EE6310: Image and Video Processing Spring 2023

Binary Morphology

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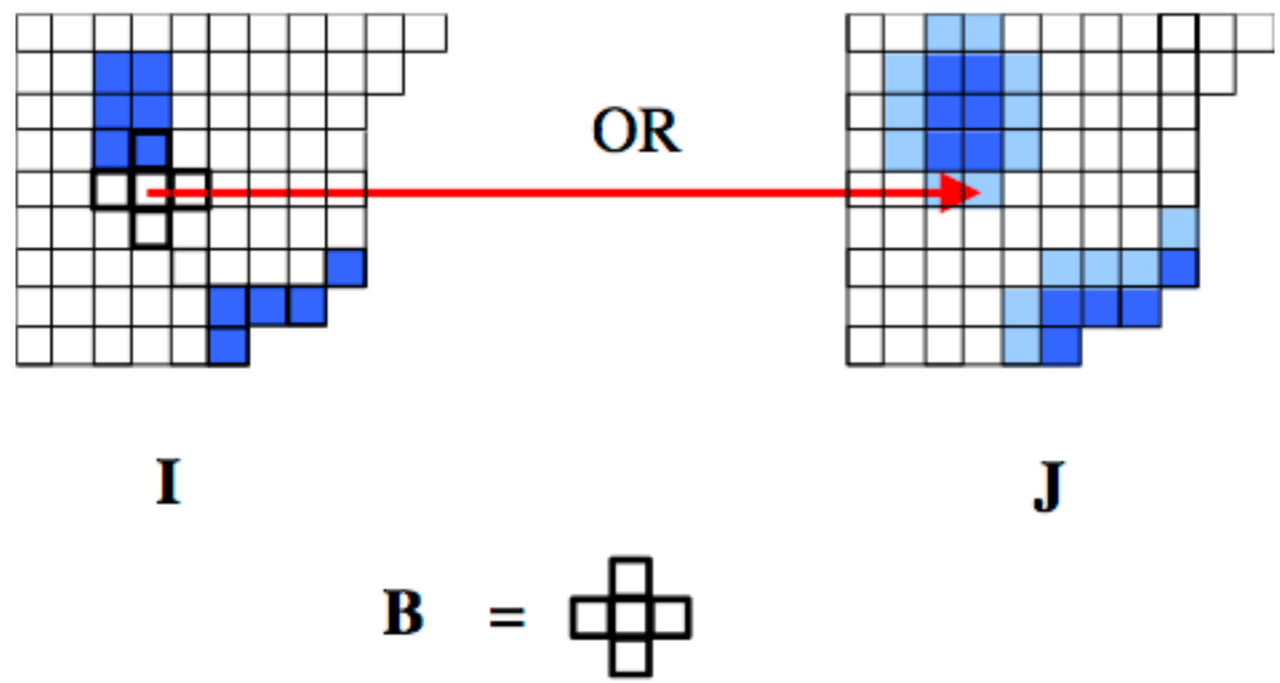
Binary Morphology

Definition

- Morphology: the study of form and structure
- Mathematical morphology: tool for extracting image components for describing shapes like boundaries, skeletons, convex hulls
- Binary morphology: a class of binary image operators



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Morphological Operations

- Morphological operations:
  - **affect the shape** of objects and regions of binary images
  - operate on a local basis i.e., on **local neighbourhoods**
- Morphological operators:
  - expand or **dilate** objects
  - shrink or **erode** objects
  - smooth object boundaries
  - eliminate holes
  - fill gaps and eliminate convex hulls
  - are logical operations

