UNIVERSITY OF OSLO

Faculty of Mathematics and Natural Sciences

Midterm Exam :	INF2310 – Digital Image Processing
Date :	Wednesday, April 1. 2009
Time :	15.00 – 18.00
Number of pages :	**5** pages
Added material :	None
Allowed aid :	**None**

- There are 7 exercises in this exam.
- Read carefully through the complete exam paper before starting to solve the exercises. Make sure that the set of exercises is complete before you start. If you feel that some information is missing, you may make your own assumptions, as long as they are not contradictory to the "spirit" of the exercise. In such a case, you should make it clear what assumptions you have made.
- Try to give an answer to all exercises. If you feel that you are getting stuck at some questions, proceed so that you at least give a brief answer to all questions.

1. Quantization

a) Assume that we start with B bits per pixel. If we then halve the number of bits per pixel, how many quantization levels will we loose?

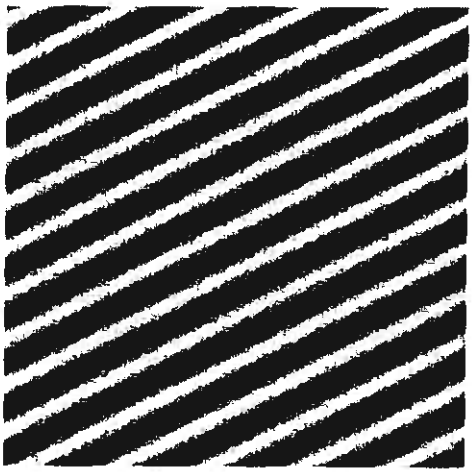
b) Assume that we start by quantizing by B bits per pixel. If we assume equal probablilities for all intensities in the input interval (uniform distribution), how big a change should we expect in the quantization error if we reduce the number of bits by one (from B to B-1)?

2. Sampling

a) The intensity of each pixel in the image below is described by

$$f(x,y) = 127 + A\cos(\frac{2\pi(ux+vy)}{N} + \psi)$$

where A = 100, u = 5, v = 10, ψ is a constant phase,
and there are N = 200 pixels in both the x- and y-direction in the image.



We are going to resample the image by an integer factor m in the x-direction and an integer factor n in the y-direction by averaging mxn pixels. What is then the maximum values of m and n that we can use i f we want to avoid aliasing?

b) Another method is to select every m-th pixel in the x-direction and every n-th pixel in the y-direction. If we fix m and n at the exact values of the Nyqvist-rate, the two methods may give very different resulting images. When and why?

3. Geometrical operations

a) The coordinates of an image are to be transformed by scaling, so that objects in the resulting image are twice as big in all directions, as compared to the original image. What is the coordinate transform for this operation?

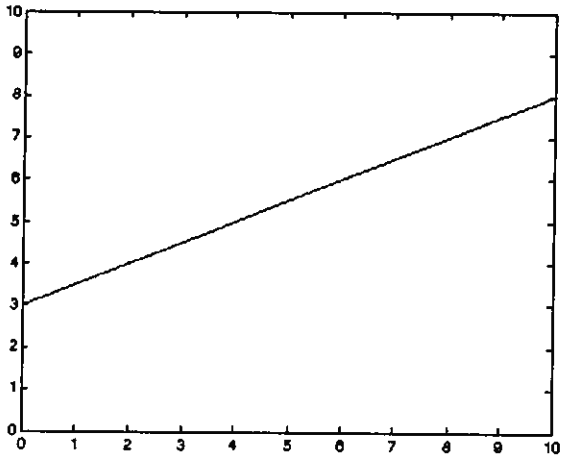
b) Furthermore, the origin is to be translated, so that the origin of the new image corresponds to pixel coordinates (100, 150) in the original image. How is this done most efficiently, and what are the transform coeffisients for this solution?

