Technische Universität Berlin

Computer Vision &
Remote Sensing

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Examination

Digital Image Processing

Winter term 2015/16

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

Berlin, Februar 16, 2016

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**.

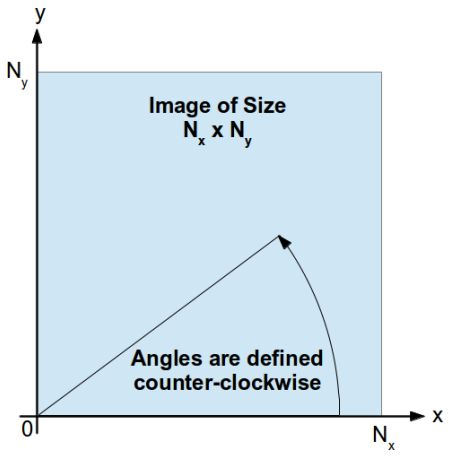
Books, notes, dictionaries, own empty sheets of paper, pocket calculators are **not allowed**.
Use only a pen. Everything written with a pencil will not be taken into account.

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:	/ 8 points
2. Task:	/ 9 points
3. Task:	/ 11 points
4. Task:	/ 9 points
5. Task:	/ 9 points
Total:	**/ 46 points**

Lot's of luck and do your best!

1 Image formation 8P

Optical cameras often consist of a complicated system of lenses that direct the incoming light to a light-sensitive sensor. Despite the complicated nature of the real image formation process, it is often modelled as a simple pinhole camera.

a) **State** the calibration matrix of the **algebraic pinhole camera model**. 1P
Provide the **names** for all corresponding internal camera parameters. 3P

b) **Describe** what the terms **digitization** and **quantization** mean in the context of image formation. 2P

c) **Describe** how an image can be properly scaled by a factor of 1.5. 3P

2 Image Filtering 9P

Many operations on images can be modelled as linear and shift invariant operations, which are completely described by the corresponding point spread function, i.e. the filter kernel.

0	0	0	0	5	10
0	0	0	5	10	10
0	0	5	10	10	10
0	5	10	10	10	10

Figure 1

a) **State** the kernel of the **Sobel filter** in x-direction. 1P

b) Use the idea of **separable filters** to convolve the image in Figure 1 and the kernel from 2.a). Use mirroring as border handling. Please also provide **intermediate results**! 4P

d) What does the **convolution theorem** state? 1P
Is it advisable to apply it in case of 2.b)? **Explain** your answer. 1P

e) **Explain** whether the Sobel filter belongs to the group of low- or high pass filters. 2P

3 Morphology 11P

Morphology is an alternative to the classical convolution-based approach to image filtering. It was originally proposed for **binary images**, where white denotes the foreground and black the background. Later it was extended to gray-scale images.

a) **Name and define** the two **basic** operations of morphology on binary images. 4P

b) Based on the definitions in 3.a), **name and explain** a technique to close small holes in the foreground of binary images while maintaining the general shape of the objects. 3P

c) Compute the **internal morphological gray-scale gradient** of the image in Figure 1. Assume that the structuring element is set as a square of 3x3 pixels and mirroring is used as border handling. Please also provide **intermediate results**! 4P

please turn the page

4 Graphical models 9P

Graphical models are powerful tools for many applications in image processing and image analysis.

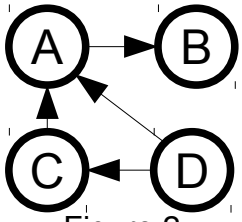


Figure 2

a) Formulate a **mathematical expression** for the joint probability of four variables A,B,C,D using the conditional independence conditions corresponding to the graphical model in Figure 2. 2P

b) What is a **maximal clique** in undirected graphical models? 2P

c) **Sketch** a part of an MRF as typically used in image processing, e.g. for denoising. Provide proper **names** for all the corresponding potential functions and **describe** their roles during the optimization process. 5P

5 General 9P

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
		Gray-level co-occurence matrices estimate the probability that two pixels with a certain distance and orientation to each other have certain intensity values.
		Optimal thresholding is a technique to iteratively adjust the threshold for binary segmentation tasks.
		Let *s* be the measured signal, *o* the original signal, *h* an operator that can be modelled as convolution and *n* a noise term. In this case, the signal model of the **Wiener filter** is: $s = h(o+n)$.
		The **exponential function** performs a contrast enhancement for bright pixels.
		Linear grey-level stretching uses the cumulative gray-level histogram as transfer function.
		If an operator is shift invariant, it can be modelled as convolution.
		Convolution (*) is an associative operation, i.e. a*(b*c) = (a*b)*c.
		For real-valued signals, the amplitudes of the negative frequencies of the **Fourier spectrum** are always zero.
		The **ringing effect** is caused by strong edges in the spatial domain.