Лекц 7: Local Operation

Газарзүйн тэнхим,
Шинжлэх ухааны сургууль,
Монгол Улсын Их Сургууль

2.3 Local Operation

2.3.1 Concepts

2.3.2 Smoothing

2.3.3 Edge detecting

2.3.4 Sharpening

2.3.1 Concepts

- Image Processing Algorithms
  - ✓ Point operation
  - ✓ Local operation
  - ✓ Total operation
  - ✓ Algebraic operation
  - ✓ Geometric operation

2.3.1 Concepts

- Local Operation
  - ✓ Gray-level value of an output pixel is calculated not only by the gray-level value of the relevant input pixel but also the gray-level values of neighborhood pixels.
- Point Operation (for comparing)
  - ✓ Gray-level value of an output pixel is calculated only by the gray-level value of the relevant input pixel.

2.3.1 Concepts

- Filters
  - ✓ In digital signal processing, local operation relates to filters.
  - ✓ Filters are optimal for doing a specific job by reducing the amplitude of some frequency components of a digital signal.
    - Low-pass filtering
    - High-pass filtering
    - Band-pass filtering

2.3.1 Concepts

- Filtering of digital signals
  - Low-pass
    - To reduce the amplitude of high-frequency component of a digital image.
    - To reduce visible effects of noise and rigid edges of objects in an image.
  - High-pass
    - To reduce the amplitude of low-frequency component of a digital image.

2.3.1 Concepts

- How to do local operation
  - A small matrix of coefficients will be used to multiply neighborhood gray-level values.
  - Names of the coefficient matrix
    - Kernel
    - Operator
    - Template

$$\begin{matrix} 1/9 & 1/9 & 1/9 \\ 1/9 & 1/9 & 1/9 \\ 1/9 & 1/9 & 1/9 \end{matrix}$$

2.3.1 Concepts

- How to do local operation
  - Kernel
    - To do filtering
  - Operator
    - To do edge detection
  - Template
    - To do template matching

- Different kernels give different filtering effects (low-pass, high-pass, etc.), so coefficients in a kernel can be designed depending on the desired filtering result.

2.3.1 Concepts

- Purposes of local operation
  - Smoothing
    - To blur or smooth images.
    - Low-pass.
  - Edge detection
    - To extract edges and textures.
    - High-pass.
  - Sharpening
    - To outline (enhance) edges and textures.

2.3.2 Smoothing

- Purposes of smoothing
  - To blur digital images.
  - To eliminate unknown noises in images.
  - To diminish spurious effects that may be present in a digital image as a result of a poor sampling system of transmission channel.

2.3.2 Smoothing

- Smoothing implementation
  - Smoothing techniques are in both the spatial (local operation) and frequency (total operation) domains where spatial domain is the natural form of an image.
  - Smoothing aims to suppress noise or other small fluctuations in the image where it is equivalent to suppressing high frequencies in the frequency domain.