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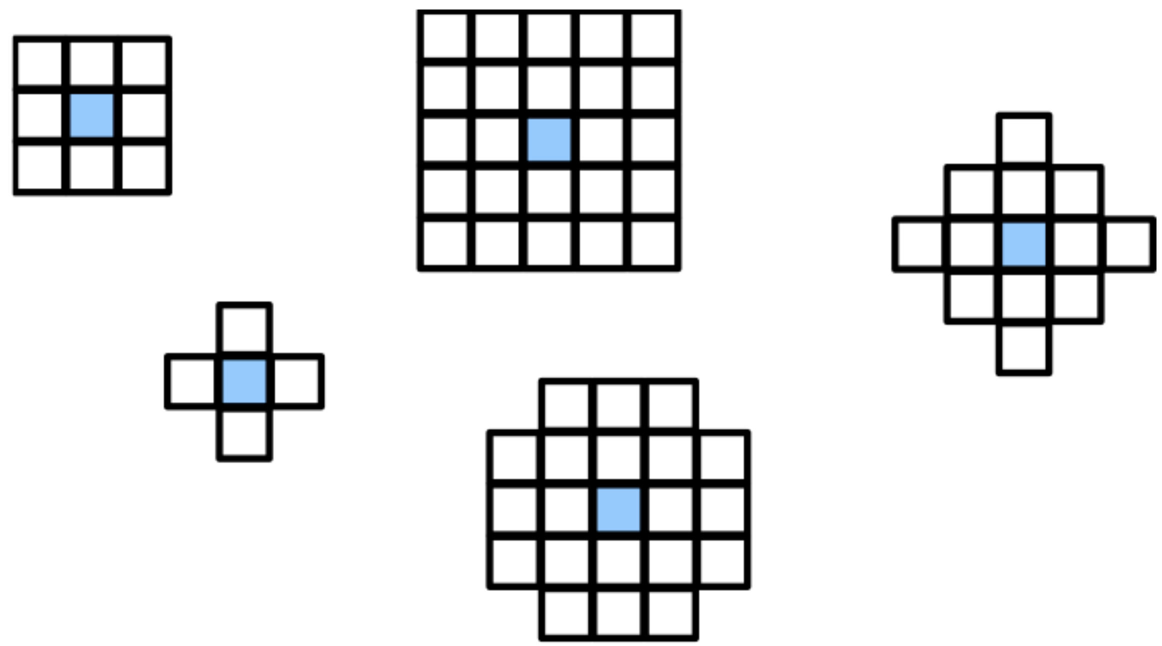
Structuring Element



- Definition: A structuring element defines a relationship between a pixel and its neighbours
- Window:
  - is a method of collecting pixels according to a geometric rule
  - is a structuring element
  - almost always contains an odd number of elements along each dimension - why?

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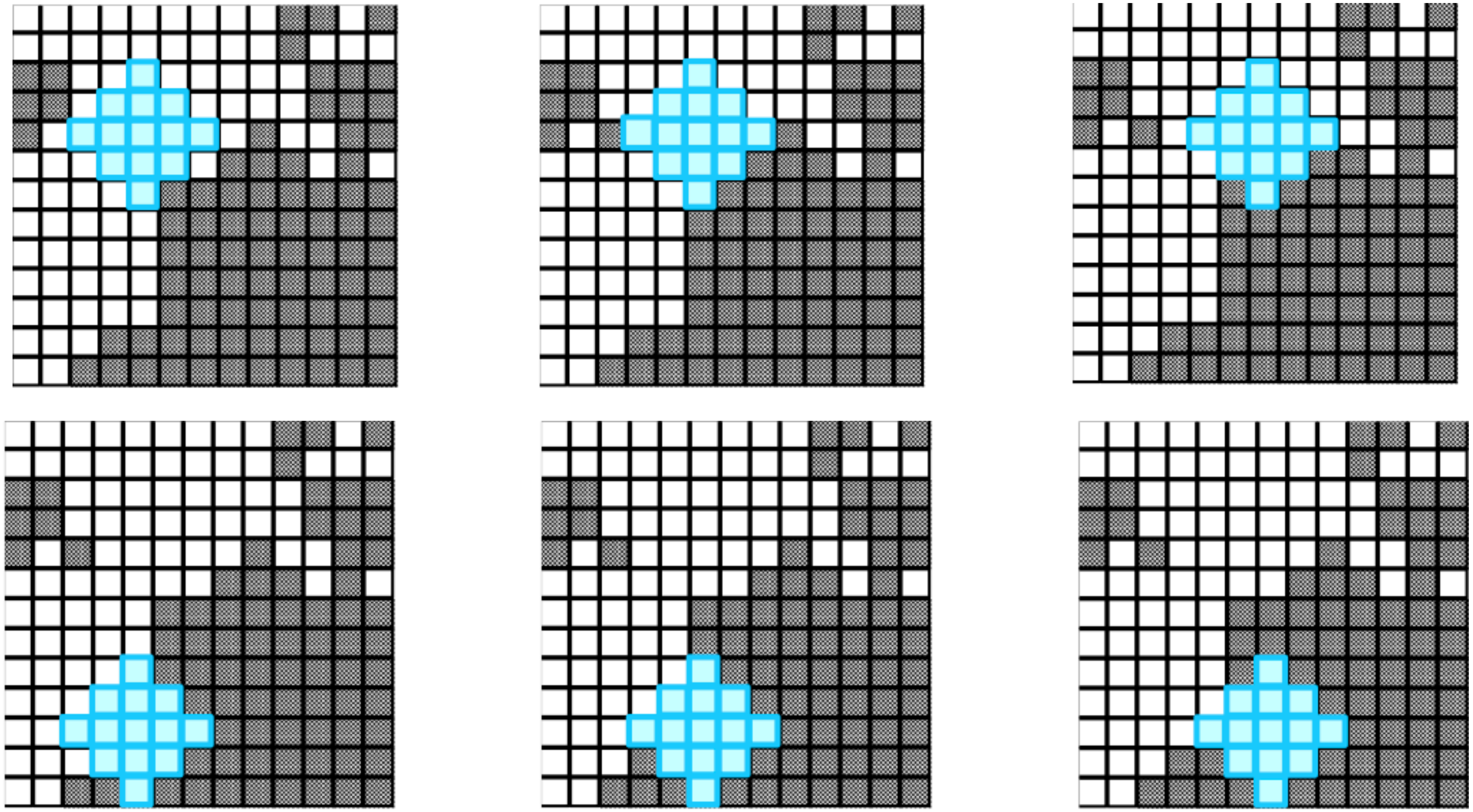
Windows



