Technische Universität Berlin

Computer Vision &
Remote Sensing

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Examination

Digital Image Processing

Summer term 2015

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

Berlin, July 23, 2015

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**.

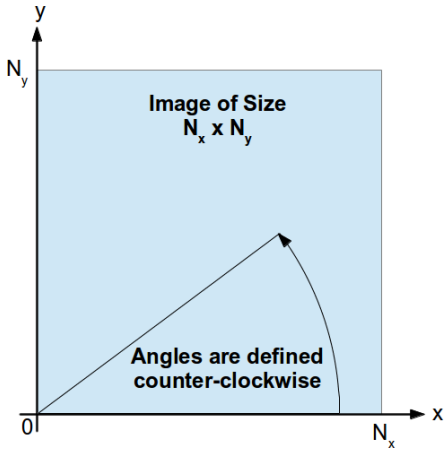
Books, notes, dictionaries, own empty sheets of paper, pocket calculators are **not allowed**.
Use only a pen. Everything written with a pencil will not be taken into account.

A short and accurate style as well as a **clear handwriting** should be intended.
Pay attention to a **clear and comprehensible** preparation of sketches.

If you do not understand a question, ask.
It will be to your advantage to read the entire examination before beginning to work.
The questions are **not ordered** by their complexity or difficulty.

Notation:

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



1. Task:	/ 30 points
2. Task:	/ 6 points
3. Task:	/ 7 points
4. Task:	/ 13 points
5. Task:	/ 6 points
Total:	**/ 62 points**

Lot's of luck and do your best!

1 Task 30P

Figure 1.a) and b) show two filter kernels.

-1	-1	-1	-1
1	1	1	1

a)

-1	1
-1	1
-1	1
-1	1

b)

Figure 1

a) Do these kernels belong to the group of low- or high-pass filters? 2P

b) **Explain** which conditions a filter needs to fulfill, so that its application can be modelled as convolution. 2P
Do these kernels fulfill these conditions? 1P

c) Besides obvious parallelization approaches (like programming on GPUs), there are also **three** algorithmic methods (known from the DIP-lecture and -exercise) to speed up a convolution with certain kinds of filters.
   i) **State** the names of these methods. 3P
   ii) Provide an **explanation** of their working principle. 7P
   iii) Under which conditions can they be applied? 3P
   iv) Do the filters in Figure 1 fulfill all the conditions of 1.c.iii)? 1P
   v) What is the time complexity for each of these three approaches? 3P

d) The image shown in Figure 2 is convolved with the filter kernels A-I as defined below. The results of the convolution are shown in Figure 3.a)-h).
Please note, that the intensity of these images has been normalized after the convolution to lie between 0 and 255.

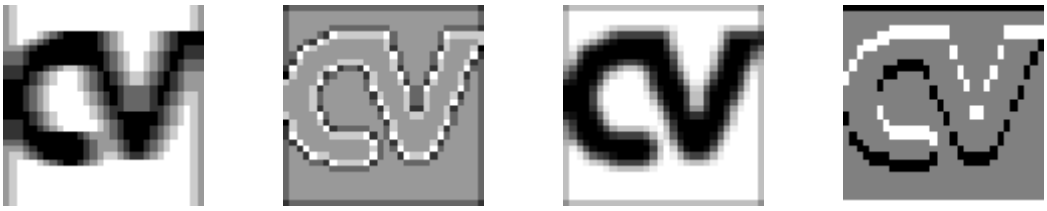
Figure 2

State which output corresponds to which filter kernel. 8P
Note that one of the filters has to be discarded!

$$A = [1 \quad 0 \quad -1]/2 \qquad B = [1 \quad 1 \quad 1 \quad 1 \quad 1]/5$$

$$C = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{bmatrix}/2 \qquad D = \begin{bmatrix} -1 \\ 0 \\ 1 \end{bmatrix}/2 \qquad E = \begin{bmatrix} 1 \\ 1 \\ 1 \\ 1 \\ 1 \end{bmatrix}/5$$

$$F = \begin{bmatrix} 0 & 1 & 0 \\ 1 & -4 & 1 \\ 0 & 1 & 0 \end{bmatrix}/8 \qquad G = \begin{bmatrix} 0 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & 0 \end{bmatrix} \qquad H = \begin{bmatrix} 1 & 2 & 1 \\ 2 & 4 & 2 \\ 1 & 2 & 1 \end{bmatrix}/16 \qquad I = \begin{bmatrix} 1 & 1 & 1 \\ 1 & -4 & 1 \\ 1 & 1 & 1 \end{bmatrix}/8$$



a) b) c) d)

e) f) g) h)

Figure 3

2 Task 6P

200	200	50	50

a)

234	164	51	45

b)

200	0	255	50

c)

195	197	61	47

d)

Figure 4

A small part of a larger noise-free image is shown in Figure 4.a). Figure 4.b)-d) show three versions of this image part, which are deteriorated by noise of different types.

a) Which type of noise has most likely caused the image values in Figure 4.b)-d)? 3P

b) Select **one** of the noise types you have named in Task 2.a) and give a **step-by-step description** of an **appropriate** noise reduction technique. 3P

3 Task 7P

A small 8x8 image is given by Figure 5.

Use the tables in Figure 6 for the following tasks. It is sufficient to state only non-zero entries $(h(g)\neq 0)$ of the histogram h for each greylevel g.
Fractions (e.g. 4/255) do not have to be calculated.

8	8	8	8	8	8	8	8
7	3	1	1	6	8	3	2
3	1	5	1	3	8	1	4
1	4	9	5	1	5	1	7
1	3	8	8	1	1	3	8
5	0	1	4	4	0	6	8
8	7	5	6	7	6	8	8
8	8	8	8	8	8	8	8

Figure 5

a) **Compute** the relative gray-level histogram of the image in Figure 5 2P

b) **Compute** the relative gray-level histogram if linear grey-level stretching would have been applied to the image in Figure 5. 2P

c) **Compute** the relative gray-level histogram if histogram equalization would have been applied to the image in Figure 5. 2P

d) What happens if histogram equalization is applied again after 3.c), i.e. if it was applied already once before? 1P

g	*h(g)*

a)

g	*h(g)*

b)

g	*h(g)*

c)

Figure 6

4 Task 13P

a) **Explain** why box filters K with size $w \times w$ perform a non-isotropic smoothing. 2P

$$K = \begin{bmatrix} 1 & \cdots & 1 \\ \vdots & \ddots & \vdots \\ 1 & \cdots & 1 \end{bmatrix} / w^2$$

b) How can edges in an image be detected by usage of the structure tensor? 2P

c) Give a **step-by-step description** of the working principle of the Förstner interest operator starting at a given color image. 9P

5 Task 6P

State for each of the statements below, whether it is true (T) or false (F).

Please note, that there is a penalty of -0.5 points for a wrong answer. However, the minimal number of points for this task is 0.

	T	F	Statement	
a)			The kernel $[-1, 2, -1]$ is meant to approximate first order derivative.	1P
b)			Each of the following filters can be implemented using convolution mechanism: Average Filter, Gaussian Filter, Bilateral Filter.	1P
c)			Transforming the pixel values of an image using a $log()$-transformation is an example of contrast compression of the dark pixels.	1P
d)			Textons are method for optical character recognition (OCR).	1P
e)			Let X be the number of foreground pixels (=1) in a binary image. If Y is the number of foreground pixels after applying a dilation operation to this binary image, then $X \geq Y$.	1P
f)			The goal of the mean-shift algorithm is to shift the mean of the gray-level histogram of an image for brightness correction.	1P