Computer Vision

Ch.6 Morphological Operation

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Introduction of Morphological Operation (1/3)

- **Morphology**

  Denote a branch of biology with the form and structure of animals and plants.

Introduction of Morphological Operation (2/3)

Original

Gray -level

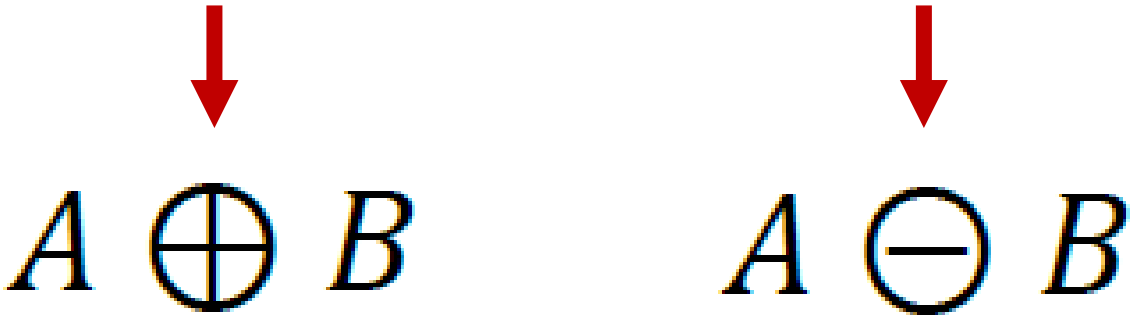
Binarization

- ✓ Otsu Algorithm

Introduction of Morphological Operation (3/3)

Morphological Operation (1/35)

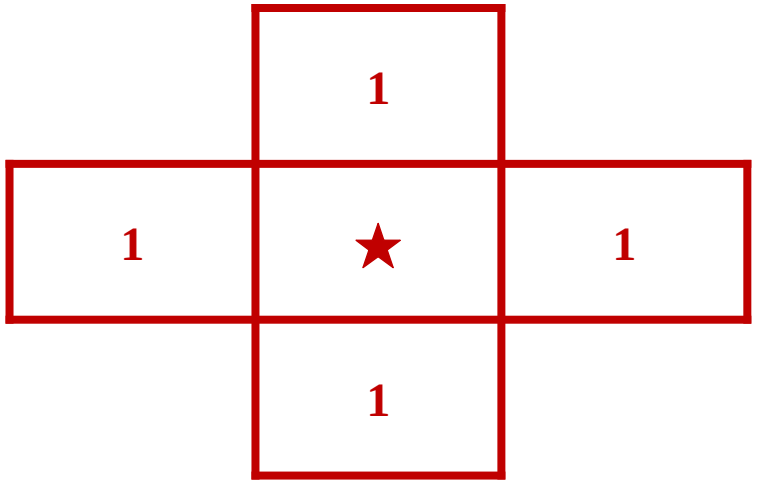
✓ Dilation and Erosion



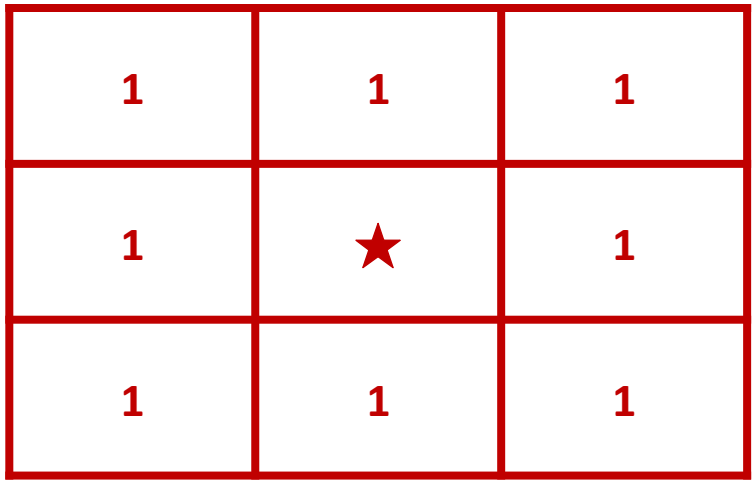
✓ Opening and Closing

Morphological Operation (2/35)