2.3.2 Smoothing

- Common Algorithms of Smoothing
  - Average filter
  - Median filter

Average Filter

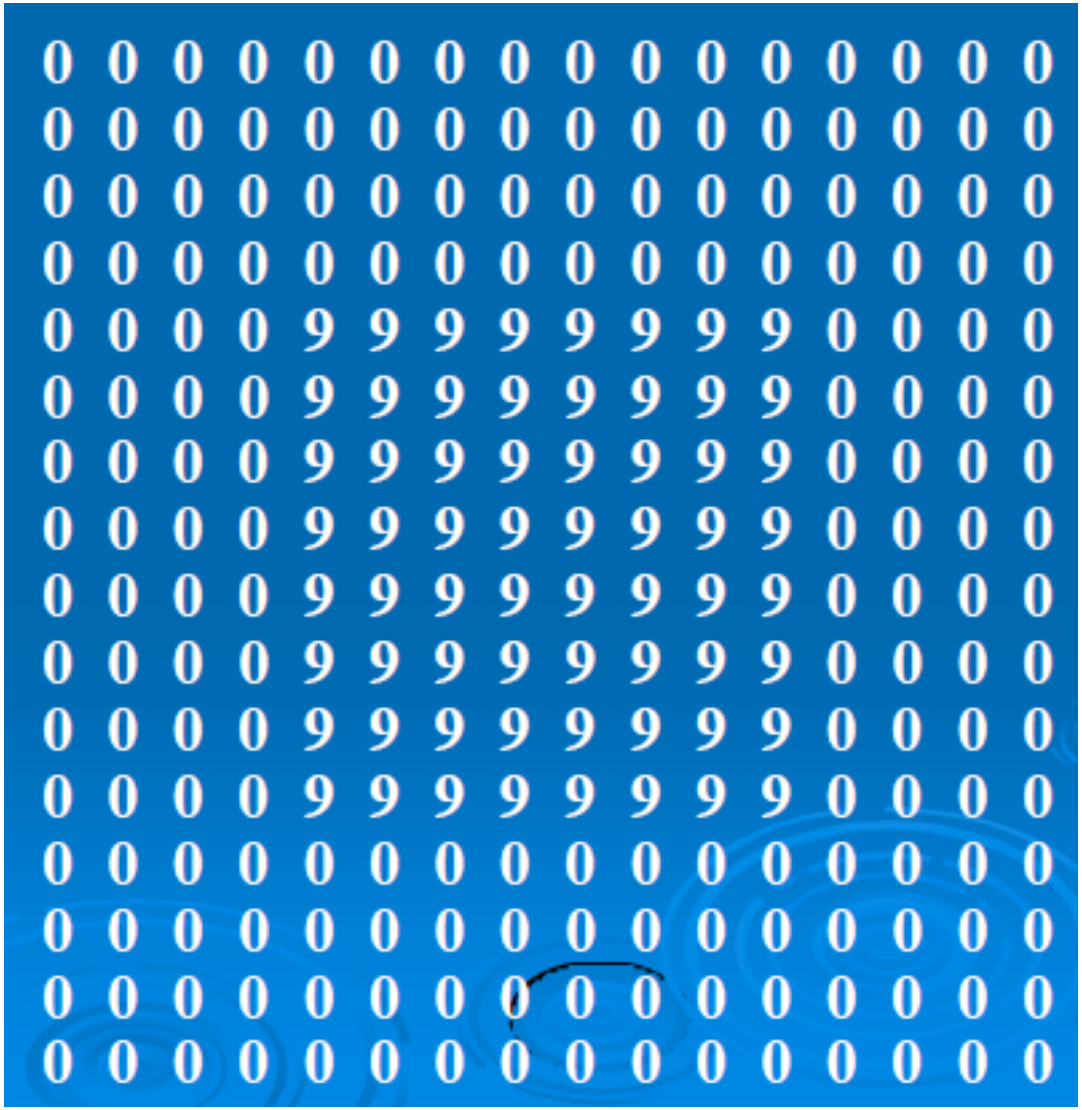
- 3x3 Average Filter
  - $$O(X,Y)=\frac{1}{9}(I(X-1,Y-1)+I(X,Y-1)+I(X+1,Y+1)$$
    $$+(I(X-1,Y)+I(X,Y)+I(X+1,Y)$$
    $$+I(X-1,Y+1)+I(X,Y+1)+I(X+1,Y+1))$$

- Kernel

$$\begin{bmatrix} 1/9 & 1/9 & 1/9 \\ 1/9 & 1/9 & 1/9 \\ 1/9 & 1/9 & 1/9 \end{bmatrix} \quad \text{or} \quad 1/9 \begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix}$$

Average Filter

- Suppose a 16 × 16 image.



