Exercises for
Pattern Analysis
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Assignment 1, 17/18.04.2018

General Information:

Lecture (3 SWS):	Tue 12.15 – 13.45 (H16) and Thu 12.15 – 13.45 (H16)
Exercises (1 SWS):	Tue 14.00 – 16.00 (02.151b-113) and Thu 10.00 – 12.00 (02.151b-113)
Certificate:	Oral exam at the end of the semester
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Mean Shift for Denoising

Exercise 1 Rules for submitting the programming exercise:

(a) Work together in pairs (max. two people).

(b) You have to show your code to the tutors not later than the deadline. It's is recommended that all team members shows up.

(c) Your code has to be in C or C++. We recommend using *OpenCV* for Matrix algebra and visualization, as it is available in the CIP pool.

(d) You can either use CIP pool PC's or your own laptop.

(e) Plagiarism will be punished by assigning zero points, removal from the programming exercises and/or by a report to the examination office. According to Wikipedia, plagiarism is *the "wrongful appropriation" and "stealing and publication" of another author's "language, thoughts, ideas, or expressions" and the representation of them as one's own original work.*

Exercise 2 Programming exercise:

In terms of image processing, the mean shift algorithm can be employed for edge-preserving smoothing. This filtering technique can be used to denoise images. The key idea of mean shift filtering is to represent each pixel of an image by a feature vector $\boldsymbol{x}$ and to define a joint probability density function $p(\boldsymbol{x})$ for the image. Mean shift iterations are performed to find a local maximum of $p(\boldsymbol{x})$ next to a given pixel. For the sake of simplicity, we consider 2-dimensional, intensity (gray value) images. For details of mean shift for edge-preserving smoothing please refer to

Comaniciu, D. and Meer, P. *Mean shift: a robust approach toward feature space analysis.* IEEE Transactions on Pattern Analysis and Machine Intelligence (2002), Volume 24, Issue: 5, pp. 603 - 619

(a) Define a feature vector $\boldsymbol{x}_i$ to model the i-th pixel for a given input image. Explain how the feature vector can be extended to handle color images represented in the RGB color space.

(b) Explain how the mean shift algorithm can be employed to denoise $\boldsymbol{x}_i$. In particular, describe which parameters are required and explain the influence

of the parameters to the outcome of mean shift.

(c) Implement mean shift denoising. Use the Epanechnikov kernel for the mean shift iterations. Your program should perform the following steps:

- Load the example *cameraman-noisy.png* image.
- Display the noisy image.
- Apply your mean shift algorithm to smooth the noisy image.
- Hint: the width of the Epanechnikov kernel can be selected empirically by visual inspection of the denoised image.
- Display the denoised image.
- Save the denoised image as *cameraman-denoised.png*.

(d) **Deadline for submission: May 2nd 2018**

Figure 1: Noisy (left) and denoised image (right) using mean shift filtering.