- **Kernel**



4-Connection

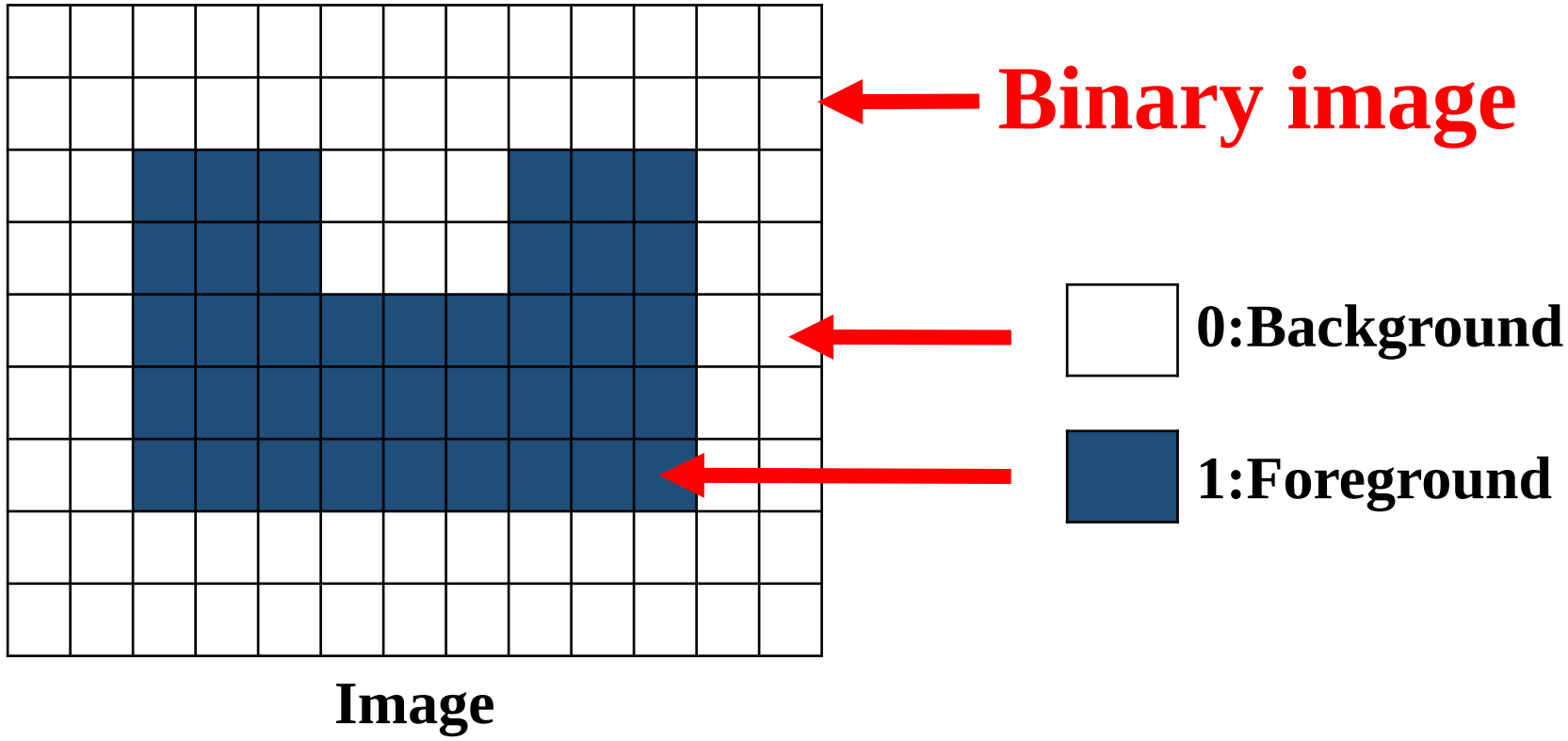


8-Connection

★ **: Anchor**

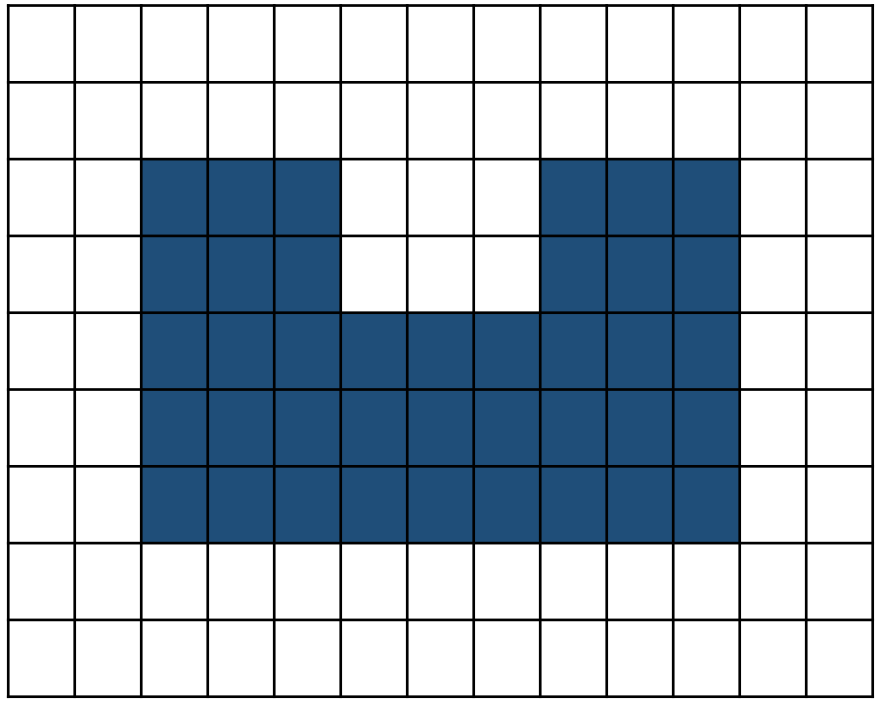
Morphological Operation (3/35)

$A \oplus B$ A : image , B : kernel



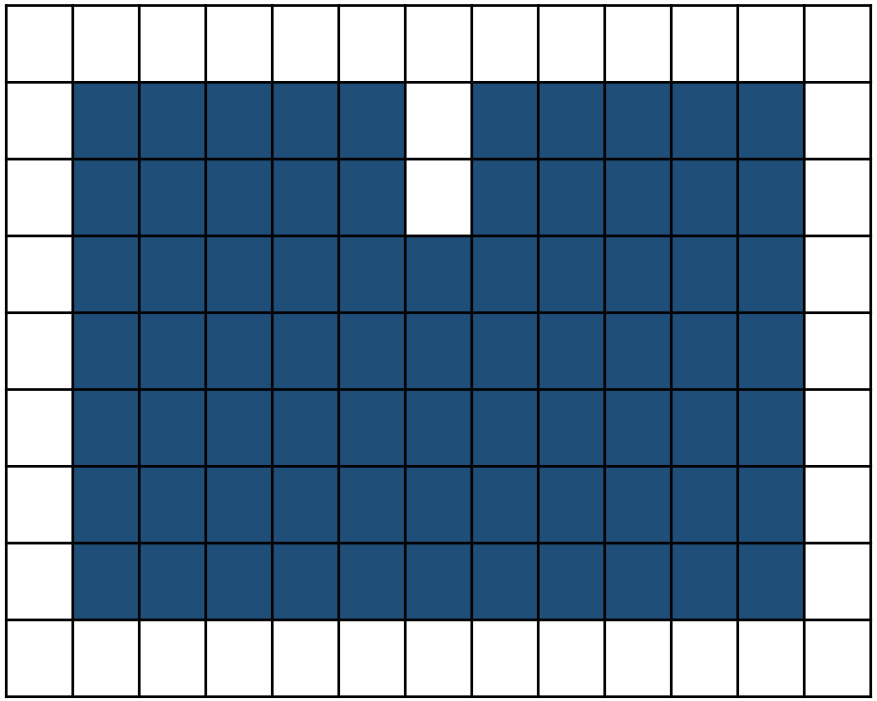
Morphological Operation (4/35)

- **Dilation** $A \oplus B$



Before

*Kernel 3*3*

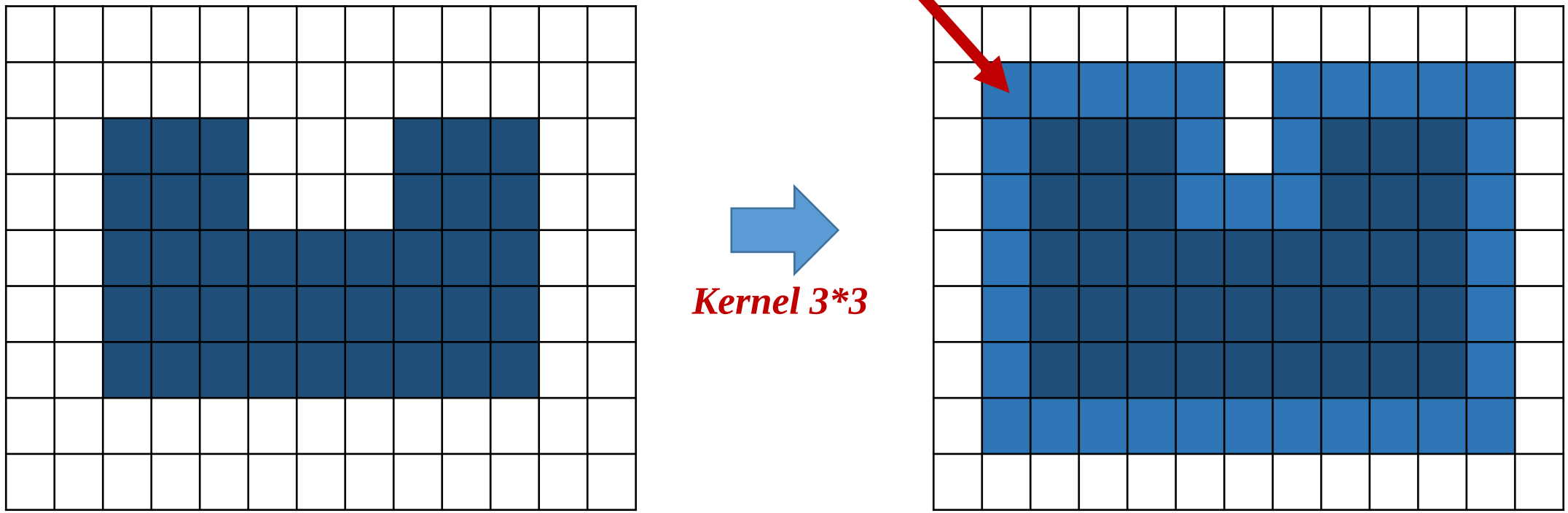


After

Morphological Operation (5/35)

- **Dilation** $A \oplus B$

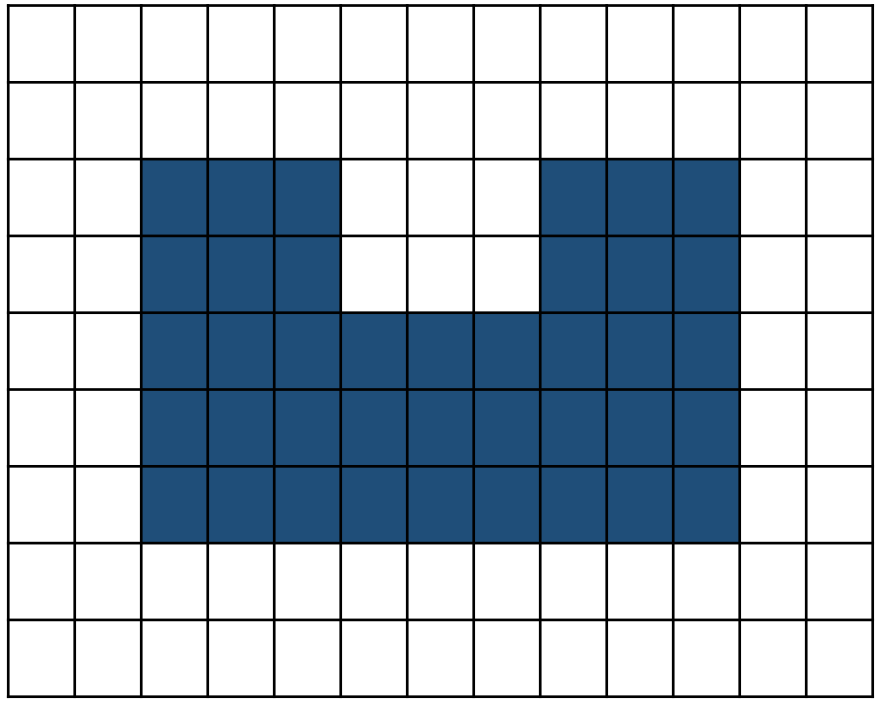
Surround the original object.