Average Filter

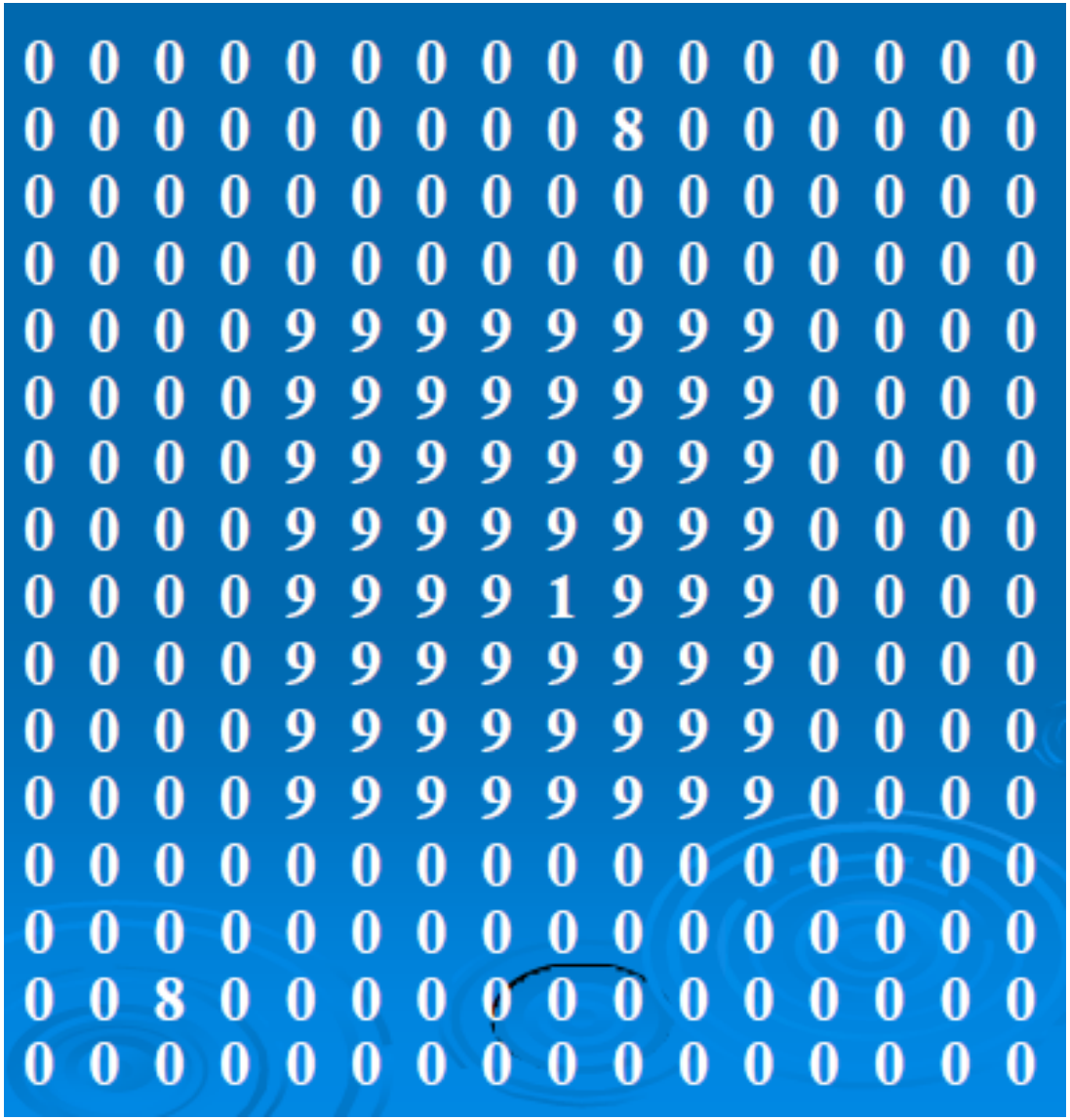
- Use 3 × 3 average filter.
- The kernel is

$$\frac{1}{9}\begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix}$$

- Result as right

Average Filter

- Suppose a 16 × 16 image.
- With some noises.



