NTNU
Kunnskap for en bedre verden

KANDIDAT

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PRØVE

TDT4195 1 Grunnleggende visuell databehandling

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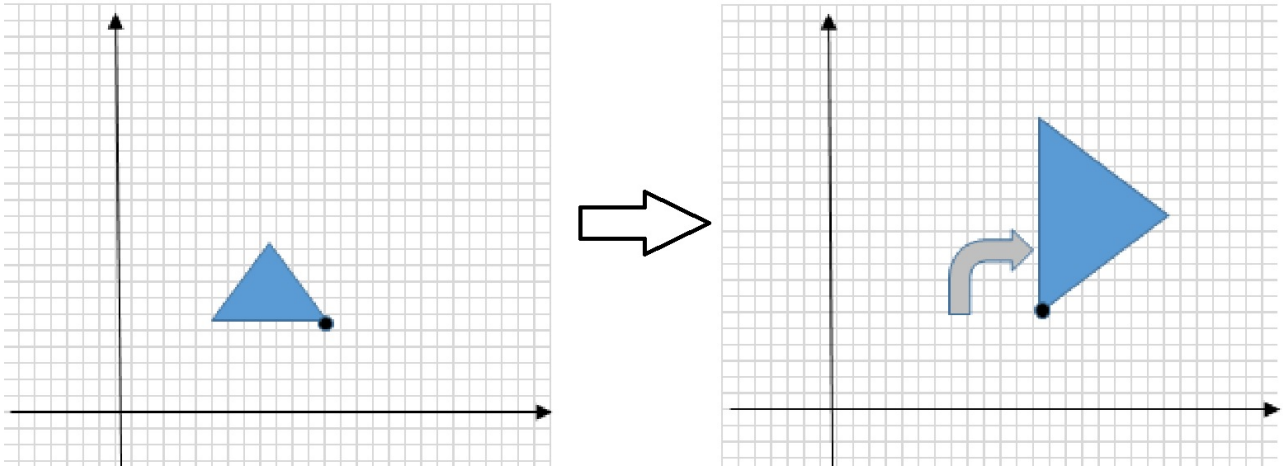
1 CG1: Q1: 2D Transformation Exercise

You are required to find the transformation that takes the object of the Figure below, isotropically doubles its size and rotates it by 90^o clockwise, while maintaining the (black) marked vartex at (2,1).

Notes:

1. All elements of the required matrix are integers.
2. The Figure is not accurate and to scale; its only purpose is to demonstrate what is required.



The required 2D homogeneous transformation is:

0	1	0
-1	0	0
0	0	1

Knytte håndtegninger til denne oppgaven?
Bruk følgende kode:

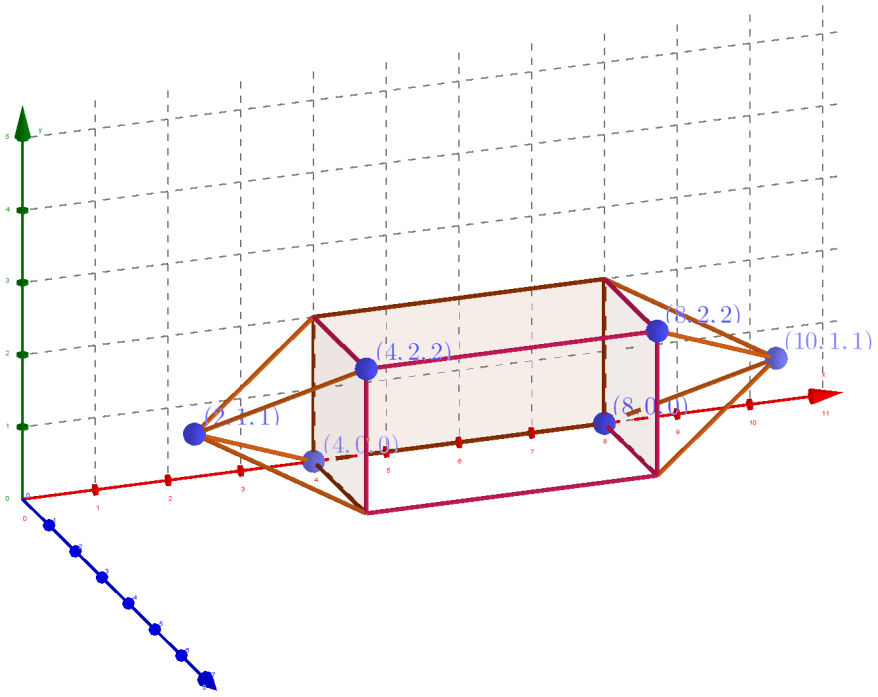
7 0 7 7 3 8 9

2 CG1: Q2: 3D Transformation Exercise

Given the following two models (in their own MCS):

$$S_1 = \begin{bmatrix} 0 & 4 & 0 & 4 & 0 & 4 & 0 & 4 \\ 0 & 0 & 4 & 4 & 0 & 0 & 4 & 4 \\ 0 & 0 & 0 & 0 & 4 & 4 & 4 & 4 \\ 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \end{bmatrix} \qquad S_2 = \begin{bmatrix} 0 & 2 & 0 & 2 & 1 \\ 0 & 0 & 2 & 2 & 1 \\ 0 & 0 & 0 & 0 & 2 \\ 1 & 1 & 1 & 1 & 1 \end{bmatrix}$$

We want to create a synthetic world (WCS) as per the image below:



where the vertices are labelled (from left to right): (2,1,1) (4,0,0) (4,2,2) (8,0,0) (8,2,2) (10,1,1). The x axis is red, the y axis green and the z axis is blue.

You are to find 3 transformations T_1, T_2 and T_3 that generate the three parts of the WCS world (two pyramids and one parallelepiped). Let us label them as Left, Middle and Right part as seen from the point of view of the image above.

You are to give the required transformation matrix for each part T_1, T_2 and T_3 as well as the MCS model used (**x**= 1 or 2). Below you should give the final transformation matrices for the Left, Middle and Right parts, in this order.

Note: The MCS models S_1 and S_2 are given in homogeneous coordinates in a right-hand coordinate system. Columns represent vertices and the order of the vertices (winding order) has to be maintained by your transformations. For each answer below the last row of the homogeneous transformation [0 0 0 1] is already filled out.