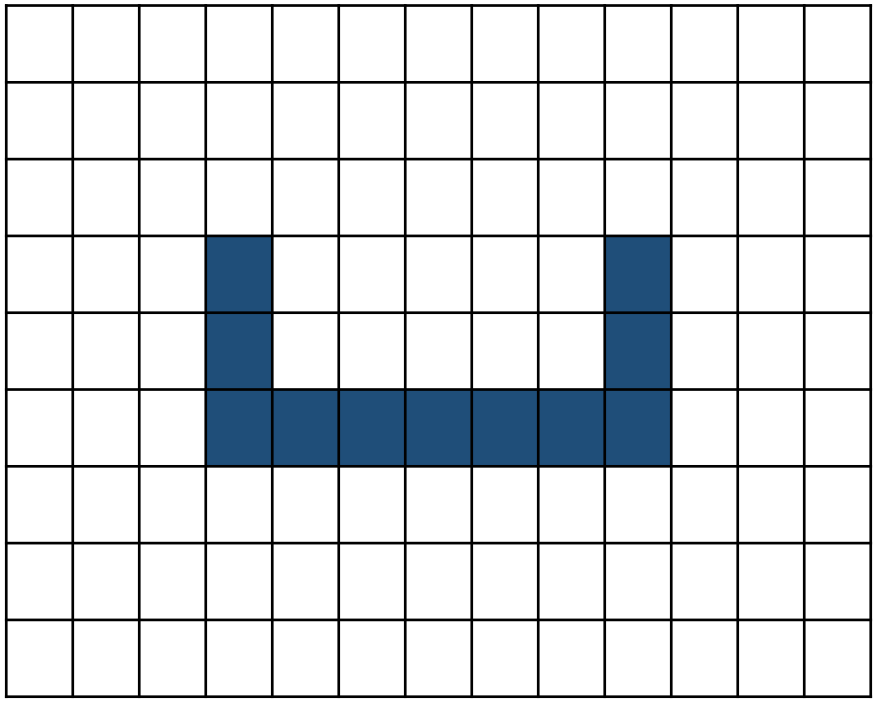
Before **After**

Morphological Operation (6/35)

- **Erosion** $A \ominus B$



*Kernel 3*3*

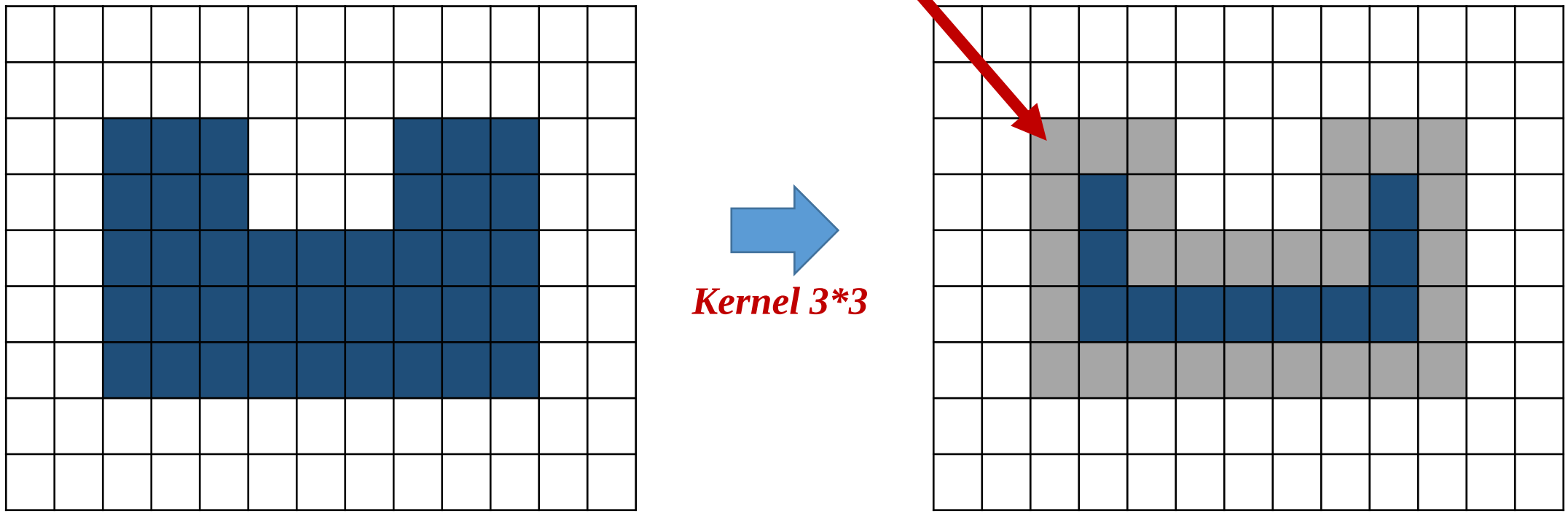


Before **After**

Morphological Operation (7/35)

- **Erosion** $A \ominus B$

Eliminate boundary of the original object.



Before **After**

Morphological Operation (8/35)

- **Two basic morphological operations**

Dilation takes **maximum** under the kernel region.

$A \oplus B$

$$\texttt{dst}(x,y) = \max_{(x',y'):\, \texttt{element}(x',y') \neq 0} \texttt{src}(x+x', y+y')$$

Erosion takes **minimum** under the kernel region.