- Using a window to perform local operations over an image

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Windows

- Definition: A window $\mathbf{B}$ is a set of coordinate shifts $\mathbf{B}_i = (p_i, q_i)$ centred around $(0,0)$ i.e.,
  $\mathbf{B} = \{\mathbf{B}_1, \mathbf{B}_2, \ldots, \mathbf{B}_{2P+1}\} = \{(p_1, q_1), (p_2, q_2), \ldots, (p_{2P+1}, q_{2P+1})\}$

- Examples:

  - $\mathbf{B} = \text{ROW}(2P+1) = \{(0, -P), \ldots (0, P)\}$

  - $\mathbf{B} = \text{COL}(2P+1) = \{(-P, 0), \ldots (P, 0)\}$

  - $\mathbf{B} = \text{CROSS}(2P+1) = \text{ROW}(2P+1) \cup \text{COL}(2P+1)$

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The Windowed Set

- Definition: For a binary image $\mathbf{I}$ and window $\mathbf{B}$, the **windowed set** at location (i, j) is given defined as
  $\mathbf{B} \diamond \mathbf{I}(i, j) = \{\mathbf{I}(i - p, j - q); (p, q) \in \mathbf{B}\}$

- Interpreted as the set of pixels covered by $\mathbf{B}$ centred at (i, j)

- Helps make simple and flexible design of binary filters

- Examples:

  - $\mathbf{B} = \text{ROW}(3); \mathbf{B} \diamond \mathbf{I}(i, j) = \{\mathbf{I}(i, j - 1), \mathbf{I}(i, j), \mathbf{I}(i, j + 1)\}$

  - $\mathbf{B} = \text{COL}(3); \mathbf{B} \diamond \mathbf{I}(i, j) = \{\mathbf{I}(i - 1, j), \mathbf{I}(i, j), \mathbf{I}(i + 1, j)\}$

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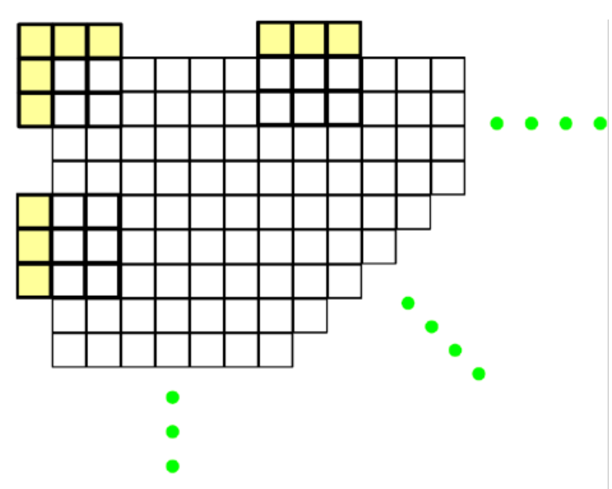
General Binary Filter

