EXERCISE 4:
IMAGE PROCESSING PART 2

Multimedia Database SS 23

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Task 1.1: Point Operations

- In this exercise, we assume that we are using an 8-Bits grayscale image. The ***HK*** point operation is defined as follows:

$$P_{output} = \alpha \, P_{input} + \beta$$

- P_{input} and P_{output}: Pixel values of the input and output image respectively.

1. How do the parameters **α** and **β** influence the result of the operation?
   - **α** known as gain, is a contrast factor
   - **β** known as bias, is a brightness factor

Task 1.2: Point Operations

Explain which HK operation could be applied to implement the image inversion function.

- Solution

$$P_{output} = -P_{input} + MaxValue$$

- Whereas :
  - P_{input} and P_{output}: Sample values of the input and output of a pixel image respectively.

Task 1.3: Point Operations

Which problem could appear, if ***HK*** is used with a none adapted **α** and **β** parameters? Propose a method to deal with these effects.

- Problem:
  - There are no limits on the values of the pixels
- Solution:
  - Clamping; given a sample with a value ***x*** such that the sample is defined on **n** bits (i.e.; ***x*** ∊ [min, max=2^n-1] s.t. min ≥ 0), a formal definition of the clamping is given as follows:

$$clamp(x, min, max) = \begin{cases} min & wenn\ x \leq min, \\ max & wenn\ x \geq max, \\ x & sonst \end{cases}$$

Task 1.4: Point Operations

Let **G** be a grayscale image with minimum pixel value **a** and maximum pixel value **b**. Which HK Operation could be applied to **G** in order to maximize its contrast ratio?

- The maximum contrast is achieved when HK(a) corresponds to the minimum pixel value and HK (b) the maximum pixel value. For a grayscale image:

$$HK(a) = 0, Hk(b) = 255$$
$$\Leftrightarrow \alpha \times a + \beta = 0; \alpha \times b + \beta = 255$$

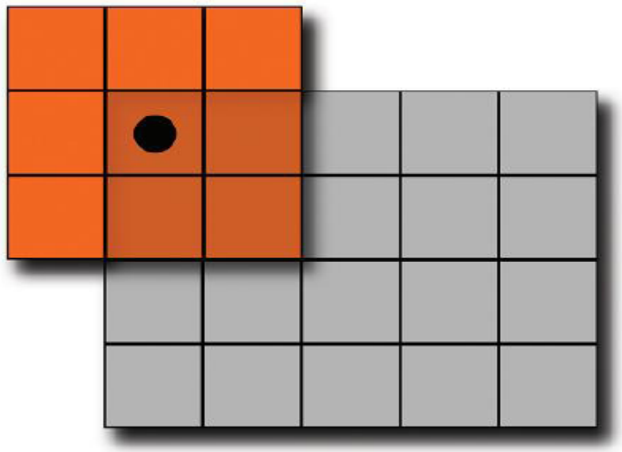
By solving the equation with two unknowns, we will have: $\beta = -a\alpha$,

$\alpha = 255/(b-a)$

Task 2.1: Linear Filter

- **Which problems can occur to edge pixels when using this filter?** How can you solve it?

Problem:



The kernel extends beyond the source image boundaries near the image edges.

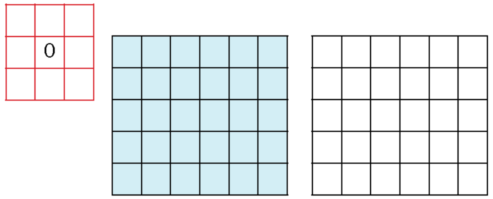
Solutions:

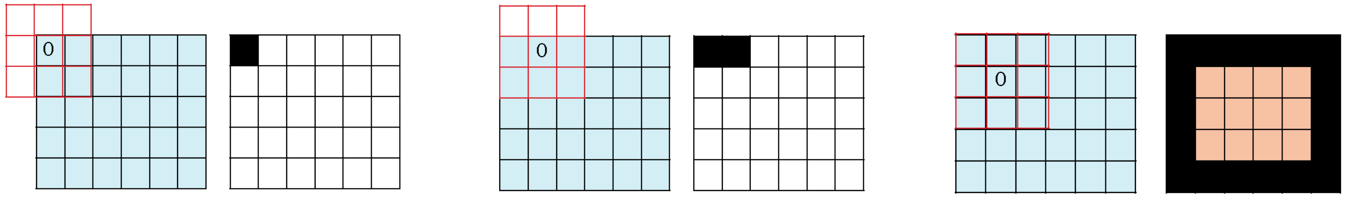
- Redefine convolution at the edge boundary.
- Padding.