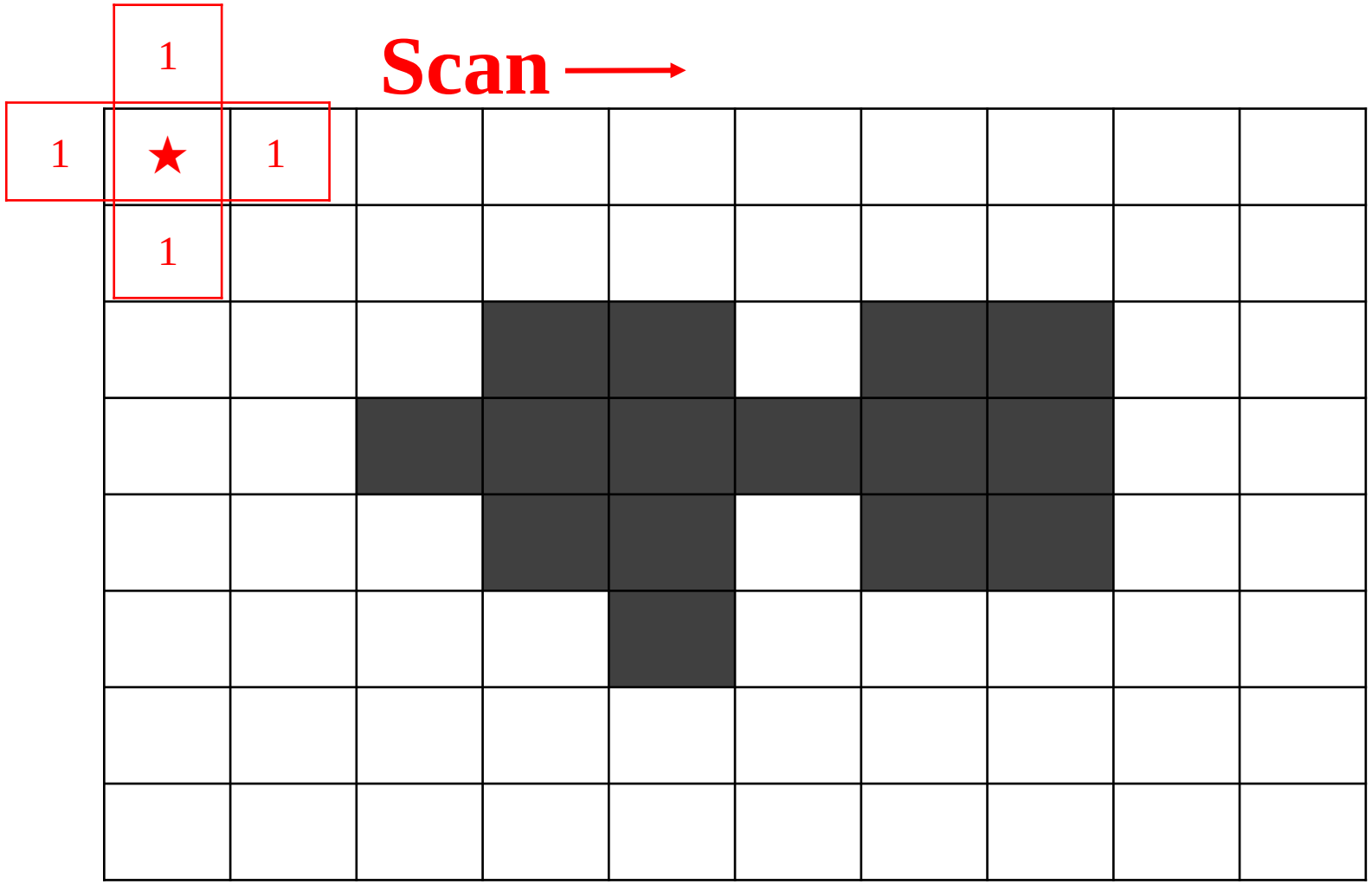
$A \ominus B$

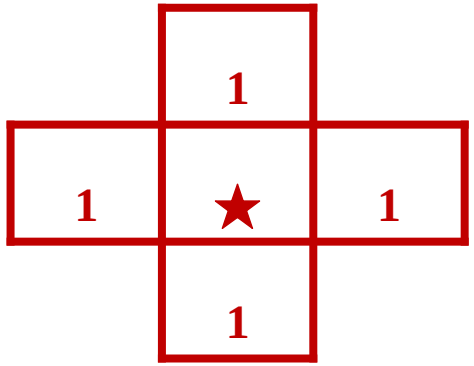
$$\texttt{dst}(x,y) = \min_{(x',y'):\, \texttt{element}(x',y') \neq 0} \texttt{src}(x+x', y+y')$$

Morphological Operation (9/35)

Morphological Operation (10/35)

- **Dilation** $A \oplus B$





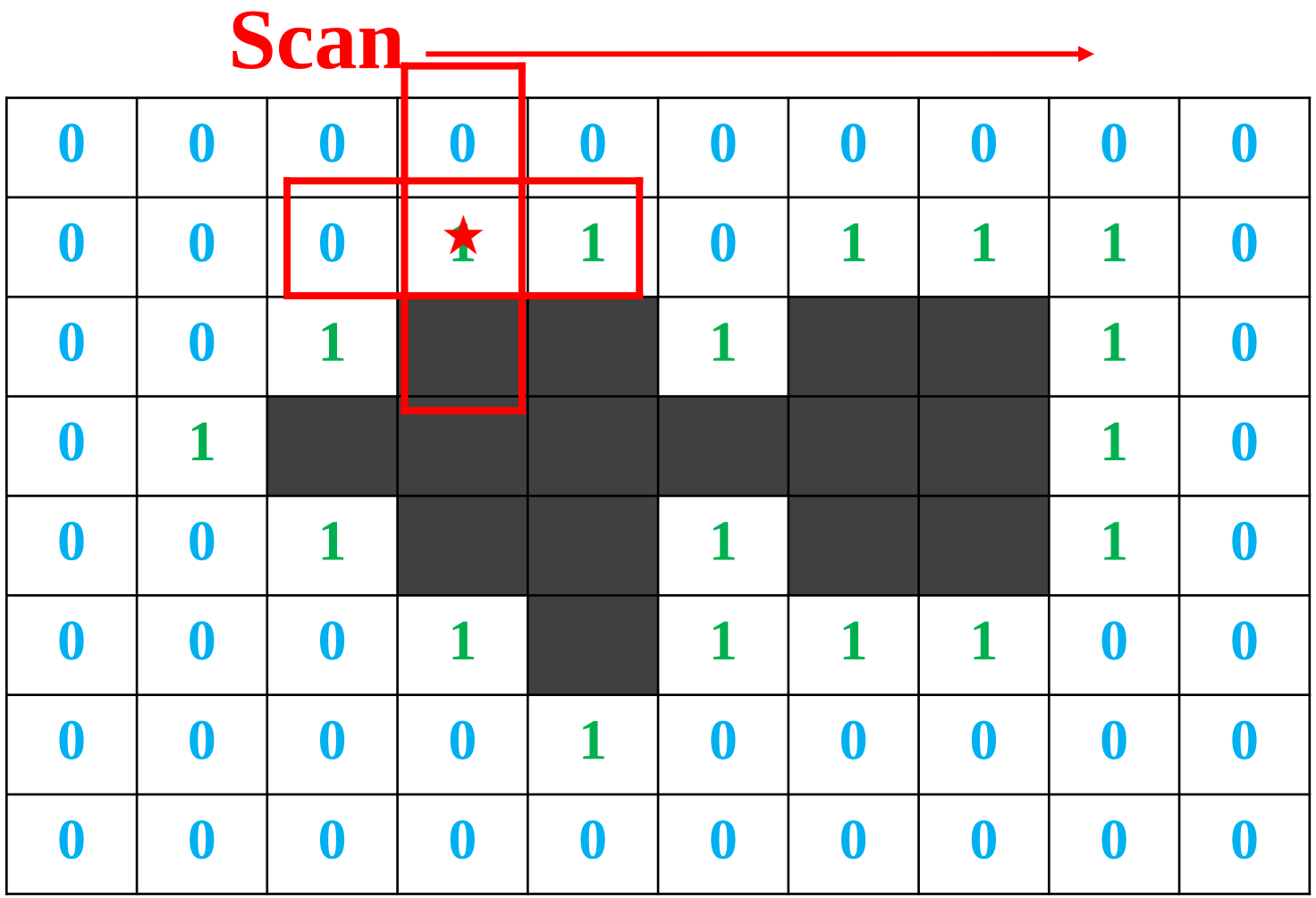
4-Connection

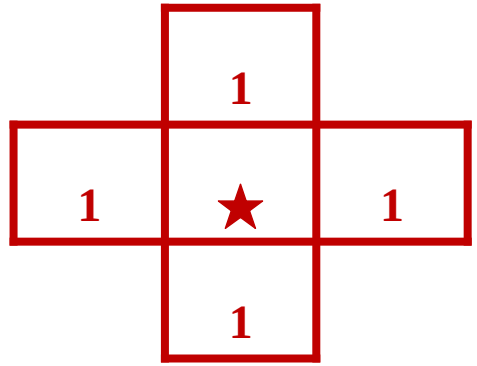
0:Background

1:Foreground

Morphological Operation (11/35)

- **Dilation** $A \oplus B$





4-Connection

0:Background

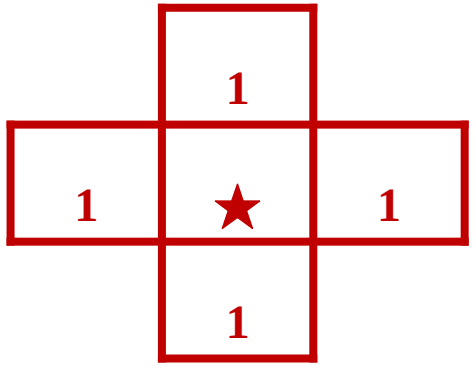
1:Foreground

Morphological Operation (12/35)

➢ Dilation $A \oplus B$

Scan →

0	0	0	0	0	0	0	0	0	0
0	0	0	1	1	0	1	1	1	0
0	0	1			1			1	0
0	1							1	0
0	0	1			1			1	0
0	0	0	1		1	1	1	0	0
0	0	0	0	1	0	0	0	0	0
0	0	0	0	0	0	0	0	0	★