- Notation: A binary operator $\mathbf{G}$ on a windowed set $\mathbf{B} \diamond \mathbf{I}(i,j)$ is denoted as
  $\mathbf{J}(i,j) = \mathbf{G}\{\mathbf{B} \diamond \mathbf{I}(i,j)\} = \mathbf{G}\{\{\mathbf{I}(i-p, j-q); (p,q) \in \mathbf{B}\}\}$
- Performing the operation at every pixel gives us the filtered image $\mathbf{J} = \mathbf{G}[\mathbf{I}, \mathbf{B}] = [\mathbf{J}(i,j); 0 \le i \le N-1, 0 \le j \le M-1]$
- How about image boundary?
  - Replication: use nearest neighbors to fill empty slots



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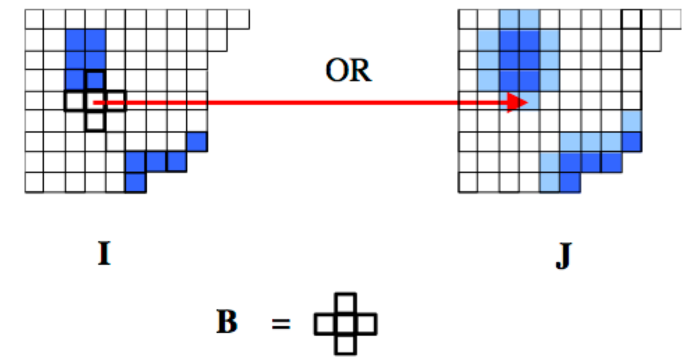
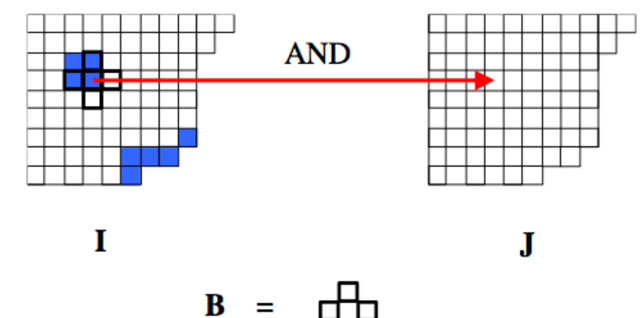
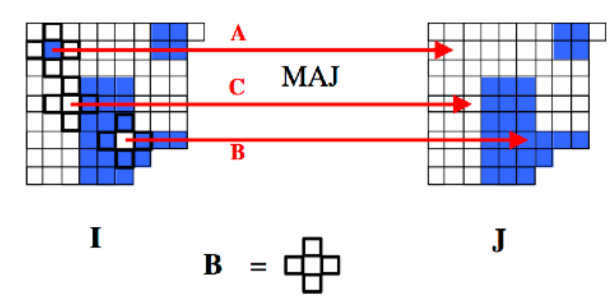
Dilation, Erosion and Median Filters



- **Dilation**: Given a window $\mathbf{B}$ and a binary image $\mathbf{I}$,
  $\mathbf{J} = \text{DILATE}(\mathbf{I}, \mathbf{B})$ if
  $\mathbf{J}(i,j) = \text{OR}\{\mathbf{B} \diamond \mathbf{I}(i,j)\} = \text{OR}\{\{\mathbf{I}(i-p, j-q); (p,q) \in \mathbf{B}\}\}$



- **Erosion**: Given a window $\mathbf{B}$ and a binary image $\mathbf{I}$,
  $\mathbf{J} = \text{ERODE}(\mathbf{I}, \mathbf{B})$ if
  $\mathbf{J}(i,j) = \text{AND}\{\mathbf{B} \diamond \mathbf{I}(i,j)\} = \text{AND}\{\{\mathbf{I}(i-p, j-q); (p,q) \in \mathbf{B}\}\}$