Average Filter

- Use 3 × 3 average filter.
- The kernel is

$$\frac{1}{9}\begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix}$$

- Result as right

Average Filter

- 5 × 5 Average Filter
  - Kernel

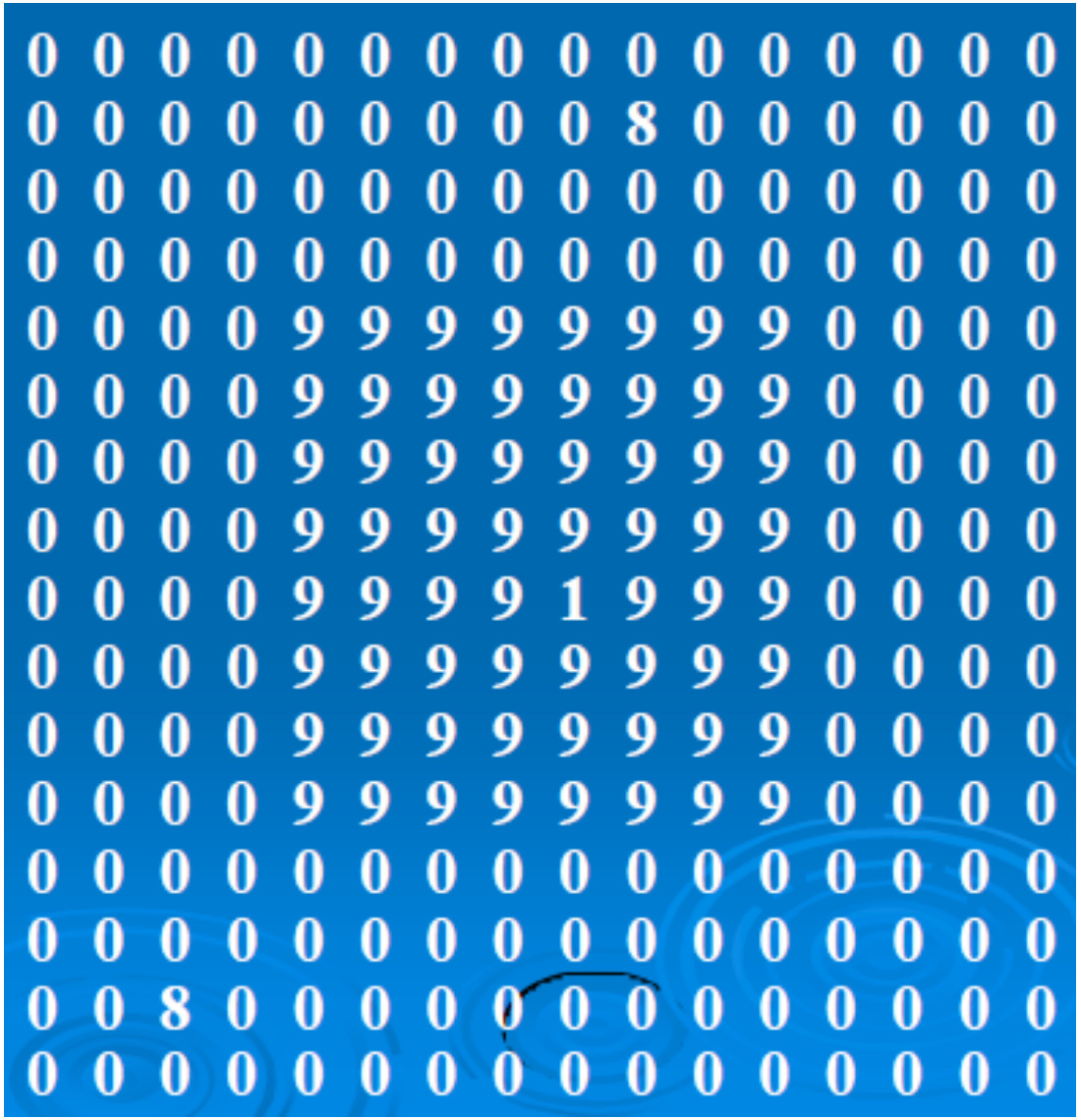
$$\begin{bmatrix} 1/25 & 1/25 & 1/25 & 1/25 & 1/25 \\ 1/25 & 1/25 & 1/25 & 1/25 & 1/25 \\ 1/25 & 1/25 & 1/25 & 1/25 & 1/25 \\ 1/25 & 1/25 & 1/25 & 1/25 & 1/25 \\ 1/25 & 1/25 & 1/25 & 1/25 & 1/25 \end{bmatrix} \quad \text{or} \quad 1/25 \begin{bmatrix} 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \end{bmatrix}$$