4-Connection

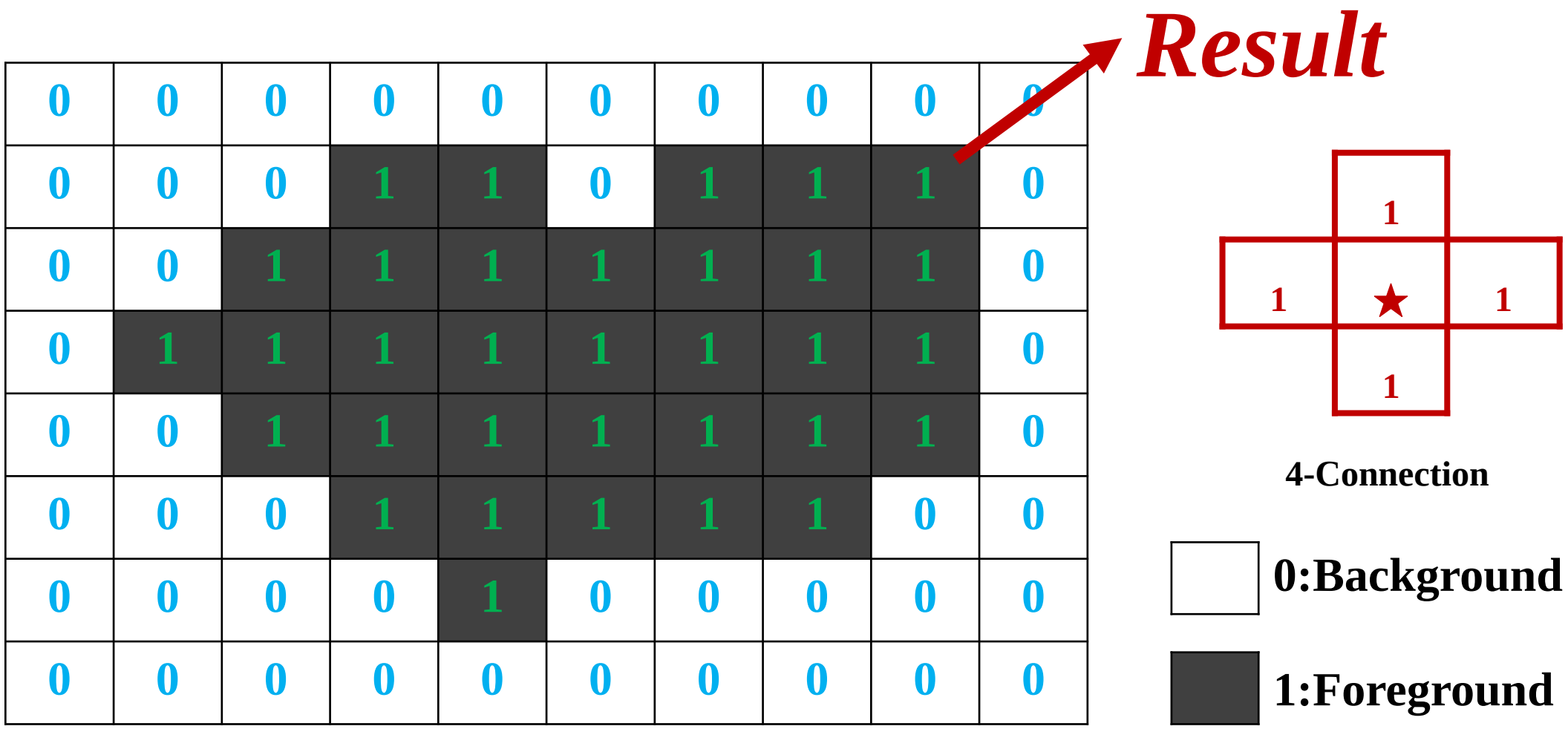
0:Background

1:Foreground

Morphological Operation (13/35)

- **Dilation** $A \oplus B$

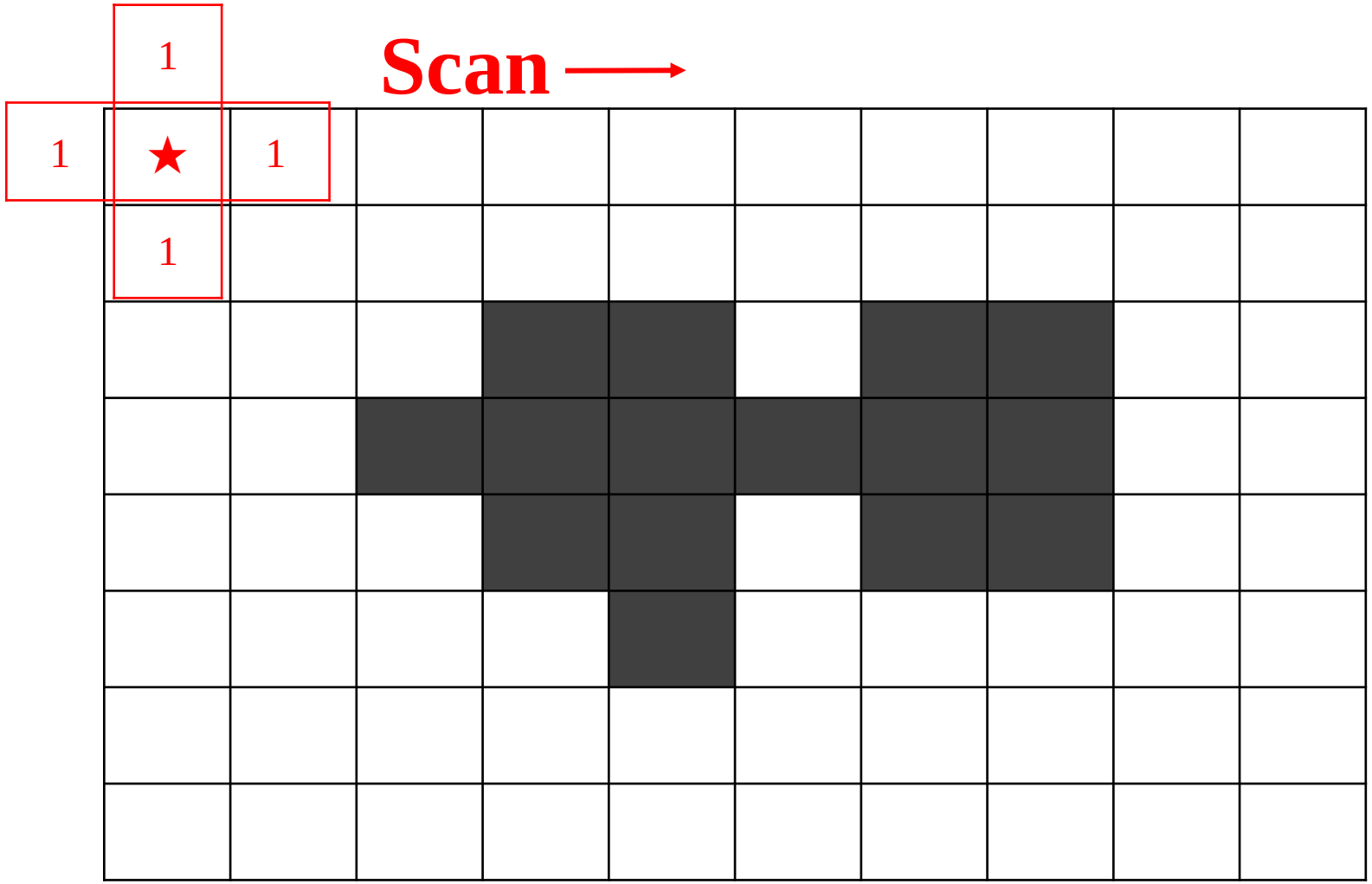
0	0	0	0	0	0	0	0	0	0
0	0	0	1	1	0	1	1	1	0
0	0	1	1	1	1	1	1	1	0
0	1	1	1	1	1	1	1	1	0
0	0	1	1	1	1	1	1	1	0
0	0	0	1	1	1	1	1	0	0
0	0	0	0	1	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0

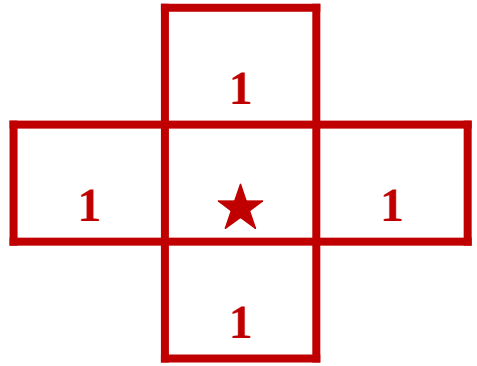


Morphological Operation (14/35)

Morphological Operation (15/35)

- **Erosion** $A \ominus B$





4-Connection

0:Background

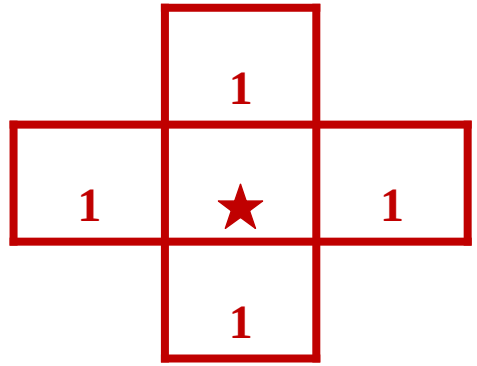
1:Foreground

Morphological Operation (16/35)