- **Median**: Given a window $\mathbf{B}$ and a binary image $\mathbf{I}$,
  $\mathbf{J} = \text{MEDIAN}(\mathbf{I}, \mathbf{B})$ if
  $\mathbf{J}(i,j) = \text{MAJ}\{\mathbf{B} \diamond \mathbf{I}(i,j)\} = \text{MAJ}\{\{\mathbf{I}(i-p, j-q); (p,q) \in \mathbf{B}\}\}$

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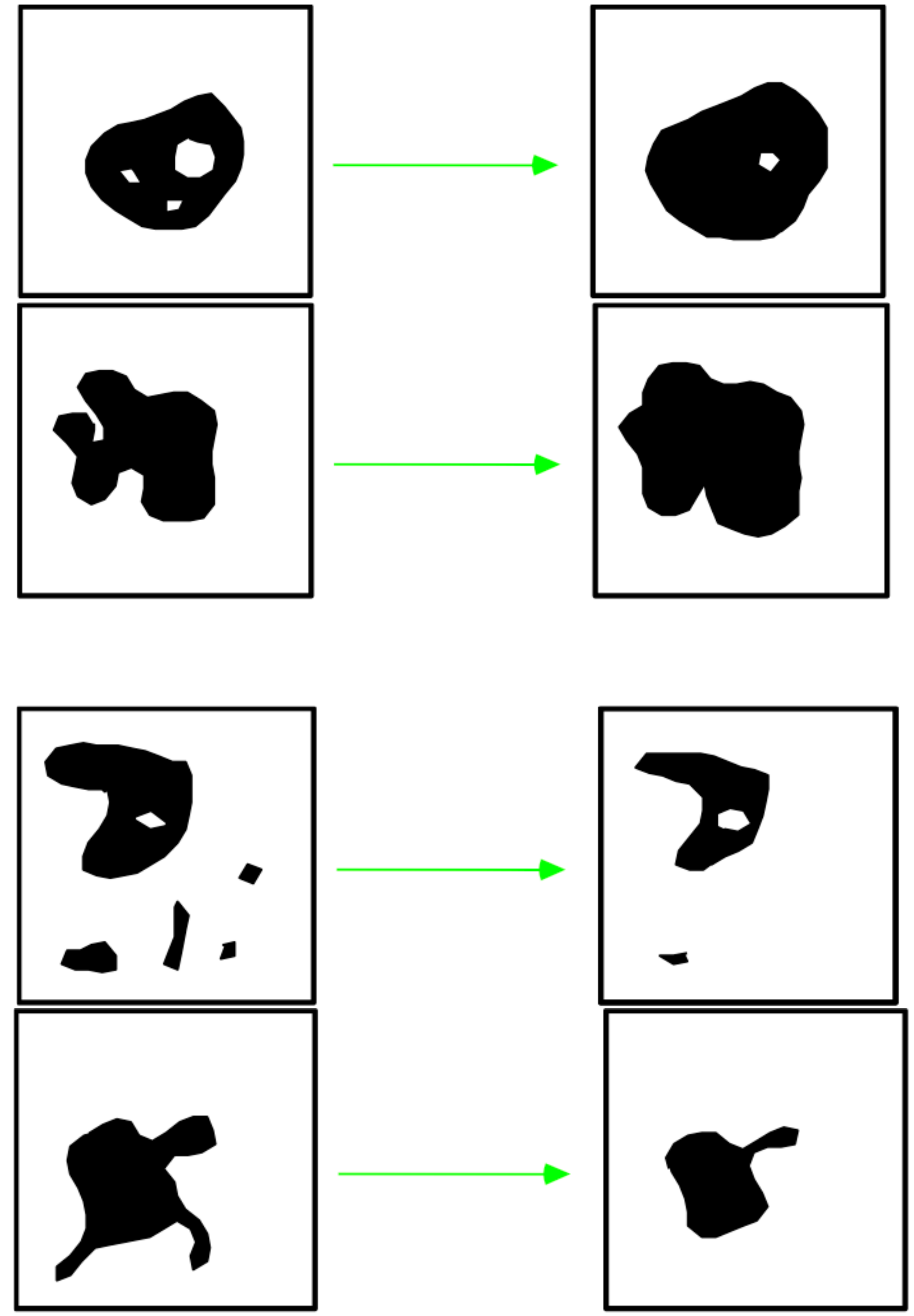
Dilation and Erosion Properties