Left part: Specify the homogeneous matrix $\mathbf{T_1}$ and the number **x** such that Left part=$\mathbf{T_1}$ *$S_{\mathbf{x}}$

$\mathbf{T_1}$ =

0 0 0 1

x=

Middle part: Specify the homogeneous matrix $\mathbf{T_2}$ and the number **x** such that Left part=$\mathbf{T_2}$ *S_x

$\mathbf{T_2}$ =

0 0 0 1

x=

Right part: Specify the homogeneous matrix $\mathbf{T_3}$ and the number **x** such that Left part=$\mathbf{T_3}$ *S_x

$\mathbf{T_3}$ =

0 0 0 1

x=

Knytte håndtegninger til denne oppgaven?
Bruk følgende kode:

9 2 6 2 1 1 6

3 CG2: Q1: Clipping as Math

Clipping a polygon against a 3D frustum is equivalent to:
Velg ett alternativ:

- (•) Determining the union of the perimeter of the polygon and the volume of the frustum.
- ( ) Determining the intersection of the perimeter of the polygon and the volume of the frustum.
- ( ) Determining the intersection of the surface of the polygon and the volume of the frustum.
- ( ) Determining the union of the surface of the polygon and the volume of the frustum.

Knytte håndtegninger til denne oppgaven?
Bruk følgende kode:

5 8 1 2 0 1 2

4 CG2: Q2: Liang-Barsky

Use the Liang-Barsky algorithm to clip the line segment defined by p_1 (x_1, y_1) = (0, 110) and p_2(x_2, y_2) = (200, 10) by the window with x_{min} = 10, y_{min} = 10, x_{max} = 110, y_{max} = 110

And specify the following quantities rounded to 2 decimals:

Δx=

Δy =

$\frac{q_1}{p_1}$ =

$\frac{q_3}{p_3}$ =

$\frac{q_2}{p_2}$ =

$\frac{q_4}{p_4}$ =

t_{in} =

t_{out} =

Knytte håndtegninger til denne oppgaven?
Bruk følgende kode:

1 5 3 3 9 7 8

5 CG2: Q3: Culling

Assume a 'classic' Graphics Pipeline, which includes 3D Frustum *Clipping* as well as Back Face and Frustum *Culling*. If we remove the Back Face and Frustum Culling stages, then:

Select one:

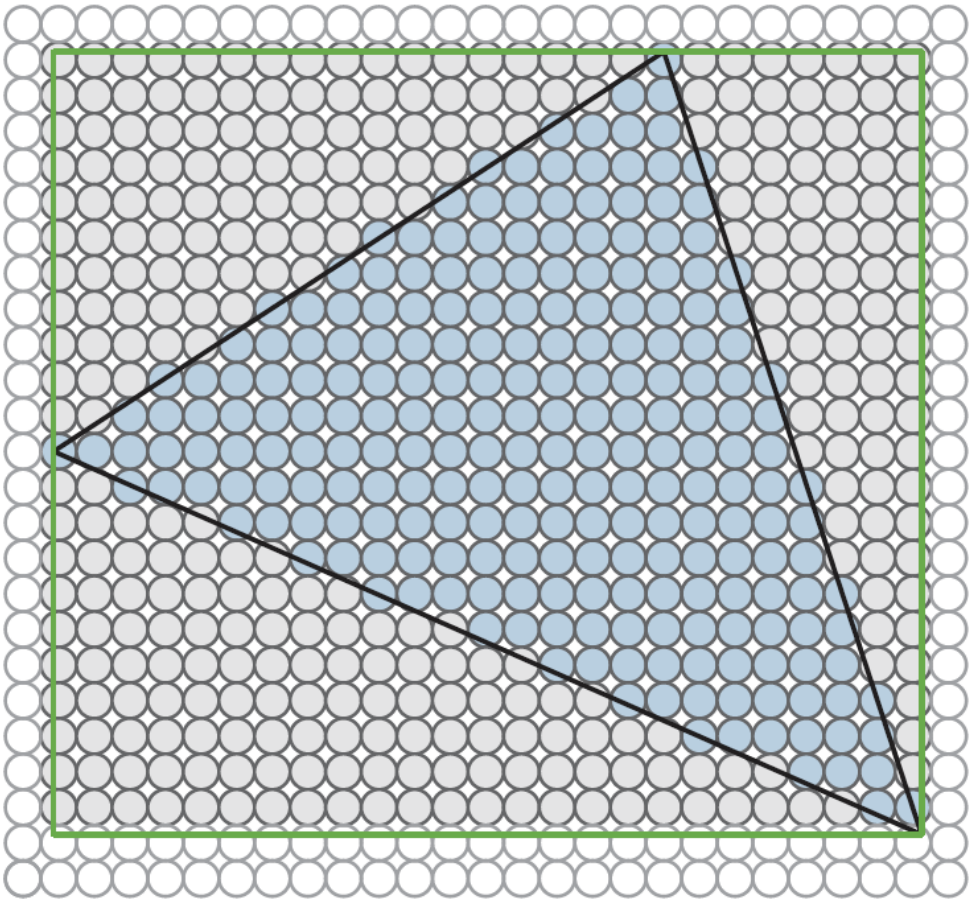
- The objects may appear to be 'inside out'.
- Objects behind the observer will appear upside down.
- Objects outside the view frustum may wrongly be rendered.
- A correct image will be formed, but much slower.

Knytte håndtegninger til denne oppgaven?
Bruk følgende kode:

0 2 9 9 8 8 7

6 CG3: Q1: Triangle Rasterization

Concerning the triangle rasterization algorithm that uses the incremental evaluation of edge functions. The triangle's bounding box includes B pixels while the triangle itself covers T pixels.



After initializations, the approximate cost required in order to determine the pixels included in the triangle is:

- 3T additions
- 3B additions
- B+T multiplications
- B+T additions

Knytte håndtegninger til denne oppgaven?
Bruk følgende kode:

6 9 1 6 5 0 6

7 CG3: Q2: Finite differences

What do we mean by finite differences of a function and how are they useful in rasterization?