➢ Erosion

Scan →

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



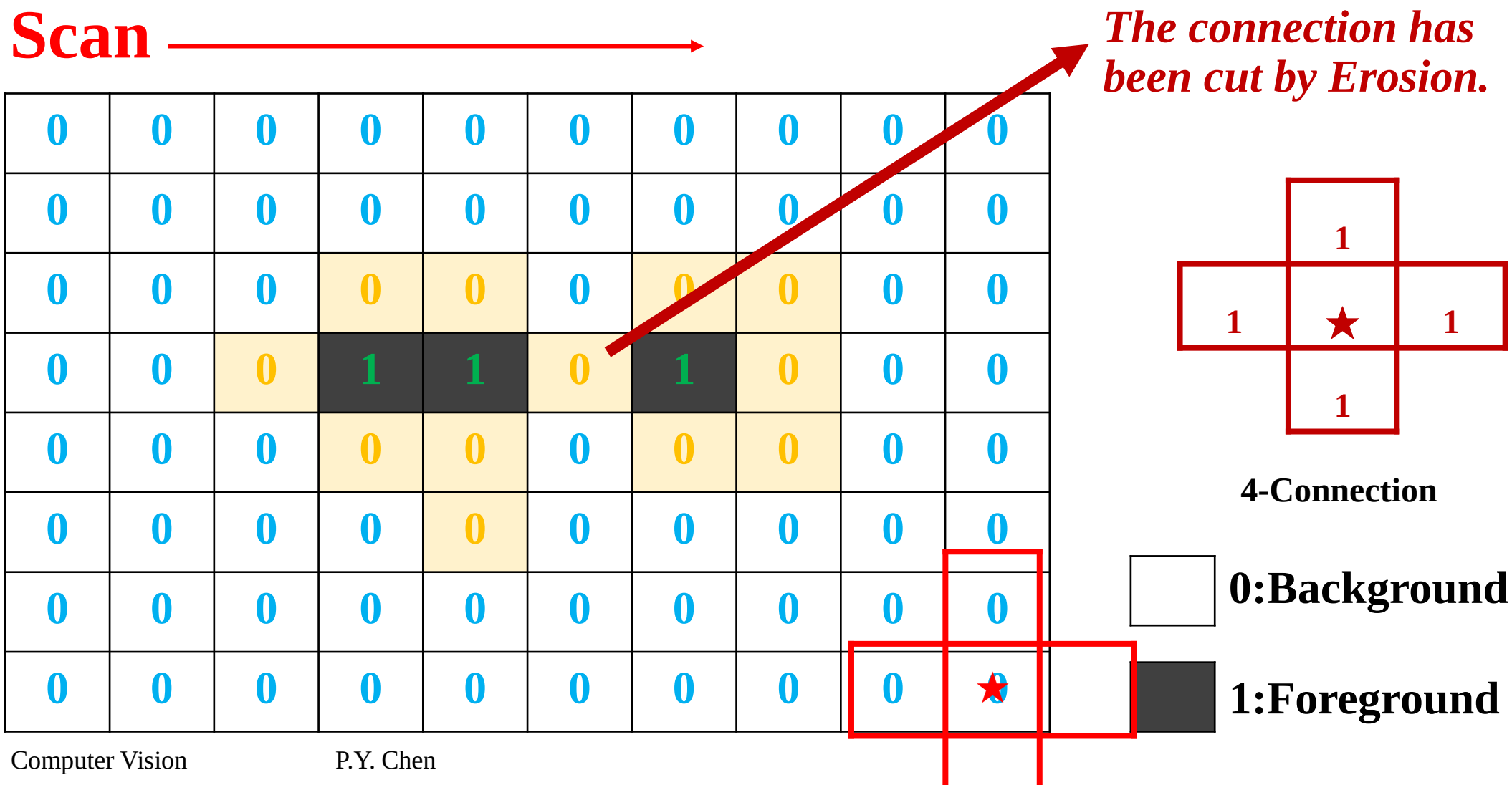
4-Connection

0:Background

1:Foreground

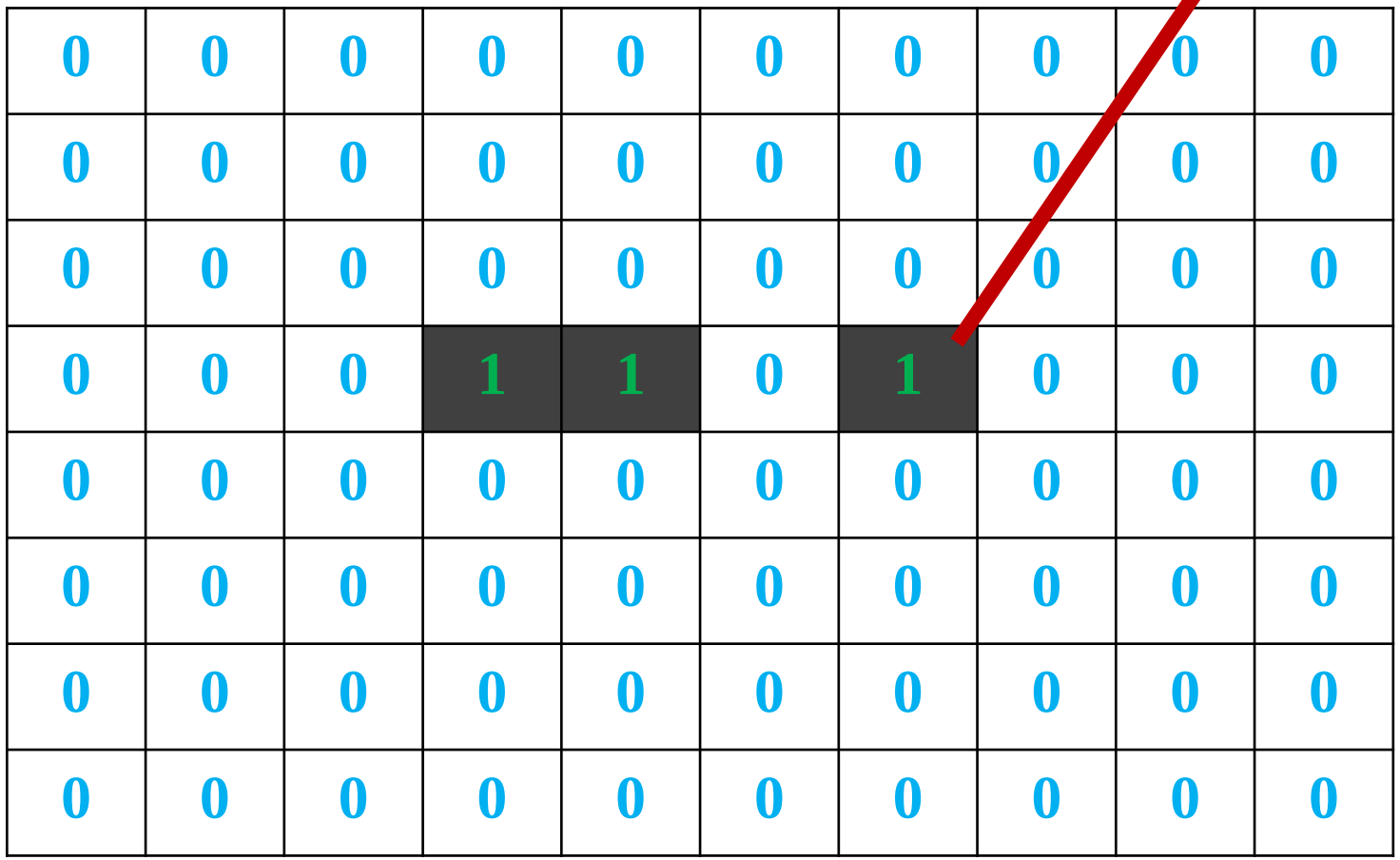
Morphological Operation (17/35)

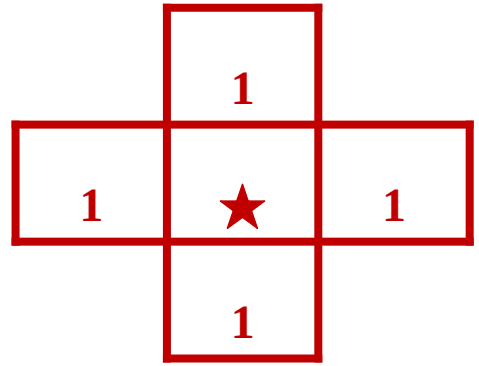
➢ Erosion



Morphological Operation (18/35)

➢ Erosion





4-Connection

0:Background

1:Foreground

Morphological Operation (19/35)

- **Header**

```
#include <opencv2/opencv.hpp>
#include <opencv2/core/core.hpp>

#include "opencv2/imgproc.hpp"
```

Morphological Operation (21/35)

- **Dilation's code**

Syntax:

dilate(src, dst, kernel) ✓ Simplified code

src − A **Mat** object representing the source (input image) for this operation.
dst − A **Mat** object representing the destination (output image) for this operation.
kernel − A **Mat** object representing the kernel. (Default 3*3)

Morphological Operation (20/35)

- **Dilation's code**

Syntax:

Mat()

dilate(src, dst, kernel, anchor, iterations)

src − A **Mat** object representing the source (input image) for this operation.
dst − A **Mat** object representing the destination (output image) for this operation.
kernel − A **Mat** object representing the kernel. (Default 3*3)
anchor − Position of the anchor within the element;
Default value (-1, -1) means that the anchor is at the element center.
iterations − Number of times which the operation is applied.