4. Histogram

a) Can one reconstruct the original image from a histogram equalized image? Justify your answer.

b) A gray level transform is given by T[i] = a i + b, where i is the original gray value. What are the transform coeffisients if we are inverting the image (finding the "negative")?

c) What are the transform coefficients for the graph below?



d) Assume that an 8-bits image has a mean value of 100 and a standard deviation of 10. What can you say about the quality of the contrast in the image?

e) If the image is passed through the gray level transform $g(x,y) = 2\, f(x,y) + 10$, what is then the mean value and variance of the transformed image g(x,y)?

5. Convolution

a) Let h_1 and h_2 be to orthogonal convolution operators:

$$h_1 = \begin{bmatrix} 0 & -1 & -2 \\ 1 & 0 & -1 \\ 2 & 1 & 0 \end{bmatrix} \qquad h_2 = \begin{bmatrix} -2 & -1 & 0 \\ -1 & 0 & 1 \\ 0 & 1 & 2 \end{bmatrix}$$

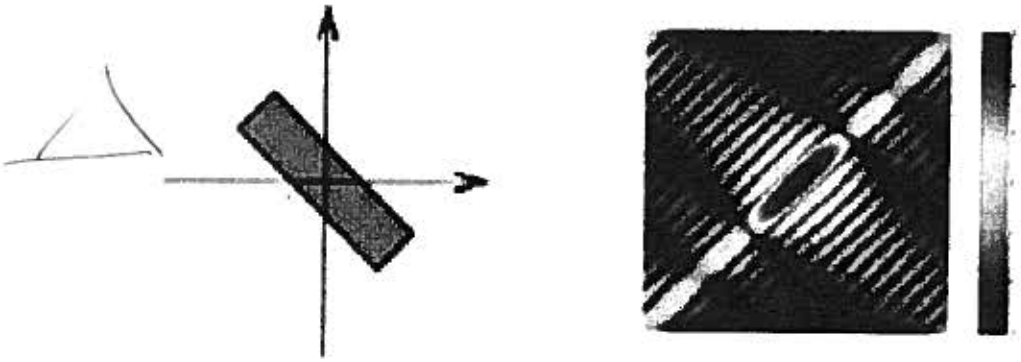
What is the difference between the estimates of gradient magnitude and gradient direction that we find based on the results from the operators h_1 and h_2, as compared to the ordinary Sobel operators h_x and h_y:

$$h_x = \begin{bmatrix} 1 & 0 & -1 \\ 2 & 0 & -2 \\ 1 & 0 & -1 \end{bmatrix} \qquad h_y = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix}$$

b) Are the filters h_1 and h_2 separable into 1D-filters?
What about h_x and h_y?
Give reasons for your answers.

6. Fourier-spectra

Given an image and a spectrum as shown below.



a) How does the spectrum change if the rectangular object is rotated?

b) How does the spectrum change if we change the width of the object so that it becomes an oblique square with sides equal to the length of the rectangle?

c) How does the spectrum change if we change the rectangular image object from having a homogeneous gray level – where a section through the object is a square profile, to a section having a triangular profile?

7. Median filtering and Huffman coding

Given a 8x5 pixels gray level image having 2 bits per piksel:

1	1	2	0	3	3	1	0
0	0	2	3	1	0	0	0
1	1	3	0	3	3	1	0
0	1	2	3	1	0	0	3
1	2	2	0	1	0	1	0

a) This image is to be filtered by a plus-shaped median filter given by

```
      1
      1
1  1  1  1  1
      1
      1
```

We assume that only pixels where image and filter overlap completely are to be computed. What is the result?

b) Show how you would perform a Huffman coding of the gray level image, and find the average number bits per pixel in the coded image.

0 1 1 1 2 1 2 2 1 3 3

~~2 2 1 3 3 3 3 3~~

0 0 0 1 1 3 3 3 3 3 3

Good Luck! 2 3 1 0

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0 1 1 1 1 0 3 3 3 3

0 0 0 0 0 1 3 3 3