Skriv ditt svar her

Ord: 0

Knytte håndtegninger til denne oppgaven?
Bruk følgende kode:

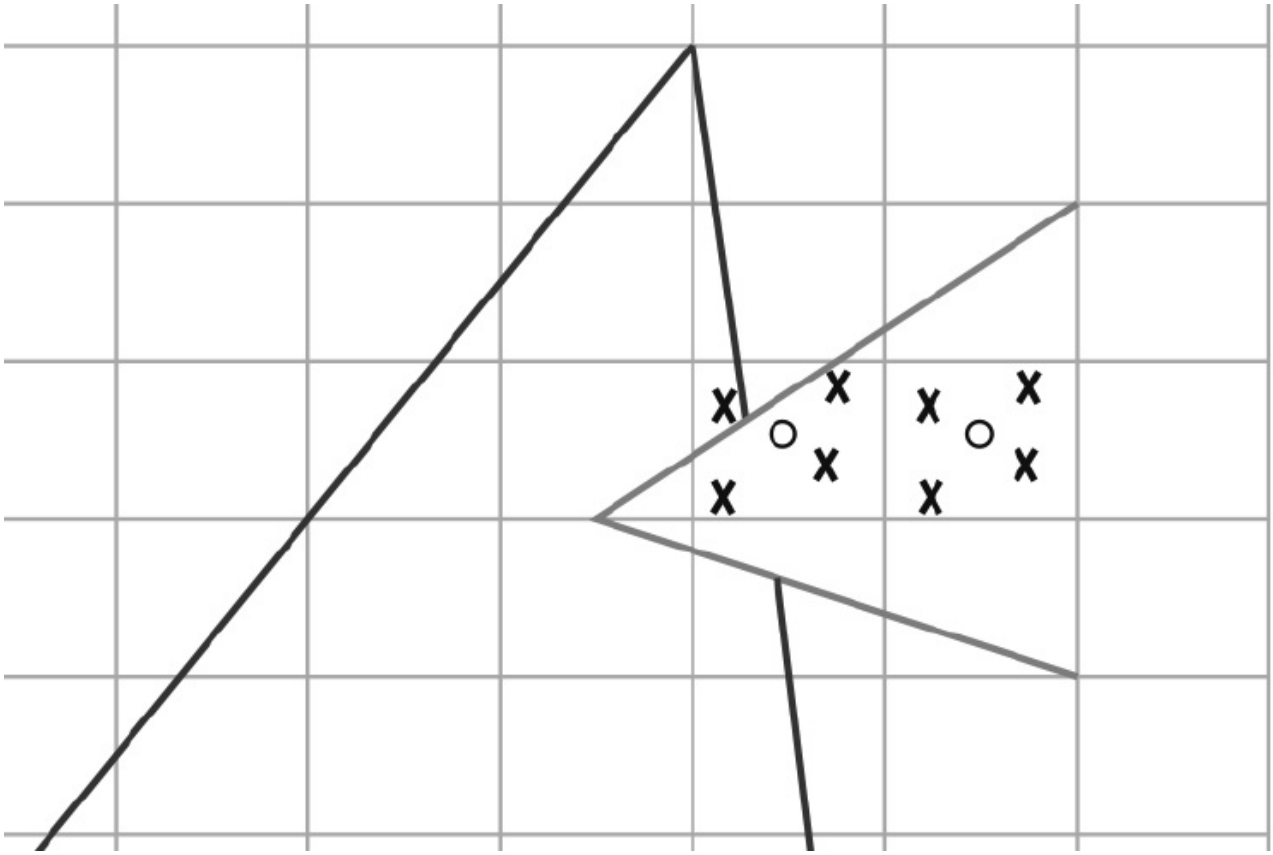
0 1 2 7 6 0 7

8 CG3: Q3: Antialiasing

A difference between post-processing and post-filtering antialiasing (AA) is:

- Post-processing AA produces the image at film processing resolution while post-filtering AA produces a reduced resolution image.
- Post-processing AA produces the image at the final resolution while post-filtering AA produces an increased resolution image.
- **Post-processing AA produces the image at a reduced resolution while post-filtering AA produces an increased resolution image.**
- Post-processing AA produces the image at an increased resolution while post-filtering AA produces a lower resolution image.

The figure below shows the pixel grid and its coverage by 2 triangles:



The MSAA algorithms would:

- perform sampling for rasterization and lighting calculations at the o's.
- perform sampling for rasterization at the o's and lighting calculations at the X's.
- perform sampling for rasterization and lighting calculations at the X's.
- perform sampling for rasterization at the X's and lighting calculations at the o's.

Knytte håndtegninger til denne oppgaven?
Bruk følgende kode:

8 7 3 0 2 1 1

9 CG4: Q1: Perspective in the Pipeline

One reason for maintaining the z coordinate after perspective projection is:

- in order to be able to solve the hidden surface problem in the rendering stage.
- in order to solve the back-face culling problem.
- so that the 'straightness' of lines is maintained.
- in order to perform frustum culling.

Knytte håndtegninger til denne oppgaven?
Bruk følgende kode:

1 0 2 1 0 2 6

10 CG4: Q2: Viewing Parameters

Assume that we are using perspective projection from ECS into NDC:

$$\mathbf{M}_{\mathbf{ECS}\rightarrow\mathbf{NDC}}^{\mathbf{PERSP}} = \begin{bmatrix} \frac{2n}{r-l} & 0 & 0 & 0 \\ 0 & \frac{2n}{t-b} & 0 & 0 \\ 0 & 0 & \frac{n+f}{f-n} & -\frac{2nf}{f-n} \\ 0 & 0 & 1 & 0 \end{bmatrix}$$

If the viewing parameters are:
Field of view in y-direction (θ) = 90º
Aspect = 1
Near clipping plane = 1
Far clipping plane =100

Then work out the elements of the above matrix (use 2 decimal places for reals):

1	0	0	0
0	1	0	0
0	0	1.02	-2.02
0	0	1	0

Knytte håndtegninger til denne oppgaven?
Bruk følgende kode:

1 3 0 6 2 3 6

11 CG5: Q1: Intensity

It is necessary to select intensity levels to be stored in 2 bits, the minimum and maximum levels being 0.01 to 1. Taking into account the characteristics of the human eye, a good selection would be:

Velg ett alternativ:

- [0.25 0.50 0.75 1.0]
- [0.01 0.046 0.215 1.0]
- [0.01 0.34 0.67 1.0]
- [0.01 1.0]

Knytte håndtegninger til denne oppgaven?
Bruk følgende kode:

8 7 0 7 5 3 5

12 CG5: Q2: CMYK

It is required to display the, rather yellow-ish, CMY colour (0.2, 0.4, 0.6) in the CMYK system. Give the values for the respective CMYK components:

b:

c' :

m' :

y':

Knytte håndtegninger til denne oppgaven?
Bruk følgende kode:

8 0 6 1 4 8 5

13 CG05: Q03: Illumination

Illumination algorithms are also known as *shading algorithms*. With the help of the Figure below, give the problems of Constant (or Flat) shading and Gouraud shading and why these problems are not present in Phong shading.

Skriv ditt svar her

Flat shading is computed by the normal vector of the surface and the position of the light source, which will make the object look more "blocky".

Gourand shading will make objects closer to the light source appear brighter, which reduces the blockiness of flat shading. However objects not beeing hit directly by a light source will appear dark, even though they should have some light.