Morphological Operation (22/35)

- **Erosion's code**

Syntax:

Mat()

```
erode(src, dst, kernel, anchor, iterations)
```

src − A **Mat** object representing the source (input image) for this operation.
dst − A **Mat** object representing the destination (output image) for this operation.
kernel − A **Mat** object representing the kernel. (Default 3*3)
anchor − Position of the anchor within the element;
Default value (-1, -1) means that the anchor is at the element center.
iterations − Number of times which the operation is applied.

Morphological Operation (23/35)

- **Erosion's code**

Syntax:

erode(src, dst, kernel) ✓ Simplified code

src − A **Mat** object representing the source (input image) for this operation.
dst − A **Mat** object representing the destination (output image) for this operation.
kernel − A **Mat** object representing the kernel. (Default 3*3)

Give it a try:
https://docs.opencv.org/master/d4/d76/tutorial_js_morphological_ops.html

Morphological Operation (24/35)

➢ Threshold (Review)

Syntax:

Binarizaition maximum

threshold(Input-Array, Output-Array, double thresh, double maxval, type)

Input Image *Output Image* *Threshold* *Operating type*

THRESH_BINARY
THRESH_BINARY_INV
THRESH_TRUNC
THRESH_TOZERO
THRESH_TOZERO_INV

Morphological Operation (25/35)

➢ Demo code

Example:

```
int main() {
Mat src = imread("D:/Data.jpg");
// Must be GrayLevel image.
Mat src2;
threshold(src, src2, 120, 255, THRESH_BINARY);
// Set up the binarization value

Mat dst1,dst2;

erode(src2, dst1, Mat());
dilate(src2, dst2, Mat());
imshow("Original", src2);
imshow("Erode", dst1);
imshow("Dilate", dst2);

waitKey(0);

return 0;
}
```

Morphological Operation (26/35)

- getStructuringElement
  - ✓ Returns a structuring element of the specified size and shape for morphological operations.
  - ✓ Kernel can be created using getStructuringElement.

Syntax: getStructuringElement(shape, ksize, anchor)

shape − Element shape : MORPH_RECT
MORPH_CROSS
MORPH_ELLIPSE
CV_SHAPE_CUSTOM

ksize − Element size.

anchor − Position within the element. The default value(-1,-1).

Morphological Operation (27/35)

- getStructuringElement

Type of shape :

MORPH_RECT – A rectangular structuring element $E_{ij} = 1$

MORPH_CROSS – a cross-shaped structuring element:

$$E_{ij} = \begin{cases} 1 & \text{if } i=\texttt{anchor.y} \text{ or } j=\texttt{anchor.x} \\ 0 & \text{otherwise} \end{cases}$$

MORPH_ELLIPSE – An elliptic structuring element, that is, a filled ellipse inscribed into the rectangle *Rect(0, 0, esize.width, esize.height)*.

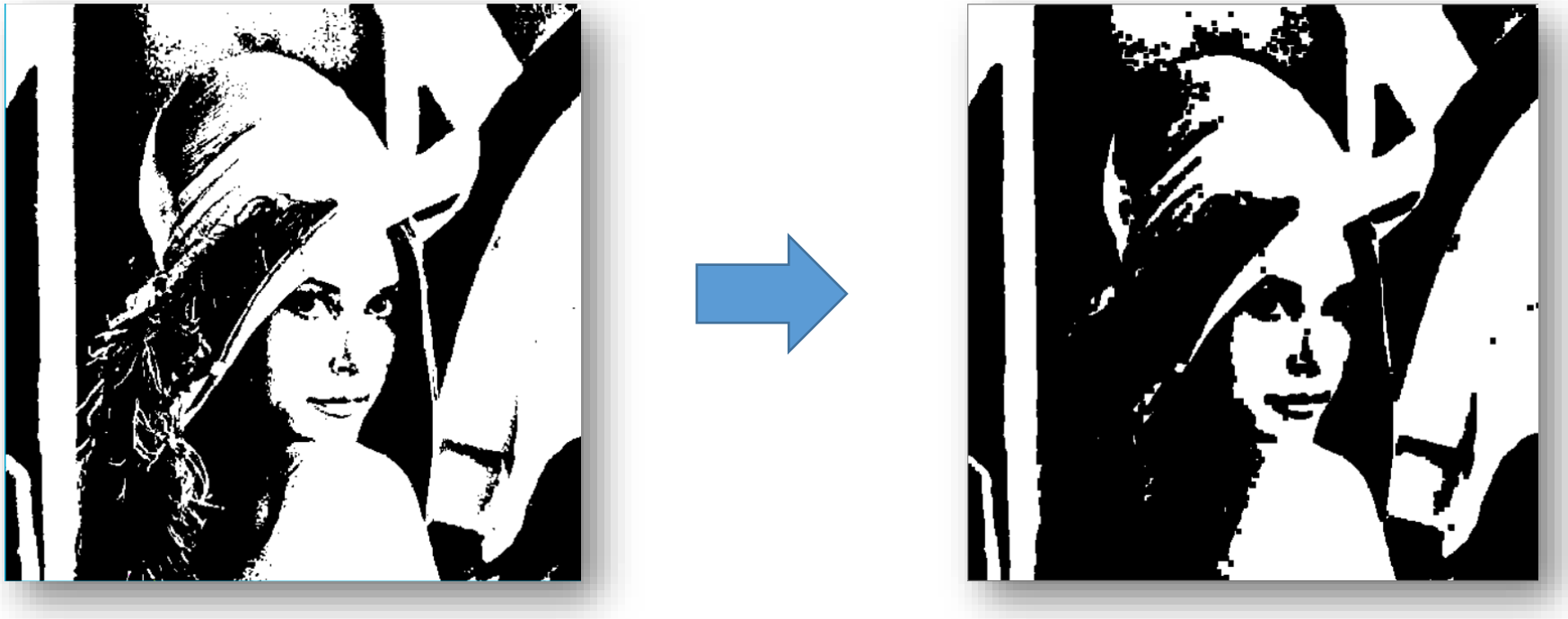
CV_SHAPE_CUSTOM –custom structuring element (OpenCV 1.x API)

Morphological Operation (28/35)

- **Demo code**

```
Mat erodeStruct = getStructuringElement(MORPH_RECT, Size(5, 5));
erode(src2, dst3, erodeStruct);

imshow("Erode by Structure", dst3);
```



Demo

Morphological Operation (29/35)

Opening and Closing

Morphological Operation (30/35)

- **Opening**
  - ✓ Erosion then Dilation

Def:

$$\text{Open}(src) = \text{Dilate}(\text{Erode}(src))$$

$$A \circ B = (A \ominus B) \oplus B$$

Morphological Operation (31/35)

- **Closing**

  - ✓ Dilation then Erosion

Def:

$$\text{Close}(src) = \text{Erode}(\text{Dilate}(src))$$

$$A \cdot B = (A \oplus B) \ominus B$$

Morphological Operation (32/35)

- **Advanced research**

Fingerprint

Source: Morphological Operation - Chen Hua-Tsung

Morphological Operation (33/35)

- **Advanced research**
  - Remove the outer noise.

Step1. Erosion $A \ominus B$

Step2. Dilation $A \oplus B$

$A \circ B$

Opening

Morphological Operation (34/35)

- **Advanced research**
  - Remove the inner noise.

Step3. Dilation $A \oplus B$

Step4. Erosion $A \ominus B$

$A \cdot B$

Closing

Morphological Operation (35/35)

- **Advanced research**

Before

After

Exercise #3

Image Source: Pixabay - Fingerprints

Please try to give a clear fingerprint for any fingerprint's image.

