DEPARTMENT OF INFORMATICS, UNIVERSITY OF OSLO

Mid-term exam

INF2310 - Digital Image Processing

Subject for exam: INF2310 - Digital Image Processing

Day of exam: Tuesday March 21. 2017

Time of exam: 09:00 - 13:00

Number of pages: 8

Appendices: None

Exam support materials: None

- There are 9 tasks in this assignment.
- Read through the entire task before you start solving it. Make sure that the assignment set is complete before you start answering it. Feel free to make reasonable assumptions if you feel that the task is missing some information, as long as you keep to the "spirit" of the task. In such a case, make sure to explain your prerequisits and assumptions.
- There are 17 subtasks in total, and it is useful to manage your time such that you have time to ansver them all. If you are stuck, move on such that you are able to answer every subtask.
- *Each subtask has equal weight in the evaluation of the submission.*
- *Each answer must be justified.* Explain the use of eventual theorems, principles or assumptions such that a third-party can follow your reasoning.

1. Sampling and geometrical transform

Suppose that we have a (continuous) band-limited image with a maximal frequency

$$f_{\max} = 5 \times 10^3 \,\mathrm{m}^{-1}$$

a)

What is being imaged is, amongst other things, some point sources that are so close that they can barely be distinguished in the image. Give a limit for how close these points are.

b)

How densely must we sample this image in order to avoid aliasing? Provide a lower bound for the *sampling frequency*, f_s. Let us further assume that we have sampled the image with a rate just above this limit.

c)

After sampling, a geometric transform is performed with these equations:

$$x' = 0.5x + 100,$$
$$y' = 0.5y + 200,$$

where x and y are the coordinates in the "input image", and x' and y' are the transformed coordinates. Let us further assume that we use an "ordinary" resampling with backward transform.

What will the effective sampling rate be after such a transform, and which (unwanted) effects could this give rise to?

2. An imaging- and image processing system

Explain potential principal problems with the order in this imaging and image analysis system:

Imaging → Sampling → Analysis of spatial resolution from the sampled image → Anti-aliasing → Further structure analysis of the image.

3. Histograms

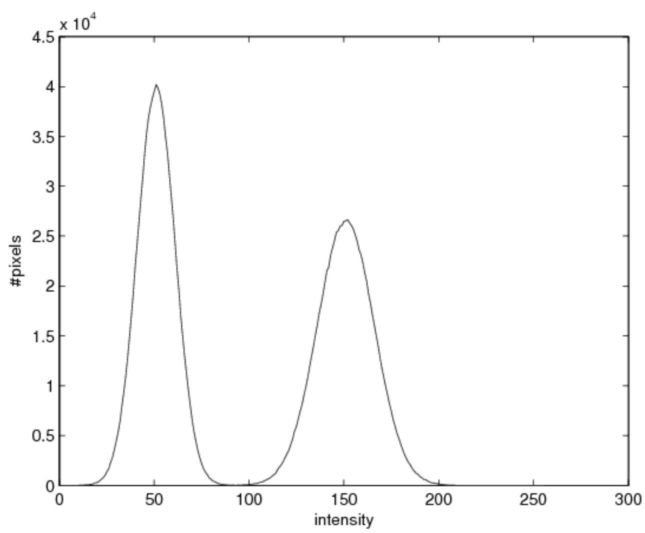
Suppose that we have the following 4×4 grayscale image:

1	3	2	1
5	4	5	3
4	1	1	2
2	3	2	1

Sketch the grayscale histogram, h, the normalized histogram, p, and the cumulative histogram, c, for this image. Provide a general expression (mathematical formula) for p and c based on h.

4. Pixel quantization and pixel reconstruction

Suppose that our 8-bit image have the following histogram:



Suppose that we are going to requantize the image to 1 bit per pixel, that is, to an image of ones and zeros. Draw the grayscale transform $T[i]$ that you would use. What value for 0 and what value for 1 would you use for reconstruction to an 8-bit image? Provide a (short) justification for your choises, both for $T[i]$ and reconstruction values.

5. Grayscale transform and image sequence standardization

Suppose that we have the grayscale transform $T[i] = ai + b$, where a and b are coefficients/constants.

a)

What effect have the parameters a and b on the grayscale histogram of the resulting image? Also explain the effect of a and b on the contrast and brightness of the image.

b)

One can give a sequence of images equal variance and mean value by utilizing such grayscale transforms. What is one trying to achieve with such standardization of variance and mean value?