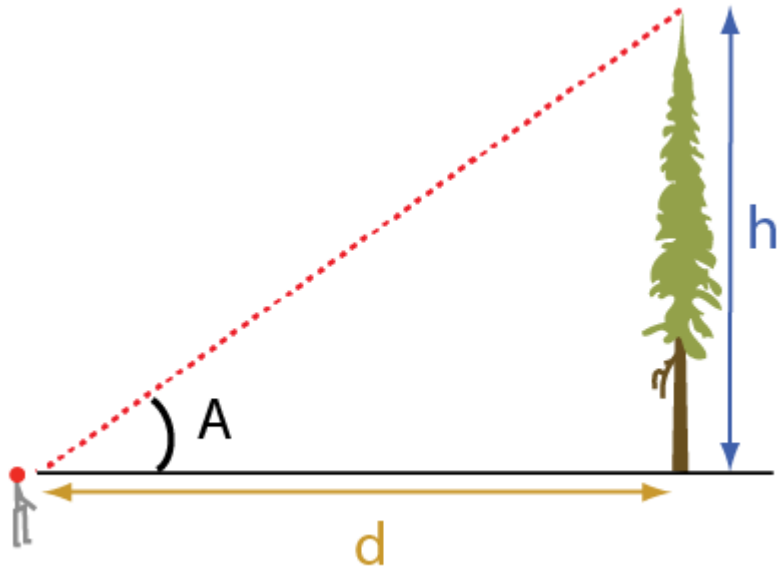
Phong shading is a combination of 3 types of shading techniques. Firstly we compute the flat shading, then we add ambient shading, and lastly we add gourand shading.

Ord: 93

Knytte håndtegninger til denne oppgaven?
Bruk følgende kode:

3 4 9 2 0 8 0

14 IP1-Q1: Human eye



A human is looking at a tree from a distance. Using the pinhole camera model as an approximation for the human eye and applying the inverted image plane trick we want to estimate the height of the tree. The depth of the eye bulb is approx. 17 mm. The distance to the tree is d = 30 m and the height of the tree on the retina / virtual image plane is 17 mm (assume it can be measured).

What is then the height of the tree in meters?

Height (h) = 30 .

Knytte håndtegninger til denne oppgaven?
Bruk følgende kode:

1 0 6 8 8 0 9

15 IP1-Q2: Histogram equalization

The table below shows the histogram H(r) of a 3-bit gray-scale image (image size = 10x5 pixels) with values r between 0 and 7.

Your job is to calculate the **normalized histogram p, the cumulative histogram F and the histogram equalization transform T** for the input image and fill out the corresponding columns in the table. Finally, based on the information calculated above you should now be able to find the **Histogram H(s) for the transformed equalized image** and fill out the last row.

r	H(r)	p	F	s =T(r)	H(s)
0	10	0.2	0.2	1	0
1	8	0.16	0.36	3	10
2	9	0.18	0.54	4	0
3	2	0.04	0.58	4	8
4	14	0.28	0.86	6	11
5	1	0.02	0.88	6	0
6	5	0.1	0.98	7	15
7	1	0.02	1	7	6

Knytte håndtegninger til denne oppgaven?
Bruk følgende kode:

6 1 2 9 1 3 9

16 IP1-Q3: Gamma transform

(a) (b) (c)

The typical gamma transform is defined as: $s = cr^{\gamma}$ for gray level images. For color images the gamma transform is implemented per channel and the same transform $s = cr^{\gamma}$ is applied for the red, green and blue channels.

Knowing that the image (b) has a gamma value = 1.0, and the other two images have gamma values of 0.33 and 2 can you identify the gamma values for images (a) and (c)?

Match the image with the corresponding gamma value:

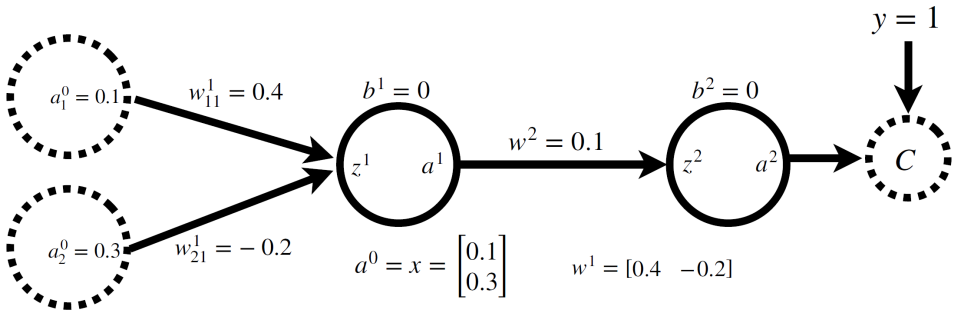
	Image (a) (on the left)	Image (c) (on the right)
Gamma = 0.33	◉	○
Gamma = 2	○	◉

Knytte håndtegninger til denne oppgaven?
Bruk følgende kode:

3 8 9 4 7 5 6

17 IP2-Q1: Forward pass

Given the fully connected network in the image below and activation and cost functions:



Activation function: $f(z) = \frac{1}{1+e^{-z}}$

$$\frac{df(z)}{dz} = f(z)(1-f(z))$$

Cost function: $C = C(a^2) = \frac{1}{2}(y-a^2)^2$

$$\frac{\partial C}{\partial a^2} = a^2 - y$$

Learning rate: $\eta = 0.01$

Your task is to find the following values (round to 4 decimals):

$z^1 =$ -0.02

$a^1 =$ 0.50

$z^2 =$ 0.05

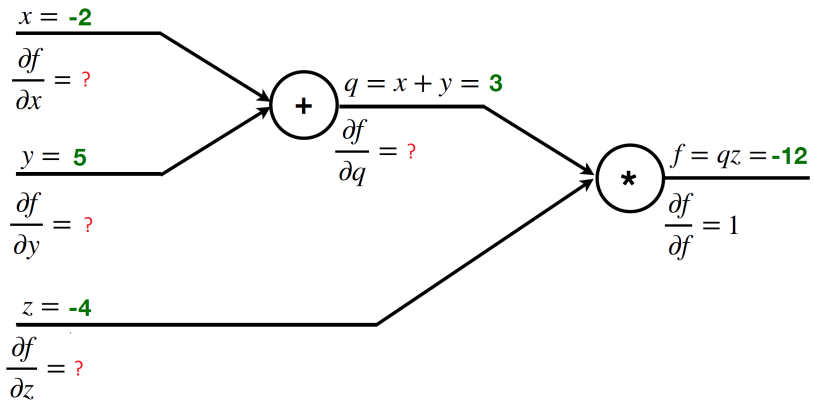
$a^2 =$ 0.51

$C =$ 0.12

Knytte håndtegninger til denne oppgaven?
Bruk følgende kode:

7 4 5 3 0 8 7

18 IP2-Q2: Back propagation



Given the computation graph above, can you compute the missing values (using the chain rule):

$\frac{\partial f}{\partial q} =$ -4

$\frac{\partial f}{\partial z} =$ 3

$\frac{\partial f}{\partial x} =$ -4

$\frac{\partial f}{\partial y} =$ -4

Knytte håndtegninger til denne oppgaven?
Bruk følgende kode:

4 2 2 7 1 8 8

19 IP2-Q3: Activation/loss functions

What are the typical combinations of **final activation function / loss function** for:

Case 1: Regression problem with a numerical value as output
Choose an alternative:

- Softmax / Cross entropy
- Sigmoid / Binary cross entropy
- Linear / Mean squared error

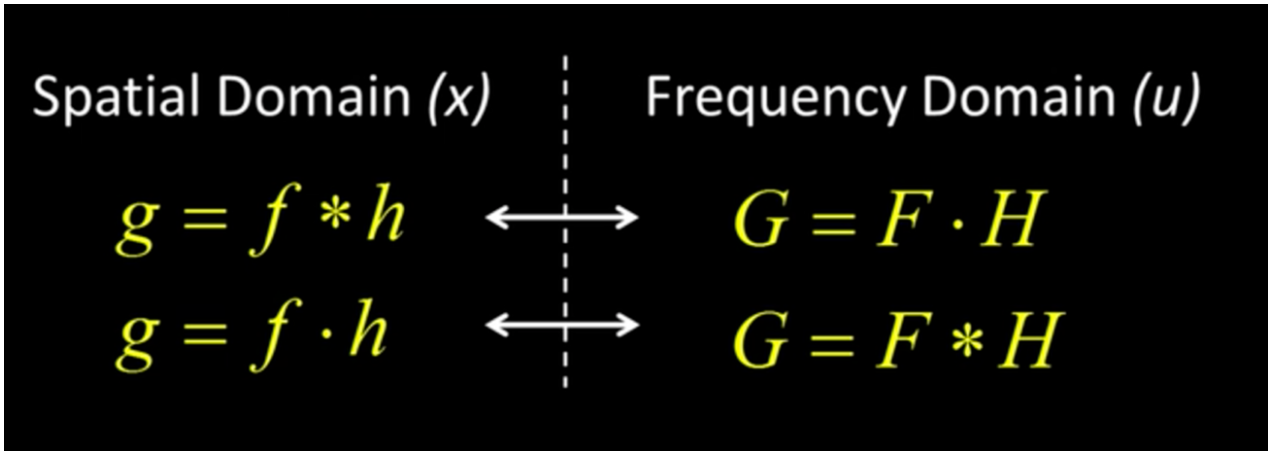
Case 2: Classification problem, single label multiple classes
Choose an alternative:

- Sigmoid / Binary cross entropy
- Softmax / Cross entropy
- Linear / Mean squared error

Knytte håndtegninger til denne oppgaven?
Bruk følgende kode:

1 6 9 0 3 2 7

20 IP3-Q1: Ringing and aliasing



In this task you are asked to show your understanding of **ringing** and **aliasing** visually with a sketch. You need to use the right form of the convolution theorem and show both the spatial and frequency representations in your explanation. What can be done to prevent the two unwanted effects?

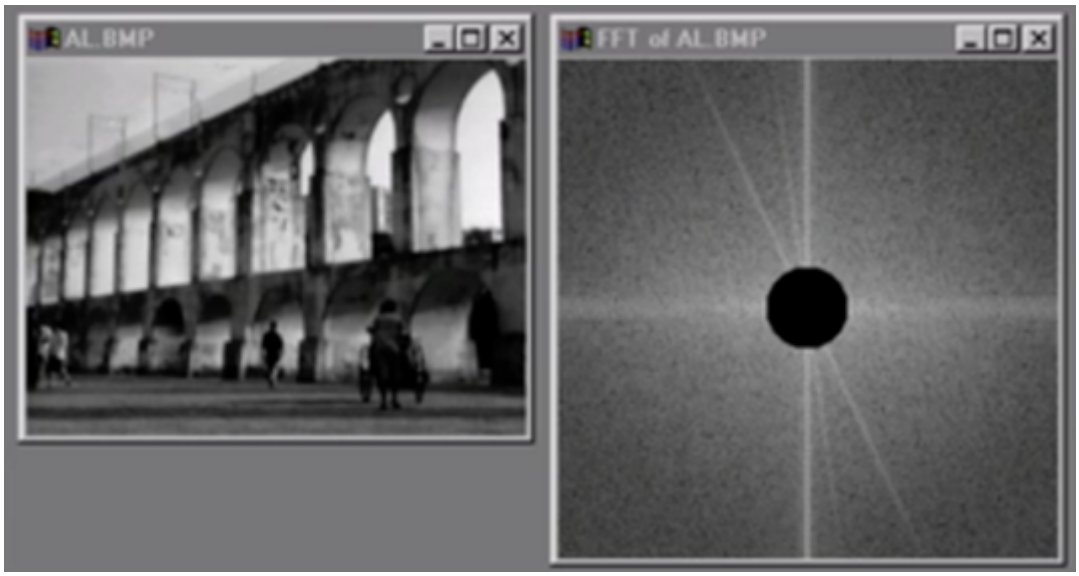
Fill in your answer here:

Knytte håndtegninger til denne oppgaven?
Bruk følgende kode:

