Part ① 06.

• Intensity Transformation and Spatial Filtering-I

Spatial Filtering and Smoothing:

* Filters in Image Processing.

Filters are essential tools in image processing used to modify or enhance images by accepting or rejecting specific frequency components.

* Filtering Function:

Filters either allow (pass) or block (reject) certain frequency components in an image.

* Types of Filtering:

– Low-Pass Filters

Suppress high frequencies, resulting in a smoother image by reducing noise and details.

- High-pass filters -
Suppress low frequencies, enhancing edges and fine details in the image.

* Processing Domains:
- Spatial Domain Filtering:
Directly applies a filter mask (kernel) to pixel values.
- Frequency Domain Filtering:
Uses Fourier ~~Transforma~~ Transform to modify frequency components of the image.

Fundamentals of Frequency Domain Filtering

Steps in Frequency Domain Filtering

1. Transform the Image to the Frequency Domain
   - Use the Fourier Transform (FT) (e.g: Discrete FT or Fast FT) to convert the image from the spatial domain to the frequency domain

2. Apply the Frequency Filter function.
   - Multiply the transformed image by a filter function that reduces or enhances specific frequencies.

3. Re-transform the Result Back to the Spatial Domain.
   - Use inverse Fourier Transform (IFT) to convert the filtered frequency domain image back to its original form.

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Fundamental of spatial Filtering

Spatial filtering modifies an image by applying a filter (also called a kernel, mask or convolution matrix) to pixel neighborhoods, producing a new processed image.

Components of Spatial Filtering:

1. Mask / Kernel / Convolution Matrix
   - A small rectangular matrix (3x3, 5x5) that defines the filter operation.

2. Filter Function
   - A mathematical operation applied to the pixel values inside the mask

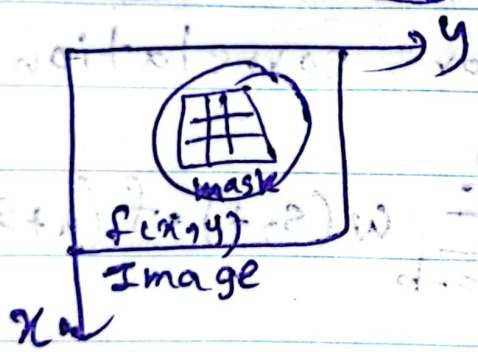
Spatial filtering

* Used primarily to remove additive random noise in images.
* Works by correlation or convolation.

* Mathematical Representation.

$w(-1,-1)$	$w(-1,0)$	$w(-1,1)$
$w(0,-1)$	$w(0,0)$	$w(0,1)$
$w(1,-1)$	$w(1,0)$	$w(1,1)$

mask coefficients.



$f(x-1, y-1)$	$f(x-1, y)$	$f(x-1, y+1)$
$f(x,y+1)$	$f(x,y)$	$f(x,y+1)$
$f(x+1, y-1)$	$f(x+1, y)$	$f(x+1, y+1)$

pixels of image section under mask

$$g(x,y) = \sum_{s=-a}^{a} \sum_{t=-b}^{b} w(s,t) \cdot f(x+s, y+t)$$

w - mask
f - image function
m, n — kernel dimensions

$m = 2a+1$
$n = 2b+1$
a and b positive integers

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* When performing linear / spatial filtering, two important concepts are;

1. Correlation

- A filter mask (kernel) is moved over the image.
- At each position, the sum of products of the mask values and the corresponding pixel values is computed.
- No modification is made to the mask before applying it.

→ Formula for correlation,

$$g(x,y) = \sum_{s=-a}^{a} \sum_{t=-b}^{b} w(s,t) \cdot f(x+s, y+t)$$

2. Convolution

- similar to correlation, but the filter mask is rotated by 180° (flipped both horizontally and vertically) before applying it.
- Convolution is used in many applications like edge detection and blurring due to its mathematical properties.

→ formula for convolution.

$$g(x,y) = \sum_{s=-a}^{a} \sum_{t=-b}^{b} \omega(-s,-t) \cdot f(x+s, y+t)$$

* Key difference.

- Correlation directly applies the mask.
- Convolution applies the flipped version of the mask.

correlation

244	255	246
255	240	183
255	250	12

* Filter

1	2	3
4	5	6
7	8	9

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244	510	738
1020	1200	1098
1785	2000	108

⇒ 8703

convolution

244	255	246
255	240	183
255	250	12

* Filter Rotated 180°

9	8	7
6	5	4
3	2	1

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2196	2040	1722
1530	1200	732
765	500	12

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* Mask / Kernel / Convolution Matrix.

* A kernel is a small matrix used in image processing for tasks like blurring, sharpening edge detection and embossing.

* size : common 3x3, 5x5, 9x9 21x21 (depends on application)

* shape : rectangular, cross, strip, circular, diamond or user-defined

* Coefficient / Values :
  Defined based on the operation (e.g. smoothing, edge ditection)

0	-1	0
-1	5	-1
0	-1	0

Anchor point (This is mostly in middle)

values for sharpening operation.

x0 139	x-1 192	x0 190
x-1 139	x5 191	197 x-1
149	191	190
x0	x-1	x0

= 236

* Key applications of Convolution:
  * Smoothing (Blurring)
    - Uses an averaging filter.
  * Sharpening
    - Uses a high-pass filter
  * Edge Detection
    - Uses Sobel, Prewitt, or Laplacian filters.
  * Embossing
    - Uses a directional kernel

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- convolution ফাংশন দিয়ে যেন mathematical operation করা