6. An exponential grayscale transform

Suppose that we have the grayscale transform $T[i] = \exp(i)$. What would this transform do with the contrast in the dark and bright intensity intervals, respectively?

7. Histogram equalization

What is histogram equalization? For a general image, describe how one can find the grayscale transform that performs a histogram equalization.

8. Filtering

In this task you will be asked to compute some convolutions. Explain your reasoning, such that if calculation errors occur, it is easy to infer if it was because of mishaps or lack of understanding.

a)

Let

$$h_1 = \begin{bmatrix} 1 & 2 \\ 3 & 4 \end{bmatrix}$$

and

$$h_2 = \begin{bmatrix} 1 & 2 & 2 \\ 1 & 1 & 1 \\ 2 & 1 & 1 \end{bmatrix}.$$

Evaluate the convolution

$$g = h_1 * h_2$$

using full convolution, that is, where you compute a respons for all overlapping pixels. Hint: g should have shape 4×4.

b)

Perform a mean value filtering on the image

$$f = \begin{bmatrix} 6 & 7 & 7 & 6 & 0 & 6 \\ 6 & 6 & 5 & 5 & 1 & 1 \\ 5 & 7 & 5 & 6 & 1 & 1 \\ 0 & 1 & 1 & 0 & 3 & 0 \\ 2 & 5 & 1 & 1 & 0 & 6 \end{bmatrix}$$

using a 3×3 mean value filter, and explain the purpose of such a filtering. Only compute respons for pixels where the entire filter overlaps with the image (that is, the result image should have shape 3×4).

c)

Perform a median filtering of the image f from *task 8 b)* above. Use a plus shaped filter shown in fig. 1. Discuss advantages and disadvantages with this filtering against the mean value filtering.

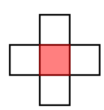


Figure 1: Median filter with the origin in the red center pixel.

d)

Describe the properties of the filter h and what it is used for.

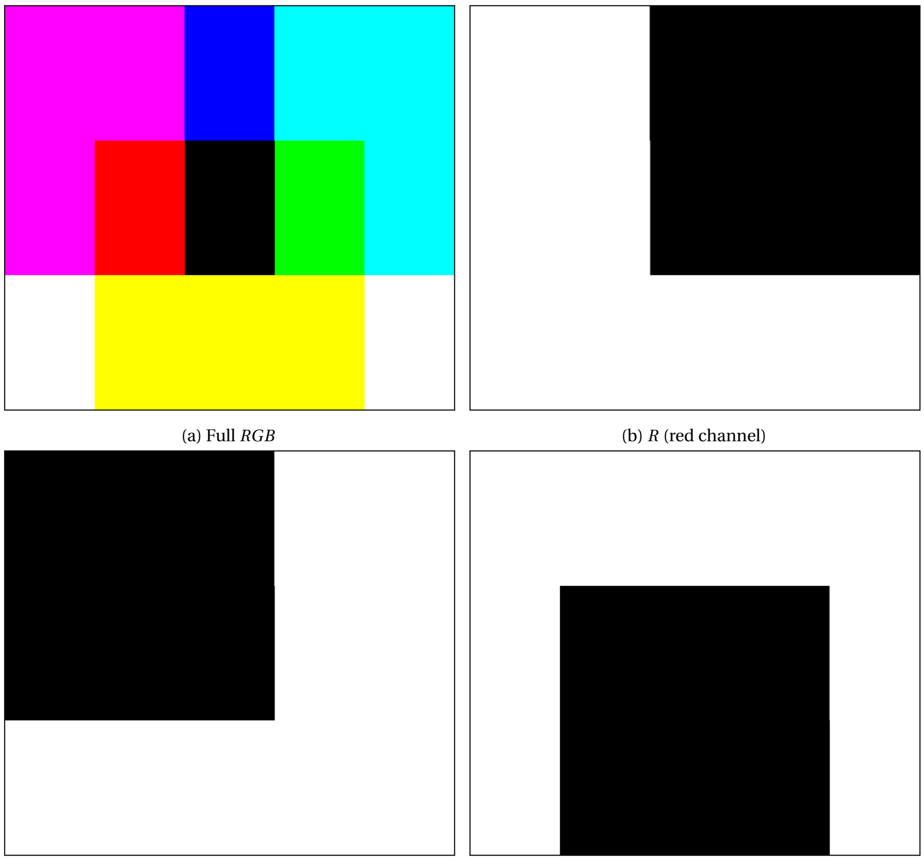
$$h = \begin{bmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix}.$$

e)

Es the filter h from *task 8 d)* separable? If so; which components can it be separated into?

