$	ii) $s=h\otimes o+n$
iii) $s=(h\otimes o)\cdot n$	iv) $s=h\otimes o$

12. Which is the signal model that the **Wiener filter** assumes(same notation as above)? 1P

i) $s=h\otimes(o+n)$	ii) $s=h\otimes o+n$
iii) $s=(h\otimes o)\cdot n$	iv) $s=h\otimes o$

Block 5

13. 

1P

The figure above shows the **grey-scale histogram** of an image.

Which of the following statements are true regarding this image?

i) The image has **low contrast**.
ii) The image is **large** (i.e. has more than 10 million pixel).
iii) The image is **dark**.
iv) The image has **strong salt-and-pepper noise**.

14. 
1P

The figure above shows on the right the result of applying a **homogeneous point operation** *q=f(p)* to the values *p* of the original image on the left. Which of the following operations was used?

i) $q=f(p)=\frac{\log_e(p+1)}{\log_e(256)}\cdot 255$	ii) $q=f(p)=\frac{p^2}{255}$
iii) $q=f(p)=p$	iv) $q=f(p)=255-p$

15.

109	100	104	106	109
109	109	107	103	107
105	105	103	109	100
108	109	102	107	102
102	104	102	108	106

3P

The matrix above denotes a small grey-scale image. Which of the following image matrices are the result of applying **linear grey-level stretching**?

i)

255	0	113	170	255
255	255	198	85	198
142	142	85	255	0
227	255	57	198	57
57	113	57	227	170

ii)

255	0	116	172	255
255	255	200	87	200
144	144	87	255	0
228	255	59	200	59
59	116	59	228	172

iii)

255	0	111	168	255
255	255	196	83	196
139	139	83	255	0
226	255	55	196	55
55	111	55	226	168

iv)

255	20	102	143	255
255	255	173	82	173
122	122	82	255	20
194	255	61	173	61
61	102	61	194	143

Block 6

16. Given an image *f* and the corresponding spatial first derivatives f_x, f_y and second derivatives $f_{xx}, f_{xy}, f_{yx}, f_{yy}$, which of the following equations defines the **structure tensor** *A*? 1P

i) $$A(x,y)=\sum_{(i,j)\in W}\begin{bmatrix} f_{xx}(i,j) & f_{xy}(i,j) \\ f_{yx}(i,j) & f_{yy}(i,j) \end{bmatrix}$$

ii) $$A(x,y)=\begin{bmatrix} \sum_{(i,j)\in W} f_{xx}(i,j) & \sum_{(i,j)\in W} f_{xy}(i,j) \\ \sum_{(i,j)\in W} f_{yx}(i,j) & \sum_{(i,j)\in W} f_{yy}(i,j) \end{bmatrix}$$

iii) $$A(x,y)=\begin{bmatrix} \sum_{(i,j)\in W} f_x(i,j)f_x(i,j) & \sum_{(i,j)\in W} f_x(i,j)f_y(i,j) \\ \sum_{(i,j)\in W} f_y(i,j)f_x(i,j) & \sum_{(i,j)\in W} f_y(i,j)f_y(i,j) \end{bmatrix}$$

iv) $$A(x,y)=\begin{bmatrix} \sum_{(i,j)\in W} f(x,j)f(x,j) & \sum_{(i,j)\in W} f(x,j)f(i,y) \\ \sum_{(i,j)\in W} f(x,j)f(i,y) & \sum_{(i,j)\in W} f(i,y)f(i,y) \end{bmatrix}$$

17. If the **structure tensor** is computed for a pixel on an image **edge**, which of the following statements is true? 1P

i) The **determinant** of the tensor is close to zero.
ii) **All Eigenvalues** of the tensor are close to zero.
iii) Only **one Eigenvalue** of the tensor is close to zero.
iv) The tensor has **full rank**.

18. Given the structure tensor *A* below, which is the correct value of the weight value of the **Förstner operator**? 3P

$$A=\begin{bmatrix} 5 & 1 \\ 1 & 5 \end{bmatrix}$$

i) 0.96	ii) 5 / 12
iii) 2.4	iv) 20

Block 7

19. 2P

5	20	55
6	14	60
8	22	50

Transform the image given on the left side of the figure above into its **integral image** representation.
This is not a multiple-choice question. Please use the empty image matrix on the right.

20. For which of the following filters can the computation time of their application be decreased by using **integral images**? 1P

i)

0	0	0	0	0	0	0
0	1	1	1	1	1	0
0	1	1	1	1	1	0
0	1	1	1	1	1	0
0	1	1	1	1	1	0
0	1	1	1	1	1	0
0	0	0	0	0	0	0

ii)

0	0	0	0	0	0	0
0	0	1	2	1	0	0
0	1	6	10	6	1	0
0	2	10	16	10	2	0
0	1	6	10	6	1	0
0	0	1	2	1	0	0
0	0	0	0	0	0	0

iii)

0	0	0	0	0	0	0
0	-1	-1	-1	-1	-1	0
0	-1	4	4	4	-1	0
0	-1	4	4	4	-1	0
0	-1	4	4	4	-1	0
0	-1	-1	-1	-1	-1	0
0	0	0	0	0	0	0

iv)

0	0	0	0	0	0	0
0	1	1	0	-1	-1	0
0	1	1	0	-1	-1	0
0	1	1	0	-1	-1	0
0	1	1	0	-1	-1	0
0	1	1	0	-1	-1	0
0	0	0	0	0	0	0

21. Based on the idea of **separable filters**, which of the following filter pairs is the correct representation of the filter *h* given below? 2P

$$h=\begin{bmatrix} 9 & 15 & 9 \\ 15 & 25 & 15 \\ 9 & 15 & 9 \end{bmatrix}$$

i) $\left([3 \quad 5 \quad 3],[3 \quad 5 \quad 3]^T\right)$	ii) $\left([9 \quad 15 \quad 9],[15 \quad 25 \quad 15]^T\right)$
iii) $\left([9 \quad 15 \quad 9],[15 \quad 25 \quad 15]\right)$	iv) $\left([3 \quad 5 \quad 3],[3 \quad 5 \quad 3]\right)$

Block 8

22. 2P

83	127	109	69	110	108	66
115	108	61	80	135	108	52
104	104	130	93	92	145	61
50	132	51	74	93	129	53
81	83	148	97	123	93	57
65	138	139	78	53	97	60
83	57	76	128	117	121	140

-1	0	1
-2	0	2
-1	0	1

Which of the matrices below are the 3×3 central part of the resulting image when a **median filter** is applied to the image on the left side above? Note: The corresponding central part is marked in **grey**.

93	92	93
97	93	93
97	93	93

i)

93	90	105
101	100	104
104	95	93

ii)

99	92	105
93	87	101
113	99	99

iii)

97	108	93
93	97	93
93	97	93

iv)

23. If an image operator *T* can be implemented as **convolution** of an image with a filter kernel, which of the following statements are correct? 1P

Note: f, g are images of same size, a is a constant scalar value, and ∇ is the derivative operator.

i) $T(\nabla f)=\nabla T(f)$	ii) $T(a\cdot f)=a\cdot T(f)$
iii) $T(f+g)=T(f)+T(g)$	iv) $T(f\cdot g)=T(f)\cdot T(g)$

24. Which of the following images is the result of **convolving the image** on the left side of the figure above with the filter stated on the right side? 4P

-108	40	187
-113	21	158
-90	-94	66

i)

108	-40	-187
113	-21	-158
90	94	-66

ii)

-2	-64	-69
19	57	14
186	56	-108

iii)

211	-4	-98
-280	-38	-46
222	-35	156

iv)