Task 2.1: Linear Filter

Redefine convolution at the edge boundary

- *Convolution is redefined to produce zero when the kernel falls off of the boundary*. If the kernel extends beyond the source image when centered on a sample I(x, y) then the output sample is set to zero.

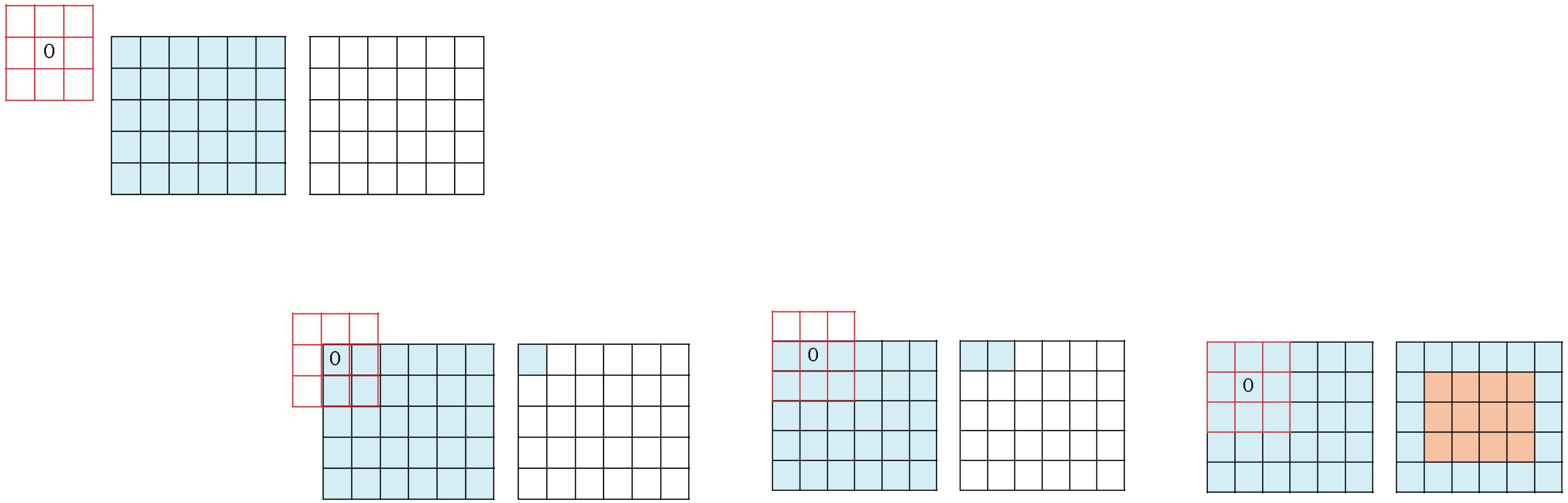




Task 2.1: Linear Filter

Redefine convolution at the edge boundary

- *Convolution is redefined to produce I(x, y) when the kernel falls off the boundary*. If the kernel extends beyond the source image when centered on a sample I(x,y) then the output sample is defined as I(x, y).



Task 2.1: Linear Filter

- Padding:
  - Zero padding
  - Symmetric Padding

$$\begin{bmatrix} 1 & 2 & 3 & 4 \\ 5 & 6 & 7 & 8 \\ 9 & 10 & 11 & 12 \\ 13 & 14 & 15 & 16 \end{bmatrix} \xrightarrow{\text{zero}} \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 2 & 3 & 4 & 0 \\ 0 & 5 & 6 & 7 & 8 & 0 \\ 0 & 9 & 10 & 11 & 12 & 0 \\ 0 & 13 & 14 & 15 & 16 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Zero Padding

$$\begin{bmatrix} 1 & 2 & 3 & 4 \\ 5 & 6 & 7 & 8 \\ 9 & 10 & 11 & 12 \\ 13 & 14 & 15 & 16 \end{bmatrix} \xrightarrow{\text{symmetric}} \begin{bmatrix} 1 & 1 & 2 & 3 & 4 & 4 \\ 1 & 1 & 2 & 3 & 4 & 4 \\ 5 & 5 & 6 & 7 & 8 & 8 \\ 9 & 9 & 10 & 11 & 12 & 12 \\ 13 & 13 & 14 & 15 & 16 & 16 \\ 13 & 13 & 14 & 15 & 16 & 16 \end{bmatrix}$$

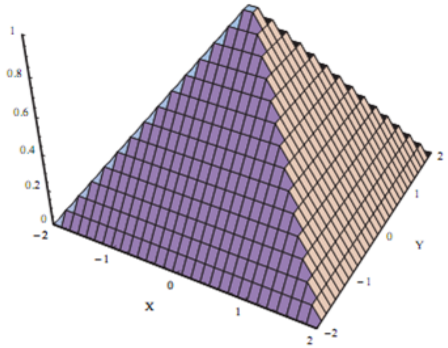
Symmetric Padding

Images from: https://www.uio.no/studier/emner/matnat/ifi/INF2310/v17/undervisningsmateriale/slides_inf2310_s17_week06.pdf

