

UNIVERSITY OF OSLO

Faculty of Mathematics and Natural Sciences

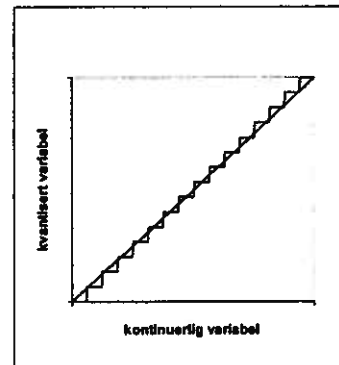
Final Exam:	INF2310 – Digital Image Processing
Date:	Wednesday, June 3. 2009
Time:	14.30 – 17.30
Number of pages:	6 pages
Added material:	None
Allowed aid:	None, not even a pocket calculator

- 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 and histogram operations

- a) Assume that we start with B bits per pixel in a digital image. If we then reduce the number of bits per pixel by two (from B to $B-2$), how many quantization levels will we lose?

- b) Assume that we have quantized by $B = 4$ bits per pixel, using a quantization as illustrated in the figure to the right, where 16 gray level intervals are mapped to 16 levels. We assume a uniform distribution of gray levels. Then assume that we reduce the number of bits per pixel by two. For what fraction of the pixel values will there be no change in the quantization error? Illustrate by a figure!



- c) Assume that we have an image f with gray tone scale $0 \leq i \leq (G-1)$, where $G = 16$, and that the normalized histogram is given by

$$p(i) = \begin{cases} 0 & 0 \leq i < G/2 \\ 2/G & i \geq G/2 \end{cases}$$

Sketch the cumulative normalized histogram of the image f .

- d) Assume that we have an image $f(x,y)$ with B bits per pixel. We produce a binary image $g(x,y)$ that consists of the most significant bitplane in the image f . which simple image processing operation does this correspond to? You may well describe it by an equation / formula!

2. Convolution

- a) You are given the following convolution operator:

$$O = -(A * A * B^T * B^T + A^T * A^T * B * B)$$

$$A = [1 \ 0 \ -1], \quad B = [1 \ 1 \ 1]$$

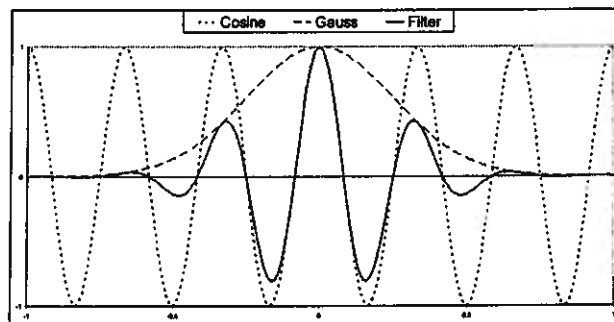
What operator is O, and what is it used for?

Use properties of convolution to state the reason for your answer without actually performing the convolution!

- b) How big is the filter matrix O above?

State the reason for your answer without performing the convolution!

- c) If we make a filter by multiplying a 2-D low pass Gaussian filter $G(x,y)$ by a 1-D cosine function $\text{Cos}(x)$, a trace through the filter along the x-axis may look like this:



The filter will have several minima and maxima with decreasing amplitudes on each side of the central peak.

Which theorem from the curriculum can be used to explain that the Fourier transform of this filter has only two maxima?

Explain how you use the theorem in this case.

3. Median filtering and Huffman coding

Given a 3 bits gray level image having 5 x 5 pixels:

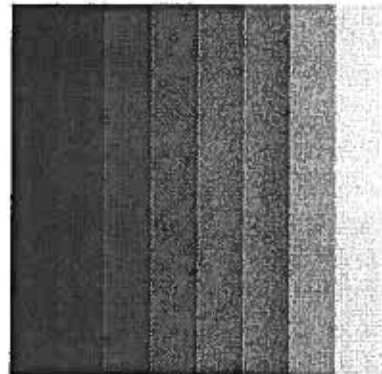
2	2	2	2	2
2	1	1	1	2
2	1	5	5	6
2	1	5	5	6
2	2	6	6	6

- This image is to be filtered by a 3x3 pixel median filter. We assume that only pixels where the image and the filter overlap completely are to be computed. What is the result?
- Perform a median filtering of each bit plane of the original image, and produce a new gray level image. Is the result the same?
- Show how to perform a Huffman coding of the original image, and find the average number of bits per pixel of the coded image.
- Is it possible to get the same code tree and codebook using Shannon-Fano coding? Give a reason for your answer!

