TENTAMEN IMAGE PROCESSING

2-2-2012

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. You can answer in English or Dutch. ***Always motivate your answers.*** *You get 10 points for free. Success!*

Problem 1 Frequency domain filtering (20 pt)

a. Describe globally how you can implement convolution filtering using frequency domain techniques.

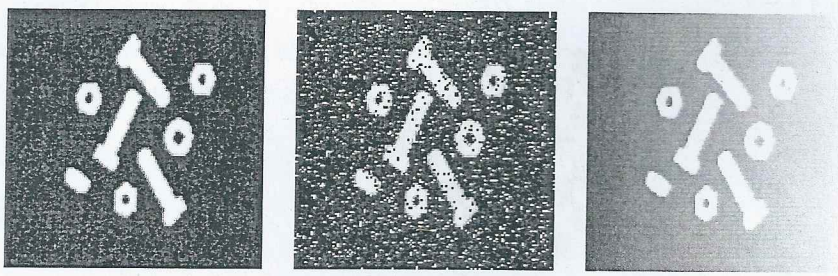
b. One of the steps in the frequency domain implementation is zero padding. Why is zero padding necessary? How much zero padding has to be applied, as a function of the size of the filter kernel?

c. What is the advantage of a frequency domain implementation?

d. The figure above shows the "trui" image, before (left image) and after (right image) corruption by motion blur and noise. To restore the input image, parametric Wiener filtering can be used. Why is it not useful to set the parameter K in the Wiener filter to zero, even when the noise is absent? How should the value of K be changed when the noise level is increased?

Problem 2 Morphological filtering (25 pt)

Consider a binary image X with nuts and bolts; see Figure 1(a). In Figure 1(b) the image has been affected by "salt & pepper noise": a fraction of foreground (white) pixels has randomly turned into background (black) pixels, and vice versa for the background pixels. In Figure 1(c) we have applied non-uniform background illumination to the input image.



(a) (b) (c)

Figure 1: *(a): input image; (b): with salt & pepper noise; (c): with non-uniform illumination.*

a. Suppose that only the following morphological filters are available to reduce the noise in Figure 1(b): dilation δ_B, erosion ε_B, opening γ_B, closing ϕ_B, or a combination of these. The filter should, as much as possible, leave the original shape of the nuts and bolts intact. Explain which filter (combination) you would use for this purpose, and how the structuring element B (shape and size) has to be chosen.

(continue on page 2)

b. The non-uniform background illumination in Figure 1(c) can be reduced by applying a "rolling ball" filter. This is a top-hat filter

$$T_{\text{hat}} = f - (f \circ b)$$

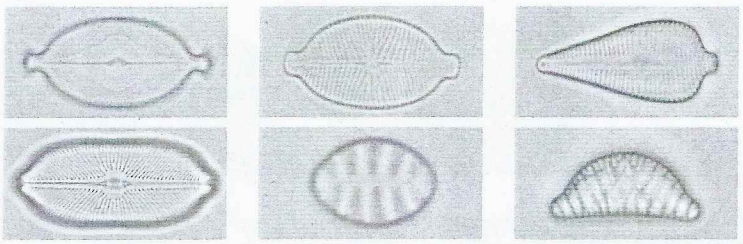
where f is the input image, and $f \circ b$ the opening of f by a sphere-shaped (i.e., non-flat) structuring element b. Explain how the action of a top-hat filter can reduce the uneven illumination. How should the radius of the sphere be chosen in comparison to the size of the nuts and bolts?

c. The dilation δ_B and erosion ε_B satisfy the following property (for any structuring element B):

$$\varepsilon_B\left(\delta_B\left(\varepsilon_B(X)\right)\right) = \varepsilon_B(X) \quad \text{for any binary image } X.$$

In words: "erosion, followed by dilation, followed by erosion, equals erosion". Give a proof of this property.
Hint: equality of sets, $A = C$, can be proven by proving that $A \subseteq C$ *and* $A \supseteq C$.

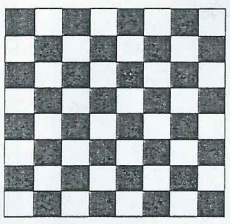
Problem 3 Image descriptors (25 pt)
Consider the optical microscopy images of 6 species of diatoms (unicellular algae) in the following figure:



We want to apply a set of image operations and descriptors to these images so that they can be distinguished. Many solutions are possible, and there is no absolutely "correct" solution. Give a set of image operations and descriptors of your choice (aim for a convincing motivation!). Clearly indicate:

a. A short explanation of each image operation / descriptor in your set.
b. How your set of operations / descriptors would allow to distinguish between the six images.

Problem 4 Image compression (20 pt)
Consider the following 8×8 checkerboard image, represented as a 1-bit (black and white) image.



a. Give an argument *without using formulas* which shows that the checkerboard image has zero coding redundancy. Verify this by computing the average length L_{avg} of the fixed-bit code and the estimated entropy of the image.
b. Does the the checkerboard image have spatial redundancy? If so, mention a compression method which can be exploited for reducing the spatial redundancy.
c. Now assume the checkerboard image is transformed by reshuffling its 64 pixels randomly. Does the new 8×8 image have coding redundancy? And spatial redundancy?