- Dilation
  - Fills small gaps or holes
  - Fills bays
- Erosion
  - Eliminates small objects
  - Eliminates peninsulas



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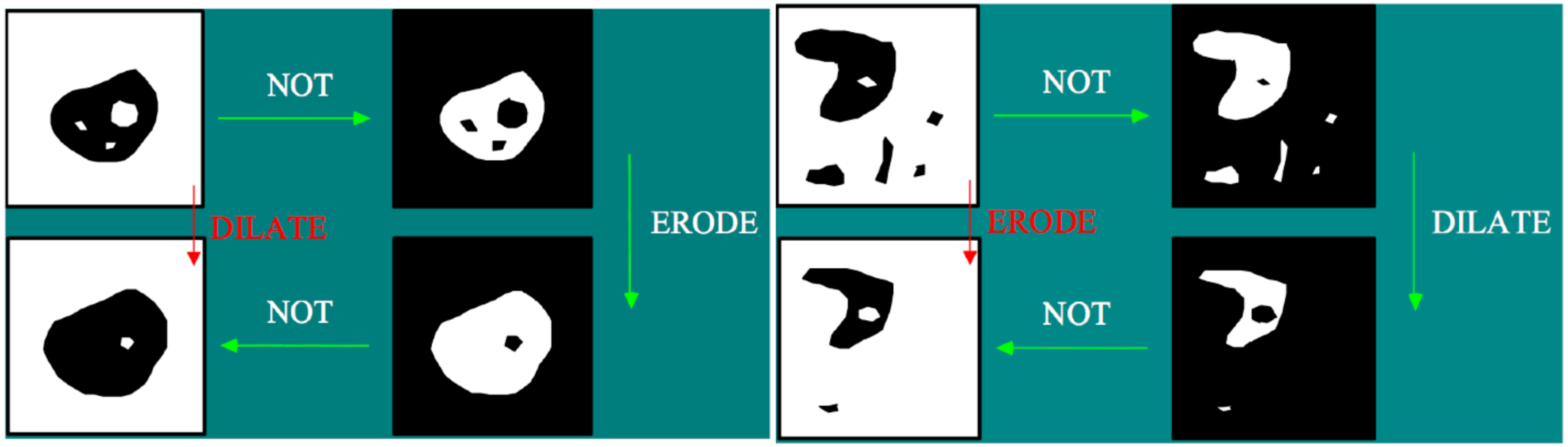
Duality Property



- Dilation and Erosion are **duals** with respect to complementation
- Median is its **own dual** with respect to complementation
- Dilation and Erosion are *approximate inverses* of one another
    - Peninsulas *eliminated* by erosion cannot be recreated
    - Small object *eliminated* by erosion cannot be recreated
    - Holes *filled* by dilation cannot be recreated
    - Gaps or bays *filled* by dilation cannot be recreated
- Median filter generally does not change object size (boundary) but alters them

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OPEN and CLOSE operators

- Definition of new operators by applying basic operators in sequence
- Given a binary image $\mathbf{I}$ and a window $\mathbf{B}$,
  - OPEN$(\mathbf{I}, \mathbf{B}) =$ DILATE[ERODE$(\mathbf{I}, \mathbf{B}), \mathbf{B})$]]
  - CLOSE$(\mathbf{I}, \mathbf{B}) =$ ERODE[DILATE$(\mathbf{I}, \mathbf{B}), \mathbf{B})$]]
- Similar to MEDIAN filter
- OPEN removes small objects better than MEDIAN but not holes, gaps or bays
- CLOSE removes small holes and gaps better than MEDIAN but not small objects
- In general, OPEN and CLOSE do not affect object size