Median Filter

- Use median value of neighborhood pixels but not average value of average filter.
- Purpose
  - ✓ To eliminate noises but do not blur the image.

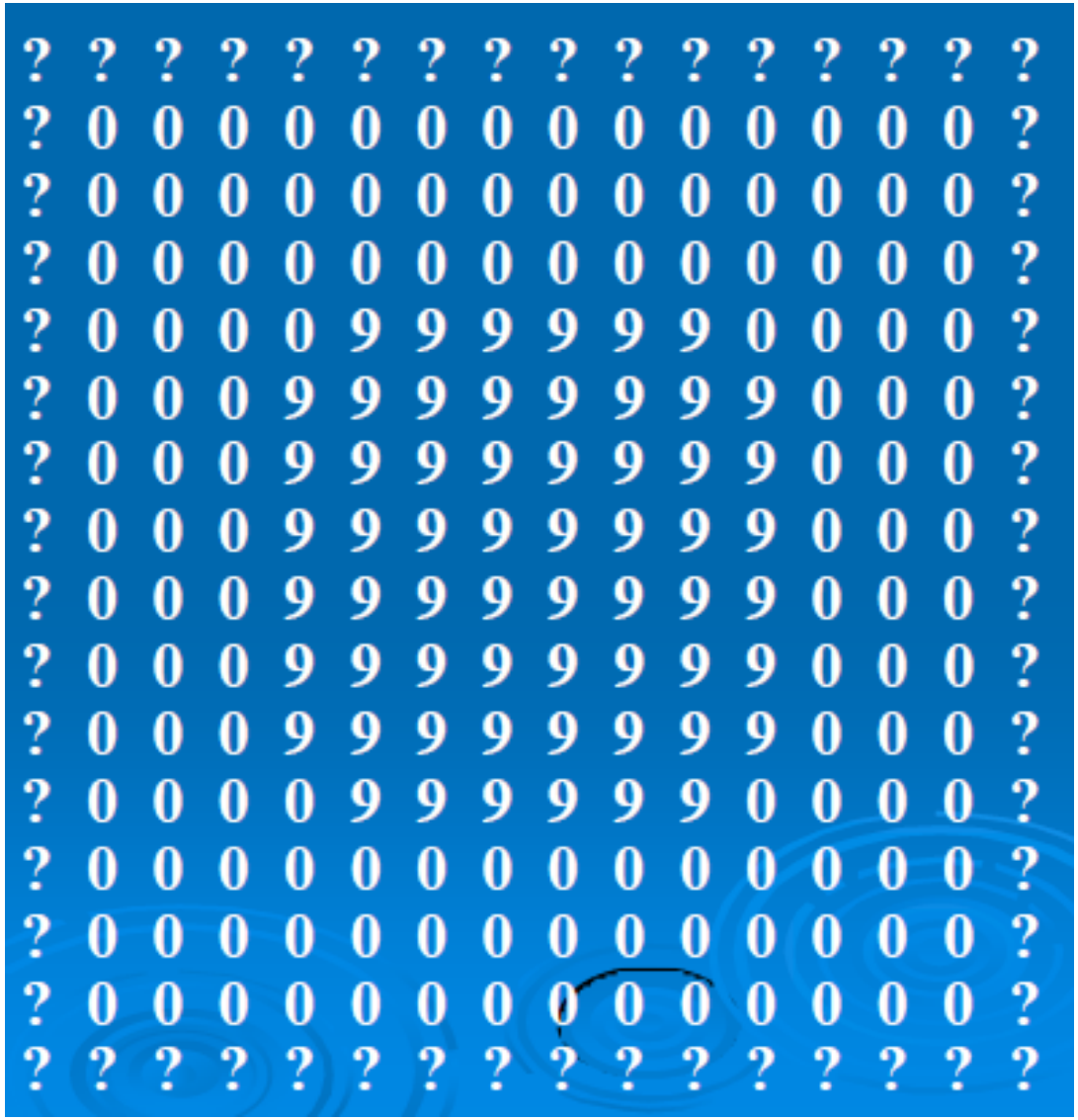
Median Filter

- Suppose a 16 × 16 image.
- With some noises.



Median Filter

- Use 3 × 3 median filter.
- Result as right.



2.3.3 Edge Detection

- Edge detection might be the first step of image segmentation and image understanding.
- Concepts
  - Image segmentation
  - Image understanding

2.3.3 Edge Detection

- An edge is a sharp discontinuity in gray-level profile. It is specified by its magnitude and its direction.
- Edge
  - Magnitude
  - Direction

2.3.3 Edge Detection

- Edge detection is a difference operation in local neighborhood of current pixel.

- Mathematics
  - Continuous function

    - Calculate differential to find edge

  - Discrete function (digital signal or image)

    - Calculate difference to find edge

2.3.3 Edge Detection

- Definition of differential for digital image

$$\Delta_X I(X,Y) \equiv I(X,Y) - I(X-1,Y)$$
$$\Delta_Y I(X,Y) \equiv I(X,Y) - I(X,Y-1)$$

  - or

