

EXAMINATION QUESTION PAPER

Exam in:	FYS-2010 Digital Image Processing
Date:	Monday 6 June 2016
Time:	09.00-13.00
Place:	Åsgårdvegen 9
Approved aids:	One A4 sheet of paper (i.e., two written A4 pages) with notes (printed or hand-written) and calculator with empty memory card.
Type of sheets (squares/lines):	Squares
Number of pages incl. cover page:	4
Contact person during the exam:	Michael Kampffmeyer
Phone:	90602098

NB! It is not allowed to submit rough paper along with the answer sheets

General Remark

In problems requiring Matlab (or equivalent) code, you may use built-in commands if you wish. You should strive to comment any code and make the code understandable by explanations, also with respect to the underlying theory, for the generally knowledgeable digital image processing person.

All sub-problems are equally important when grading the exams.

Problem 1

We will in this problem study the role of the histogram in image processing.

- (a) Describe the role of histograms in image processing.
- (b) Histograms can be used to automatically enhance contrast in images. However, sometimes we instead want to *specify* a particular histogram for our output image. Explain how both these operations can be performed.
- (c) Given the 3-bit 4×4 image

$$M = \begin{array}{|c|c|c|c|} \hline 0 & 0 & 0 & 4 \\ \hline 1 & 1 & 1 & 5 \\ \hline 1 & 2 & 2 & 7 \\ \hline 2 & 2 & 2 & 7 \\ \hline \end{array}$$

perform histogram equalization and find the resulting image.

- (d) Given a 3×3 image

$$f = \begin{array}{|c|c|c|} \hline 0 & 2 & 4 \\ \hline 2 & 4 & 6 \\ \hline 4 & 6 & 8 \\ \hline \end{array}$$

we want to enlarge the image to a 5×5 image. Explain nearest neighbor and bilinear interpolation and show how the resulting 5×5 image will look for each of the two interpolation methods.

Note: As there are multiple valid interpolation results in the nearest neighbor case it is enough to show one valid result for the nearest neighbor interpolation.

Problem 2

We will in this problem study image restoration and reconstruction.

- (a) Sketch a block diagram model for the image degradation/restoration process and give the equations describing the model in both the spatial and frequency domain. Given two images, one degraded by Gaussian noise and one degraded by impulse noise, name two filters (one for each image) that can be used to remove the noise.
- (b) Describe how inverse filtering can be used to restore a degraded image and how the degradation can be estimated if unknown. Under what assumption can we perfectly restore the image (given knowledge of the exact degradation function) and how can we avoid erratic behavior when the assumption is not met.
- (c) The Wiener filter, given by

$$W(u, v) = \left[\frac{1}{H(u, v)} \frac{|H(u, v)|^2}{|H(u, v)|^2 + S_\eta(u, v)/S_f(u, v)} \right],$$

is often referred to as the least square error filter. Explain the statement, define the terms in the equation, and explain under which conditions the Wiener filter is equal to the inverse filtering procedure.

Problem 3

We will in this problem study filtering in the spatial and frequency domain.

- (a) The filter

$$W = \frac{1}{(2+b)^2} \begin{array}{|c|c|c|} \hline 1 & b & 1 \\ \hline b & b^2 & b \\ \hline 1 & b & 1 \\ \hline \end{array},$$

where $b > 0$, is a general representation of an often used filter mask in image processing. Provide Matlab code (or equivalent) that will implement filtering using mask W .

- (b) Show that the filter mask W corresponds to a lowpass filter operation.

- (c) Given the filter

$$H(u, v) = (b + 2\cos(2\pi \frac{u - \frac{P}{2}}{P}))(b + 2\cos(2\pi \frac{v - \frac{Q}{2}}{Q}))/ (2 + b)^2,$$

provide Matlab code (or equivalent) that will filter an image f in the frequency domain. Here you can assume that f and H are variables containing the image and the filter. Comment the code and explain the procedure.

Problem 4

We will in this problem study image segmentation.

- (a) One category of image segmentation is referred to as edge-based segmentation. Describe how the first and second order derivatives can be used to detect edges, how they differ from each other, how they are affected by noise, and which filter masks can be used.
- (b) Describe the Marr-Hildreth (LoG) edge detector and give a brief description of the 3 steps applied by this detector.
- (c) Another form of image segmentation is referred to as region based segmentation. Describe the RGB color model and how you would perform segmentation in the RGB vector space.
- (d) Given an 24-bit color image f , provide Matlab code (or equivalent) that performs image segmentation. The colors of interest lie inside a sphere centered at $(R = 0.7, G = 0.2, B = 0.3)$ with radius $r = 0.2$, where the RGB values have been scaled to be in the range $[0,1]$.