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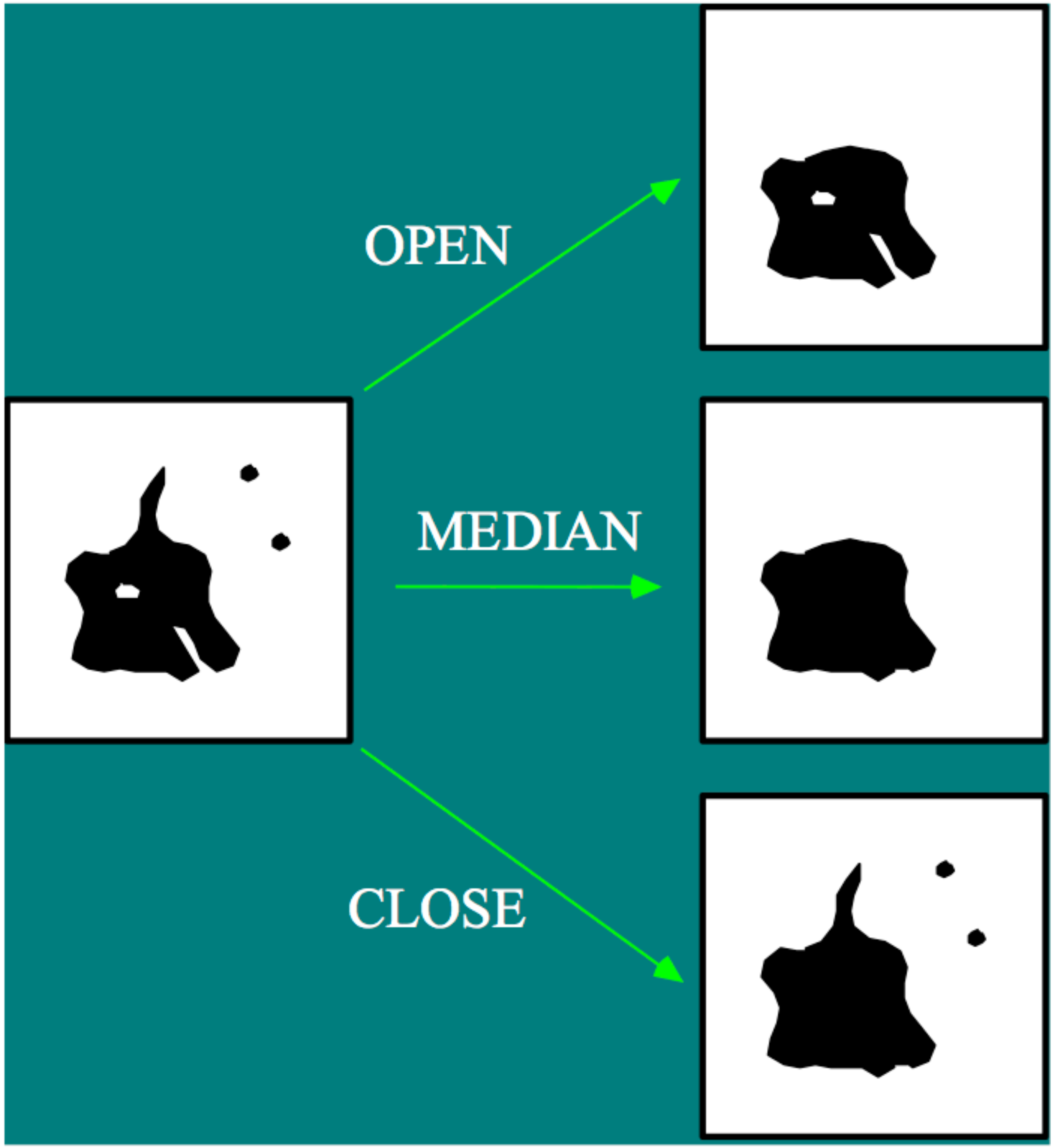
Comparing OPEN, CLOSE and MEDIAN



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OPEN-CLOS and CLOS-OPEN operators

- Continue to cascade basic operators:
  - OPEN-CLOS$(\mathbf{I}, \mathbf{B}) =$ OPEN[CLOSE$(\mathbf{I}, \mathbf{B}), \mathbf{B})]]$
  - CLOS-OPEN$(\mathbf{I}, \mathbf{B}) =$ CLOSE[OPEN$(\mathbf{I}, \mathbf{B}), \mathbf{B})]]$
- Properties:
  - Good smoothing operators
  - Remove small objects without affecting size
  - Similar to MEDIAN filter but more smoothing
  - OPEN-CLOS tends to link neighboring objects together
  - CLOS-OPEN tends to link neighboring holes together