4. Thresholding of gray level image

In a 3 bit gray level image of size 64 x 64 pixels the background consists of vertical stripes that are 8 pixels wide. The intensity of the stripes increase from left to right, from 0 to 7, as illustrated in the figure to the right, which only shows the background in the image.

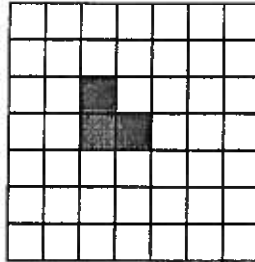
Onto each of the four central stripes are placed objects that constitute 1/2 of the area of the stripe, and that are one gray level brighter than the background.



- Sketch the normalized histograms of background and object pixels in the image.
- Sketch the normalized histograms scaled by *a priori* probability.
- Explain why we here have neither a unique solution to whether we need one or two thresholds to achieve a minimal total segmentation error by thresholding, nor a unique solution to the placement of the threshold(s).

5. Morphological operations

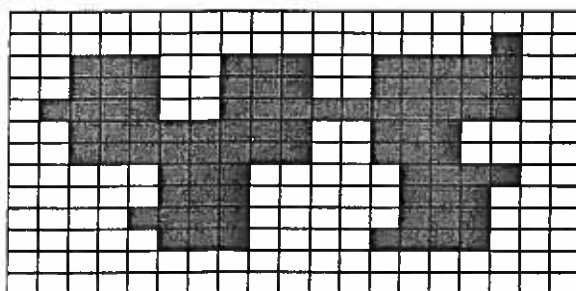
Given the image f where the object pixels are gray:



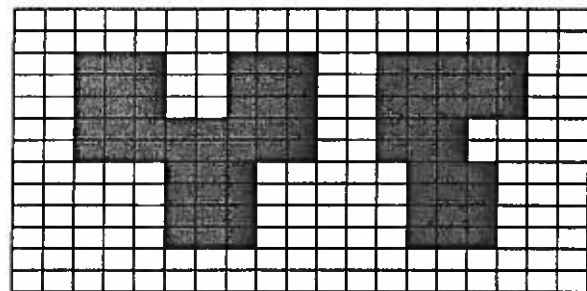
and the structure element S



- Sketch the result after a dilation of f by S .
- What is the result after repeated dilations of f by S ?
- Below you see two images, an original and a filtered image. The filtered image is produced by performing a morphological operation on the original image, using a 3×3 structuring element. Which morphological operation has been performed, and what does the 3×3 structure element look like? Give a reason for your answer.



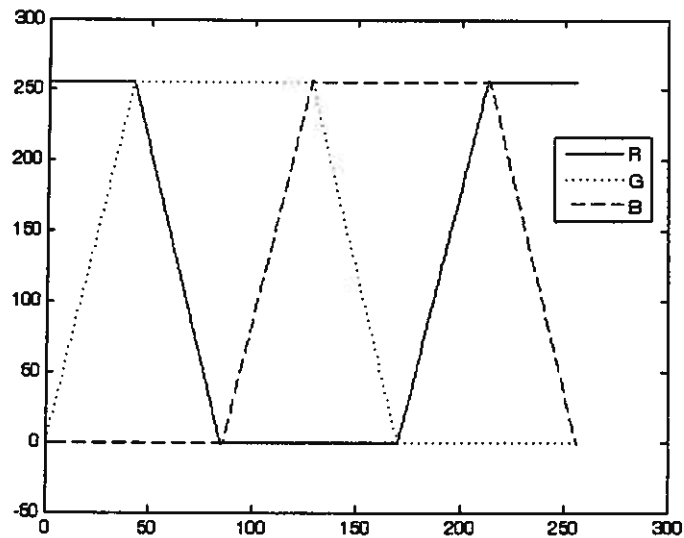
Original



Filtered image

6. Color images and color spaces

An 8 bit gray level image (having $G=256$ gray levels) is being displayed using an RGB pseudo color table where the R, G and B components are as shown in the figure.



- Which color will pixels having gray level $G/6$ be displayed as?
- Which color will pixels having gray level $2G/3$ be displayed as?
- Can you describe how the colors will change as the gray level goes from 0 to 255, i.e., what the color table looks like?
- If you draw an RGB cube, what parts of the RGB cube will the color table cover? Illustrate by drawing a figure!

Good Luck!

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