9. RGB and HSI

Fig. 2 shows an RGB image of the primary and secondary colors in a $CMYK$ model, together with its individual color components as grayscale images.

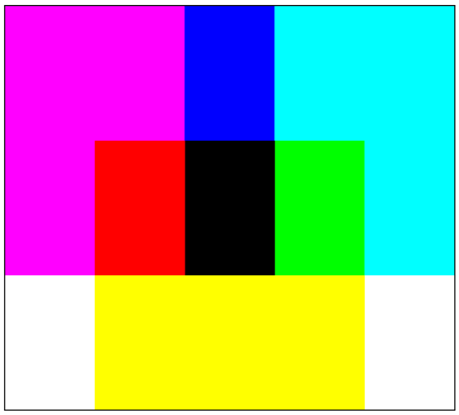


(a) Full RGB (b) R (red channel)

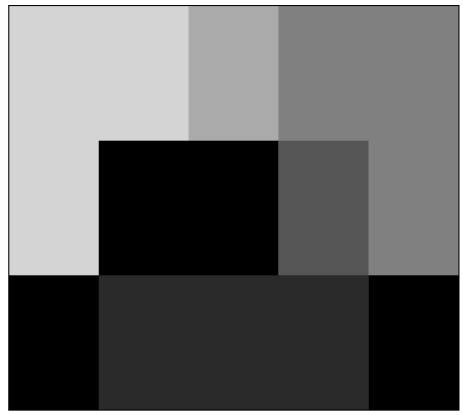
(c) G (green channel) (d) B (blue channel)

Figure 2: An RGB image and its color channels.

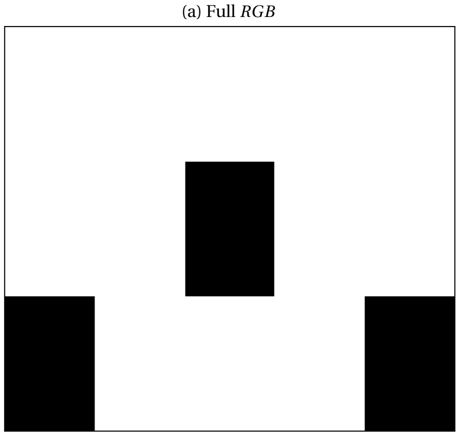
Fig. 3 shows the same image as fig. 2 with its HSI components.



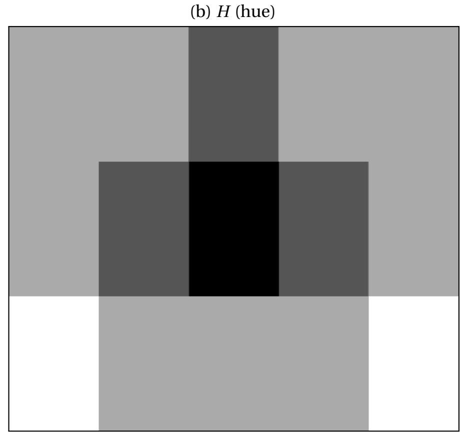
(a) Full RGB



(b) H (hue)



(c) S (saturation)



(d) I (intensity)

Figure 3: An RGB image with its H, S, og I channels.

a)

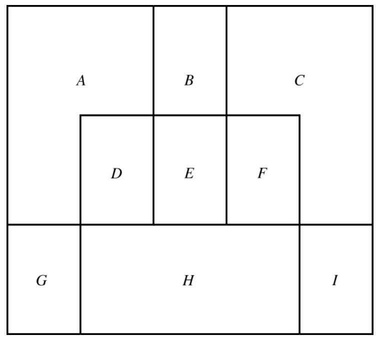


Figure 4: Reference

Use the mask in fig. 4 as a reference, and complete the table below. Notice that H (hue) takes values in the interval $[0,360]$, while S, I (intensity), R, G, and B takes values in $[0,1]$. Also notice that we define $H = 0$ where $R = G = B$ and $S = 0$ where $I = 0$.

	Hue	Saturation	Intensity
A (magenta)			
B (blue)			
C (cyan)			
D (red)	0		
E (black)	0	0	
F (green)			
G (white)	0		
H (yellow)	60		
I (white)	0		

b)

If one shall perform a contrast adjustment (e.g. histogram equalization) on an image, it is often common with the following procedure:

1. Transform the RGB image to HSI.
2. Perform the contrast adjustment *only* on the I component.
3. Transform the result back to RGB.

Explain the motivation behind such a strategy.

Good luck.