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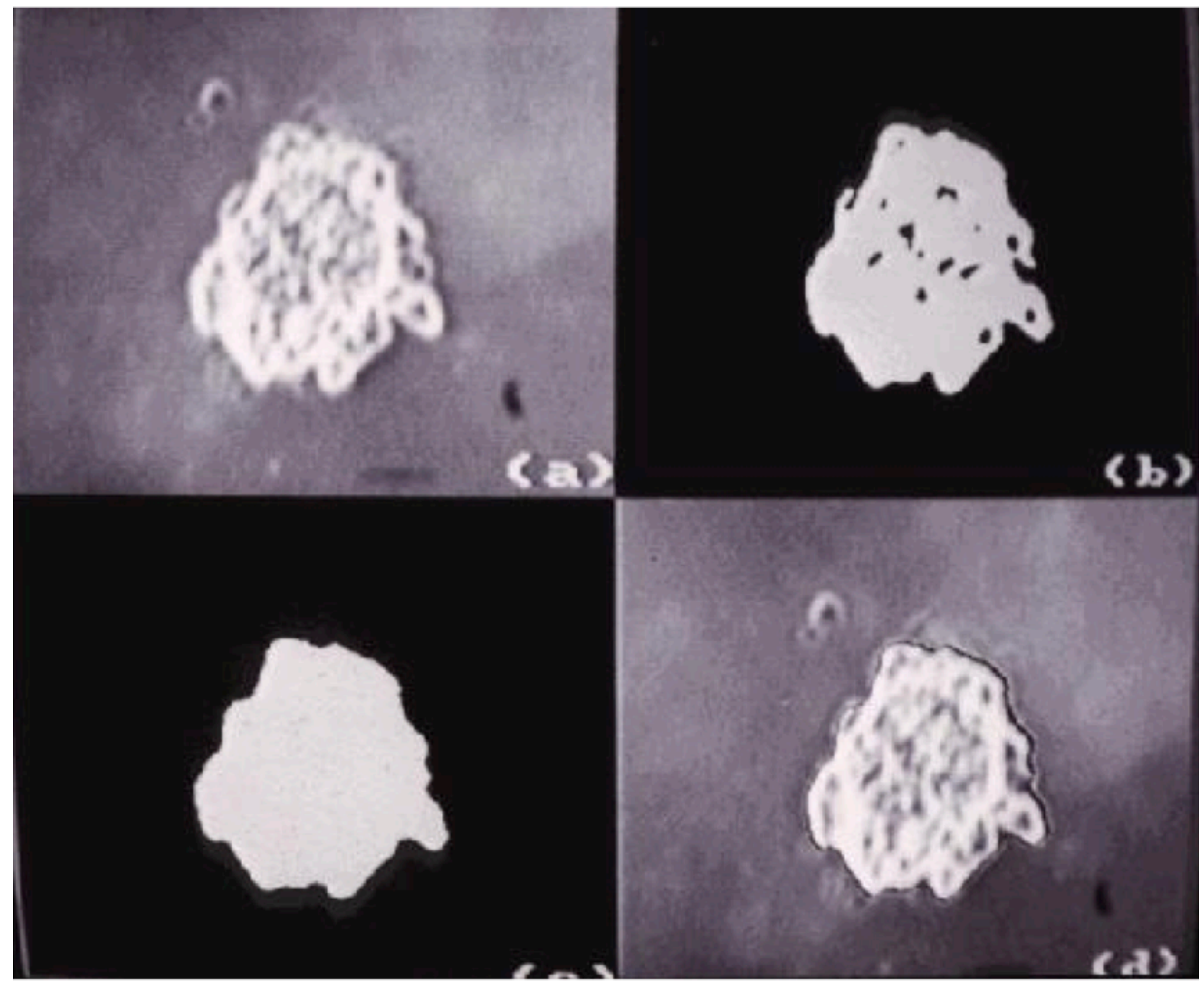
Application

- **Measuring cell area**
- Binarise image using thresholding
- Apply region correction
  - Blob colouring
  - Minor blob removal
  - CLOS-OPEN
- Display result for verifying operator
- Count pixels for cell area calculation
- True cell area computed using perspective projection



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Summary

- Binary images are a very useful class of gray scale images
- Binary morphology provides techniques for accomplishing several useful tasks