$$\Delta_X I(X,Y) \equiv I(X+1,Y) - I(X-1,Y)$$
$$\Delta_Y I(X,Y) \equiv I(X,Y+1) - I(X,Y-1)$$

2.3.3 Edge Detection

- Differential kernels

$$\begin{bmatrix} -1 & 1 \end{bmatrix} \qquad \begin{bmatrix} -1 \\ 1 \end{bmatrix} \qquad \begin{bmatrix} -1 & 0 & 1 \end{bmatrix} \qquad \begin{bmatrix} -1 \\ 0 \\ 1 \end{bmatrix}$$

2.3.3 Edge Detection

- Prewitt operator

$$\begin{bmatrix} 1 & 0 & -1 \\ 1 & 0 & -1 \\ 1 & 0 & -1 \end{bmatrix} \qquad \begin{bmatrix} 1 & 1 & 1 \\ 0 & 0 & 0 \\ -1 & -1 & -1 \end{bmatrix}$$

2.3.3 Edge Detection

- Sobel operator

$$\begin{bmatrix} 1 & 0 & -1 \\ 2 & 0 & -2 \\ 1 & 0 & -1 \end{bmatrix} \qquad \begin{bmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix}$$

2.3.3 Edge Detection

- Laplacian operator

$$\begin{bmatrix} 0 & 1 & 0 \\ 1 & -4 & 1 \\ 0 & 1 & 0 \end{bmatrix} \quad \text{or} \quad \begin{bmatrix} 0 & -1 & 0 \\ -1 & 4 & -1 \\ 0 & -1 & 0 \end{bmatrix}$$

2.3.4 Sharpening

- To draw outline of objects in an image.

- Principle
  - Source image + edge detecting result.
  - Kernel example

$$\begin{bmatrix} 0 & -1 & 0 \\ -1 & 5 & -1 \\ 0 & -1 & 0 \end{bmatrix}$$

2.3.4 Sharpening

- Embossing