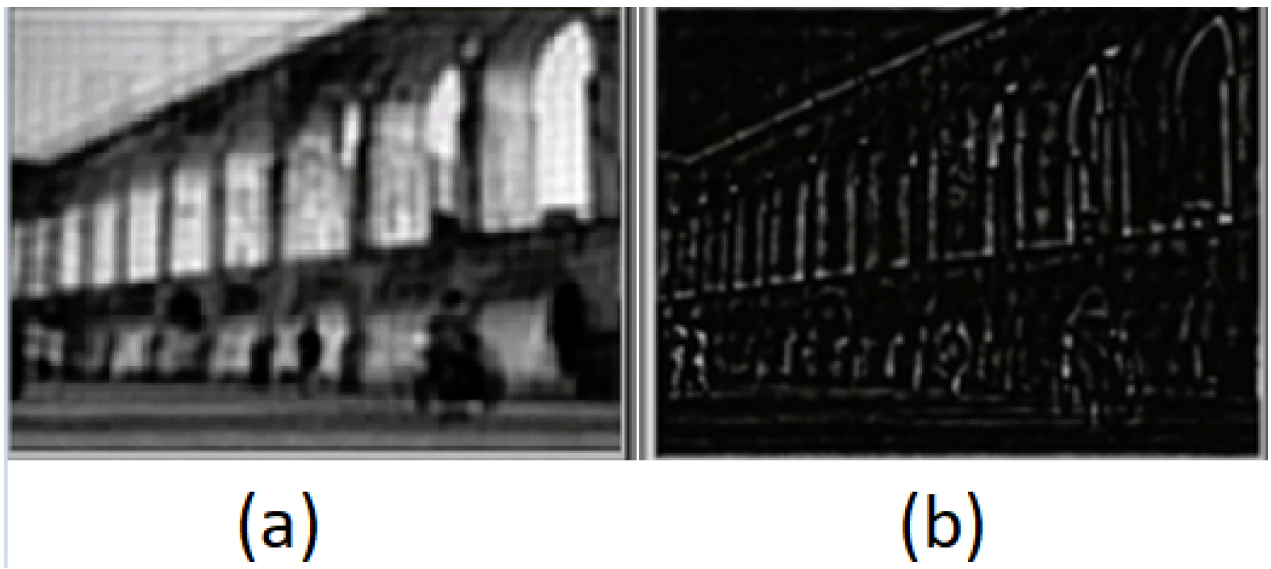
4 7 2 6 8 1 1

21 IP3-Q2: FFT filtering

Given the gray level image on the left, and its modified FFT spectrum, on the right:



What will be the resulting image when the modified FFT spectrum is converted back to the spatial domain?



Choose an alternative:

- Image (b) - on the right
- Image (a) - on the left

Knytte håndtegninger til denne

oppgaven?

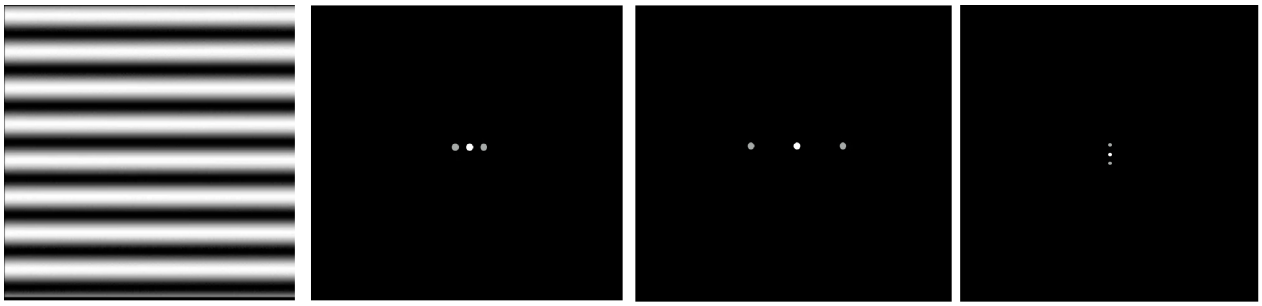
Bruk følgende kode:

5 8 5 0 8 9 6

22 IP3-Q3: FFT spectra

Solve the following **3 examples** by identifying the FFT spectrum of a given image.

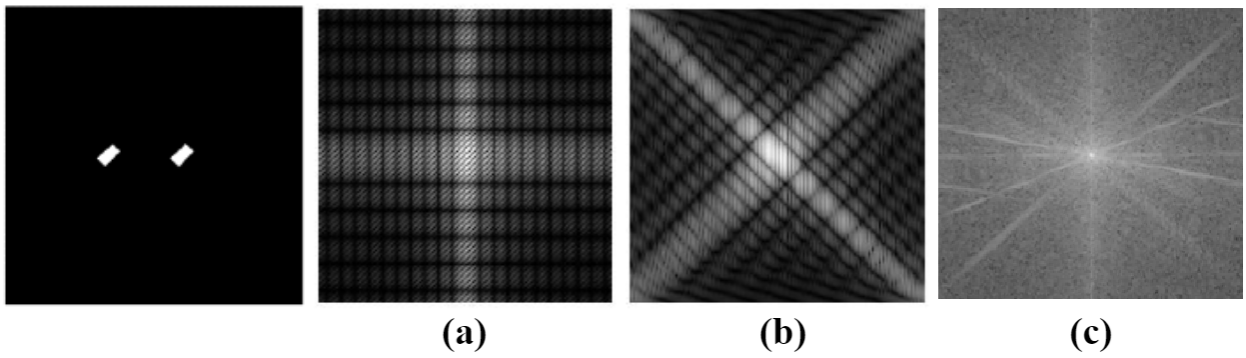
Example 1: given the gray image on the left, what will be its corresponding FFT spectrum?



Choose an alternative:

- Spectrum (b)
- Spectrum (c)
- Spectrum (a)

Example 2: given the gray image on the left, what will be its corresponding FFT spectrum?

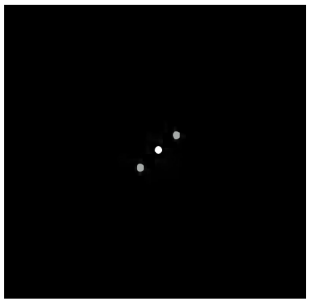


Choose an alternative:

- Spectrum (a)
- Spectrum (c)
- Spectrum (b)

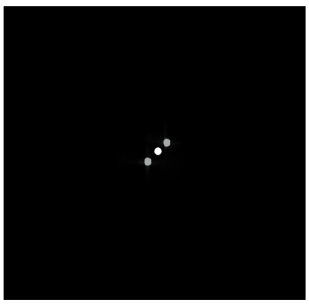
Example 3: Assuming that the gray level image (Image 1) has the corresponding FFT spectrum (Spectrum 1):

Image 1

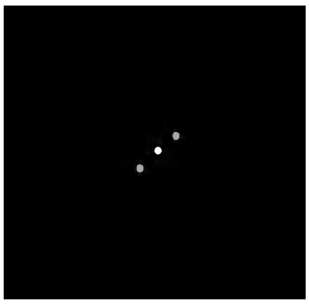


Spectrum 1

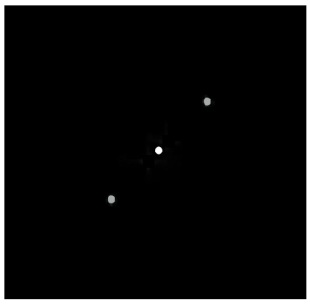
Image 2



(a)



(b)



(c)

What is the FFT spectrum corresponding to Image 2, knowing that Spectrum 1 is identical to Spectrum (b)?

