TENTAMEN IMAGE PROCESSING

31-1-2013

A FORMULA SHEET IS INCLUDED ON PAGES 3-4

Put your name on all pages which you hand in, and number them. Write the total number of pages you hand in on the first page. Write clearly and not with pencil or red pen. ***Always motivate your answers.*** *You get 10 points for free. Success!*

Problem 1 Median filtering (20 pt)

The *median filter* $\mathcal{M}(f)$ replaces the value of each pixel p of an image f by the median of the 9 values in a 3×3 neighbourhood centered on pixel p. Consider the following two grey scale images f_1 and f_2. Pixels outside the domain are assumed to have the value zero.

0	0	0	0	0
0	0	5	0	0
0	4	10	9	0
0	0	1	0	0
0	0	0	0	0

f_1

0	0	0	0	0
0	0	10	0	0
0	12	1	3	0
0	0	13	0	0
0	0	0	0	0

f_2

a. (5pt) Draw pictures of the median-filtered images $\mathcal{M}(f_1)$ and $\mathcal{M}(f_2)$.
b. (5pt) Compute the sum image $f_1 + f_2$, and determine its median-filtered image $\mathcal{M}(f_1 + f_2)$.
c. (5pt) Is the median filter a linear image operation?
d. (5pt) Is the median filter shift-invariant? Can the median filter be represented as a convolution filter?

Problem 2 Frequency domain filtering (20 pt)

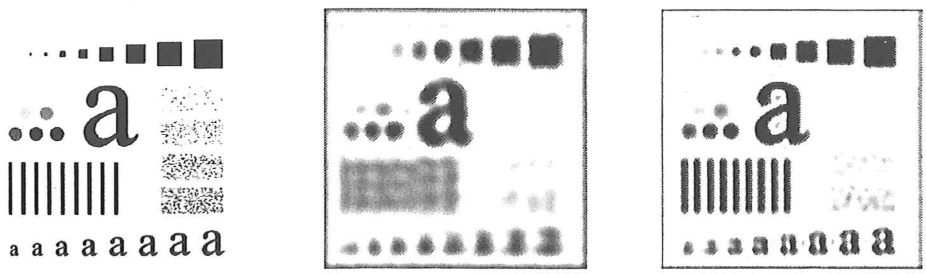

Figure 1: *Left: input image; Middle: ILPF-filtered,* $D_0 = 30$*; Right: ILPF-filtered,* $D_0 = 60$.

An example of frequency domain filtering is the ideal lowpass filter (ILPF), defined by the transfer function

$$H(u,v) = \begin{cases} 1 & \text{if } D(u,v) \leq D_0 \\ 0 & \text{if } D(u,v) > D_0 \end{cases}$$

$D(u,v)$ is the distance of the point (u,v) to the origin of the frequency domain, and D_0 the cut-off radius.

(*continue on page 2*)

a. (5pt) What is the purpose of lowpass filtering?
b. (5pt) ILPF filtering causes two main types of artefact, as you can observe in the example of Figure 1. Describe these two artefacts.
c. (5pt) Explain both artefacts by considering the spatial representation $h(x)$ of a one-dimensional ILPF ($H(u) = 1$ for $-D_0 \leq u \leq D_0$ and zero elsewhere).
d. (5pt) How do the two artefacts change when the cut-off radius D_0 is increased?

Problem 3 Morphological filtering (20 pt)

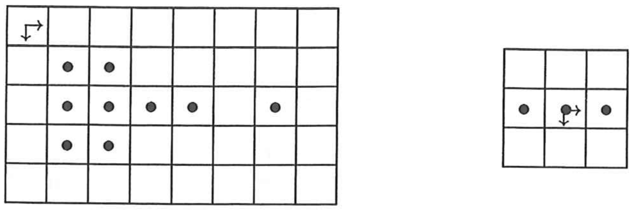

Figure 2: *Left: binary image X. Right: structuring element B.*

Consider a binary image X and a structuring element B, as shown in Figure 2. Black dots denote elements of the sets X and B, respectively, while empty cells denote elements of the background.

a. (10pt) For the case of Figure 2, sketch the erosion $\varepsilon_B(X)$, the dilation $\delta_B(X)$, the opening $\gamma_B(X)$, and the closing $\phi_B(X)$.
b. (10pt) Sketch the result of the opening by reconstruction for the case of Figure 2, where the marker is equal to the erosion of X by B, the mask is equal to the input image X, and the structuring element is B. Explain the difference between the opening by reconstruction of X and the opening of X.

Problem 4 Image segmentation (15 pt)

a. (5pt) Give a definition of image segmentation.
b. (5pt) In edge-based segmentation one often uses a preprocessing step where the image is smoothed by a Gaussian convolution filter. Explain when this preprocessing is necessary and why.
c. (5pt) One of the region-based segmentation procedures is the *split-and-merge* method. Describe this method.

Problem 5 Image description (15 pt)

a. (5pt) Consider a checkerboard image composed of alternating black and white squares, each of size $m \times m$. Give a position operator (spatial predicate) Q that would yield a diagonal co-occurrence matrix.
b. (5pt) Suppose the checkerboard image is represented as an 8-bit image. Does the image have coding redundancy? Does the image have spatial redundacy? Motivate your answers.
c. (5pt) Mention at least one image compression method which can be used in the case of (i) coding redundancy; (ii) spatial redundacy.