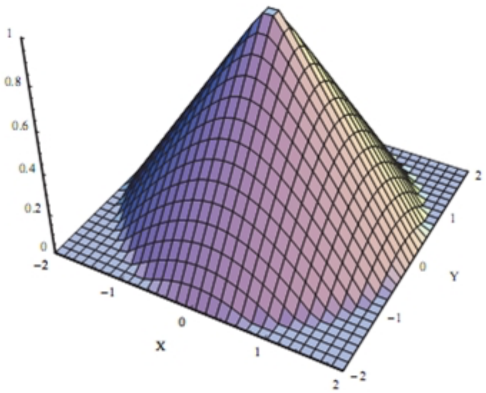
Task 2.2: Moving Average Filter

$$\begin{bmatrix} 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \end{bmatrix} * \frac{1}{25}$$

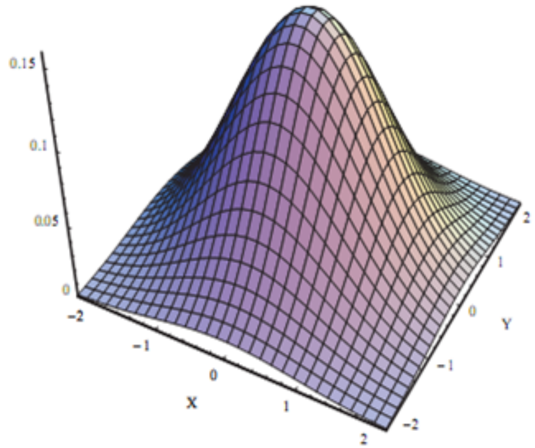
Weighted Smoothing



Pyramid



Cone



Gaussian

Task 2.3: Weighted smoothing

- **The pyramid area function:**

$$f(x,y) = -\alpha.max(|x|,|y|) + k$$

x and ***y*** designate the distance to the target pixel on the ***x*** and ***y*** axes, **α** is a parameter of the function and ***k*** a constant which you add for creating positive values.

Pyramid-area (5x5, α = 2, k=0)

$$\begin{bmatrix} -4 & -4 & -4 & -4 & -4 \\ -4 & -2 & -2 & -2 & -4 \\ -4 & -2 & 0 & -2 & -4 \\ -4 & -2 & -2 & -2 & -4 \\ -4 & -4 & -4 & -4 & -4 \end{bmatrix}$$

Pyramide-are (5x5, α = 2, k=4)

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 0 \\ 0 & 2 & 2 & 2 & 0 \\ 0 & 2 & 4 & 2 & 0 \\ 0 & 2 & 2 & 2 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Task 2.3

- **The conical area function:**

  x and ***y*** designate the distance to the target pixel on the ***x*** and ***y*** axes, **α** is a parameter of the function and ***k*** a constant which you add for creating positive values.

$$f(x,y) = -\alpha.\sqrt{x^2+y^2}+k$$

Conic-area (5x5, α = 2, k=0, exact)

$$\begin{bmatrix} -2\sqrt{8} & -2\sqrt{5} & -4 & -2\sqrt{5} & -2\sqrt{8} \\ -2\sqrt{5} & -2\sqrt{2} & -2 & -2\sqrt{2} & -2\sqrt{5} \\ -4 & -2 & 0 & -2 & -4 \\ -2\sqrt{5} & -2\sqrt{2} & -2 & -2\sqrt{2} & -2\sqrt{5} \\ -2\sqrt{8} & -2\sqrt{5} & -4 & -2\sqrt{5} & -2\sqrt{8} \end{bmatrix}$$

Conic-area (5x5, α = 2, k=2√8, rounded)

$$\begin{bmatrix} 0 & 1 & 2 & 1 & 0 \\ 1 & 3 & 4 & 3 & 1 \\ 2 & 4 & 6 & 4 & 2 \\ 1 & 3 & 4 & 3 & 1 \\ 0 & 1 & 2 & 1 & 0 \end{bmatrix}$$

Task 2.4 : Laplacian Filters

- Laplacian filters are derivative filters used to find areas of rapid change (edges) in images.
- The Laplacian *L(x,y)* of an image with pixel intensity values *I(x,y)* is given by:

$$L(x, y) = \frac{\partial^2 I}{\partial x^2} + \frac{\partial^2 I}{\partial y^2}$$

- Since images comprise of a set of discrete pixels, we calculate filters that approximate the second derivative

0	−1	0
−1	4	−1
0	−1	0

Details: https://stackoverflow.com/questions/53544983/how-is-laplacian-filter-calculated