Choose an alternative:

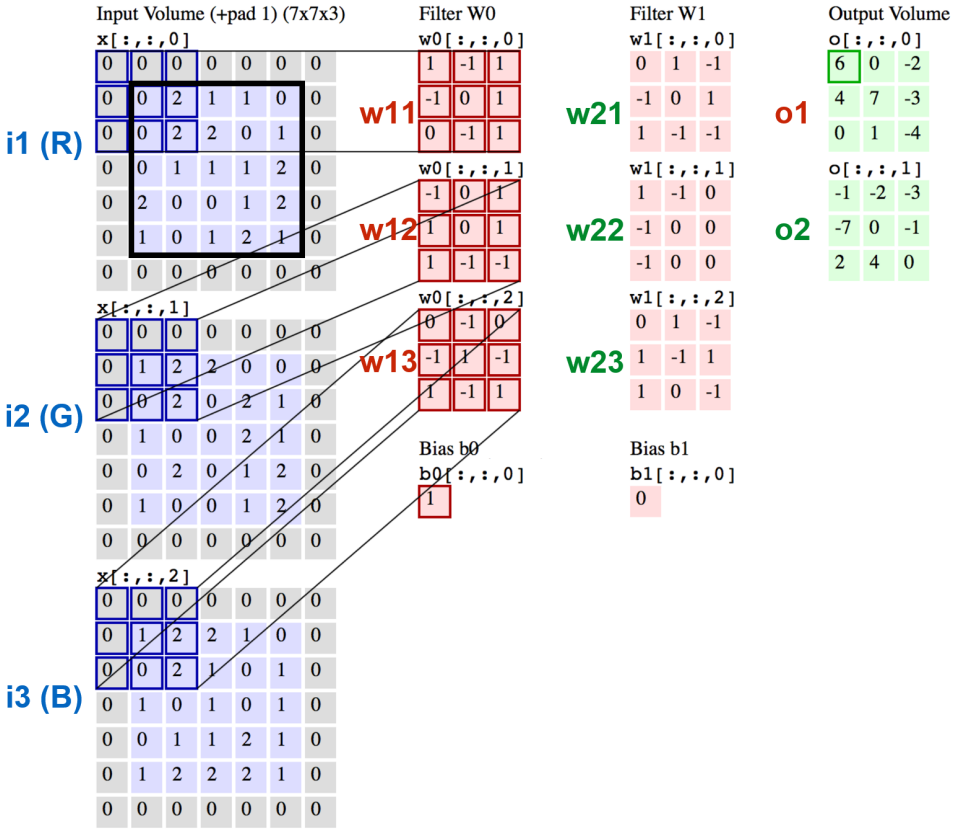
- Spectrum (a)
- Spectrum (b)
- Spectrum (c)

Knytte håndtegninger til denne oppgaven?
Bruk følgende kode:

3 9 2 9 9 7 5

23 IP4-Q1: Weights and biases

Given the following illustration for a CNN network:



Can you fill out the following parameters of the network:

Hyperparameters:

Zero paddings **P =** 1

Receptive field **F =** 3

Stride **S =** 1

Number of filter/kernels **K =** 6

Size:

Input volume size (W x H x D) = 5 x 5 x 3

Output volume size (W x H x D) = 3 x 3 x 2

Weights and biases:

Number of weights = 54

Number of biases = 6

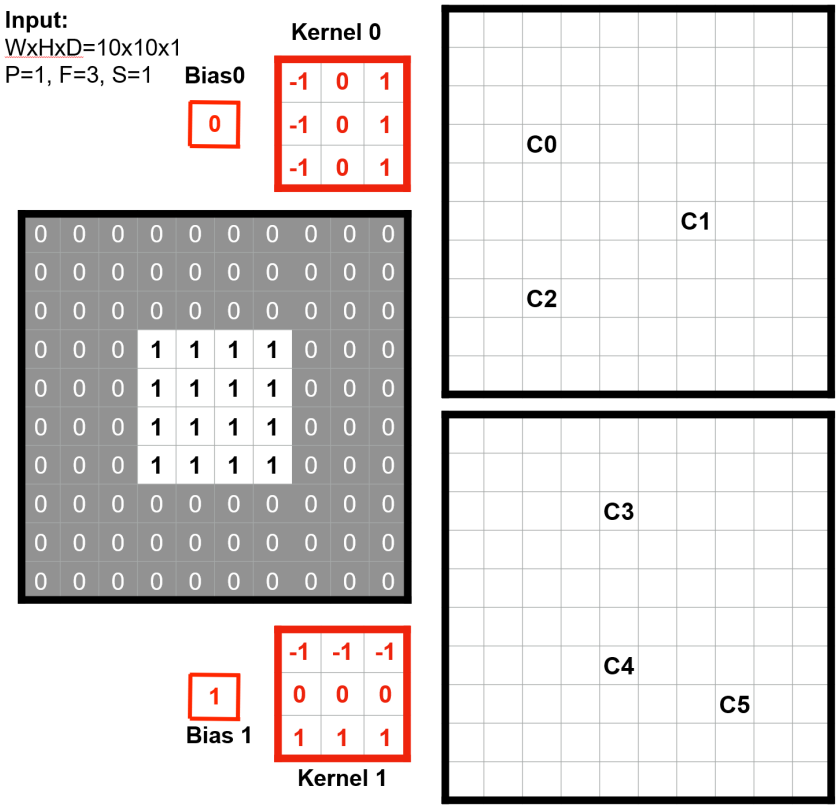
Overall trainable parameters = 60

Knytte håndtegninger til denne oppgaven?
Bruk følgende kode:

4 1 2 7 5 1 5

24 IP4-Q2: Convolution and pooling

Weighted input: Given the input layer below and the two kernels + bias values that you want to apply to the input can you compute the weighted input at the six locations?



Specify the values for:

C0 = -2

C1 = 3

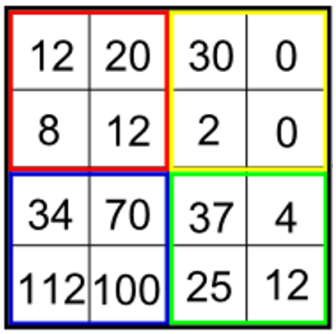
C2 = -1

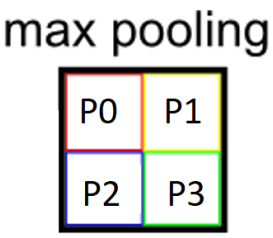
C3 = -2

C4 = 4

C5 = 2

Max pooling: Assuming that 2x2 max pooling is employed, can you specify the resulting values for each cell on the left?





P0 = 20

P1 = 30

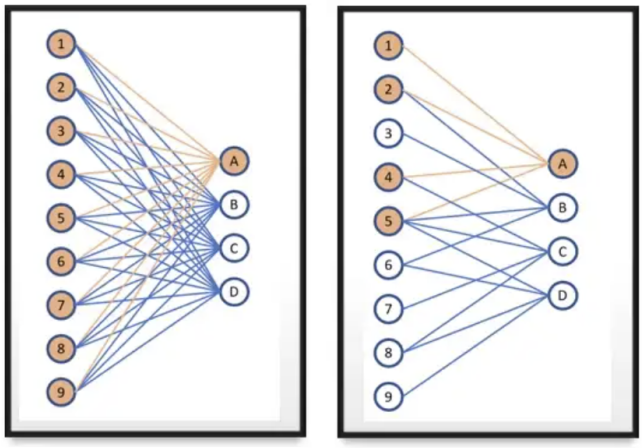
P2 = 112

P3 = 37

Knytte håndtegninger til denne oppgaven?
Bruk følgende kode:

1 0 6 6 3 8 7

25 IP4-Q3: Difference between FCNN and CNN



The image above shows the main difference between FCNN (left) and CNN (right) networks. If a 20x20 pixel image is considered as input, a fully connected layer with 10 neurons in the second layer will have 4 000 trainable weights, whereas a convolutional layer with 10 kernels of size 3x3 will give 90 trainable weights.

Can you predict how this will change if an image of size 200x200 pixels is given as input?

Trainable weights for a FCNN with 10 neurons:
Choose an alternative:

- 4000
- 40000
- 400000

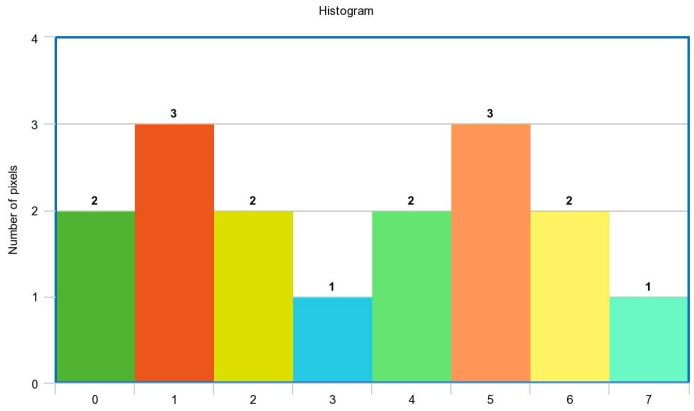
Trainable weights for a CNN with 10 kernels of size 3x3:
Choose an alternative:

- 90
- 18000
- 400000

Knytte håndtegninger til denne oppgaven?
Bruk følgende kode:

7 9 1 1 5 8 3

26 IP5-Q1: Otsu thresholding



The image above is a histogram for a 3 bit image, and is summarized in the table below:

r	0	1	2	3	4	5	6	7
H(r)	2	3	2	1	2	3	2	1

Knowing that the image can be separated into foreground and background, and after analyzing the histogram you suspect that the optimal threshold is k=3, however can you prove this by Otsu's method by providing the variance between the groups σ_B^2? To spare time you are required to provide the σ_B^2 only for 3 threshold values namely: k= 2, 3 and 4.

Remember that the variance between groups is of the form:

$$p_i, i = 0,1,..,L-1$$

$$P_1(k) = \sum_{i=1}^{k} p_i$$

$$m(k) = \sum_{i=1}^{k} i p_i$$

$$m_G = \sum_{i=1}^{L-1} i p_i$$

$$\sigma_B^2(k) = \frac{(m_G P_1(k) - m(k))^2}{P_1(k)(1 - P_1(k))}$$

Fill in the required values here:

σ_B^2 *for* $k = 2$ *is* : 1.24

σ_B^2 *for* $k = 3$ *is* : 1.50

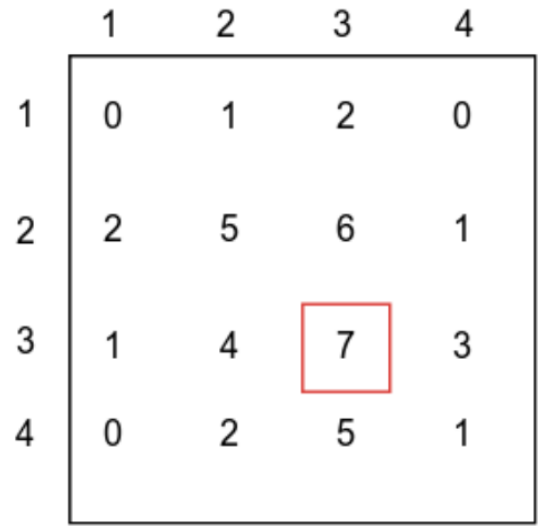
σ_B^2 *for* $k = 4$ *is* : 1

Knytte håndtegninger til denne oppgaven?
Bruk følgende kode:

5 6 0 3 8 1 2

27 IP5-Q2: Region growing

Apply region growing on the following 3bit gray level image. Initial seed point is at (3,3). Threshold is 2 and you are supposed to use 4 neighbor connectivity.



Fill out the final result in the table below. The pixels belonging to the object of interest get a value of 1, background pixels will be set to 0.

0	0	0	0
0	1	1	0
0	0	1	0
0	0	1	0

Knytte håndtegninger til denne oppgaven?
Bruk følgende kode:

2 0 2 5 7 7 5

28 IP5-Q3: Anonymize Mr. Snowden

You are given the task to anonymize Mr. Snowden (left image) and generate the image on the right, a process called pixelization. Each super pixel on the right is 5x5, takes the minimum value of all the original values that it covers and you know the location of these super pixels.

1. Can we do this pixelization with typical convolution/correlation filters (assume you can use only Gaussian, median and Prewitt)? Briefly explain your answer.

2. How about a morphological operator (binary or gray level)? Briefly explain your answer.

Write your answer here

1. No we cannot do it with typical convolution/correlation filters. Because using a filter would result in a change for every pixel, not just the face.

2. Yes, it can be done with a morphological operator. We could segment the image, to just pixelate the face.

Knytte håndtegninger til denne oppgaven?
Bruk følgende kode:

0 2 8 8 4 1 6