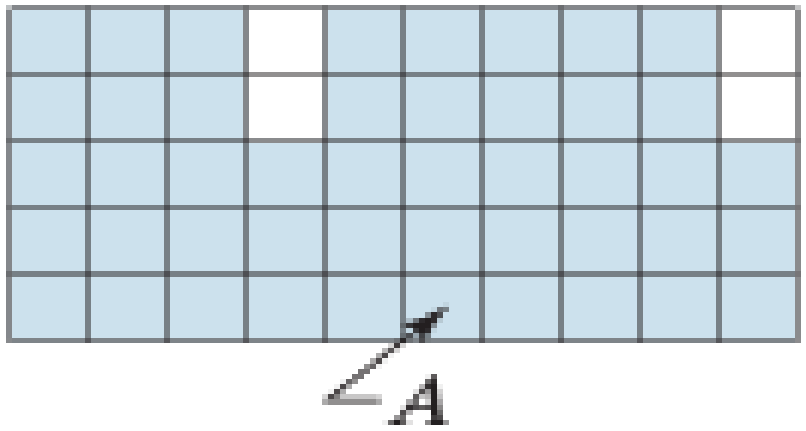
- ✓ **Note:** ****.sln & *.ppt(or *.pptx)*** are necessary and compress in a *.rar file.

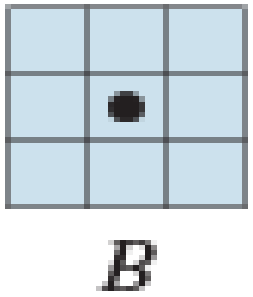
Boundary Extraction

Boundary Extraction (1/3)

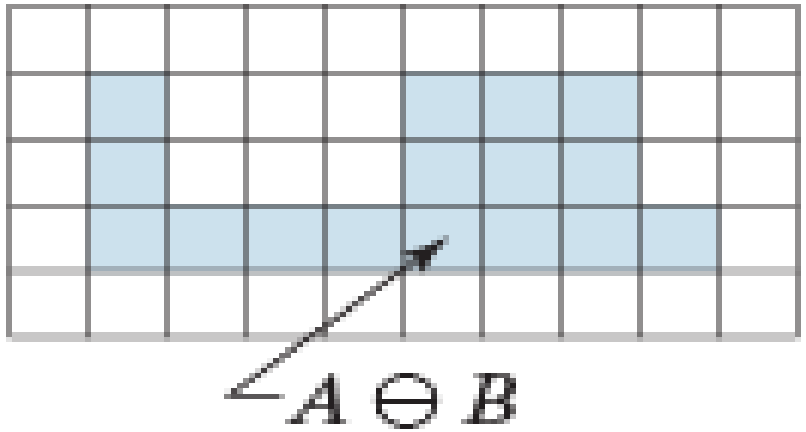
Before After

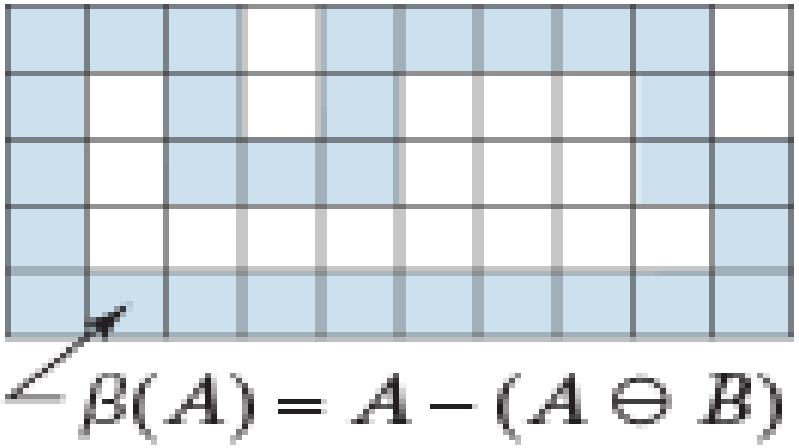
Boundary Extraction (2/3)





- The difference between ***A*** and its erosion forms the boundary.





A: A set of foreground pixels.
B: A structuring element.

Practice

Boundary Extraction (3/3)

Man

Apple

Grayscale Morphological Operation

Grayscale Morphological Operation (1/18)

- **Two basic morphological operations (Review)**

Dilation takes maximum under the kernel region.

$A \oplus B$

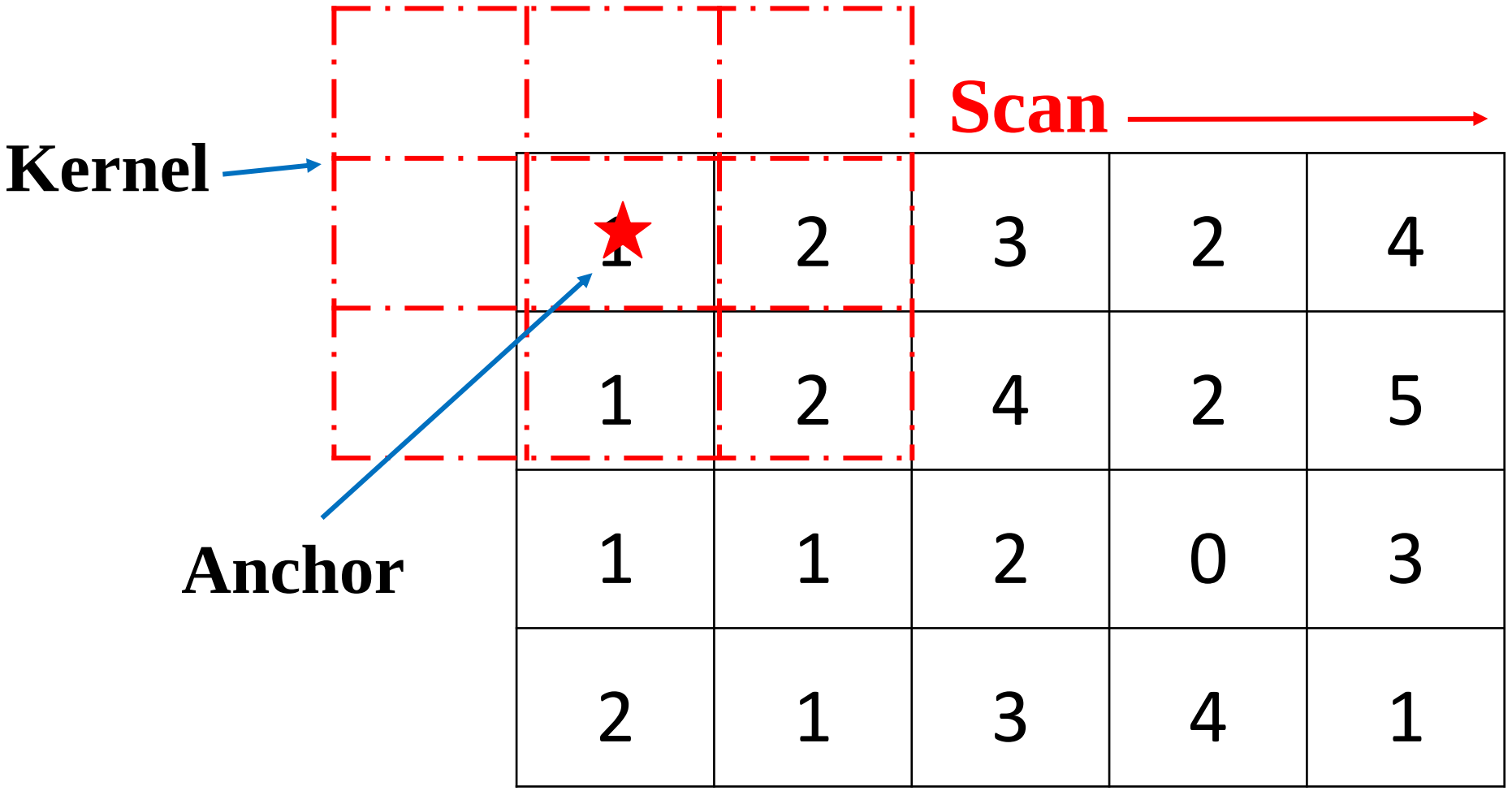
$$\texttt{dst}(x,y) = \max_{(x',y'):\, \texttt{element}(x',y') \neq 0} \texttt{src}(x+x', y+y')$$

Erosion takes minimum under the kernel region.

$A \ominus B$

$$\texttt{dst}(x,y) = \min_{(x',y'):\, \texttt{element}(x',y') \neq 0} \texttt{src}(x+x', y+y')$$

Grayscale Morphological Operation (2/18)

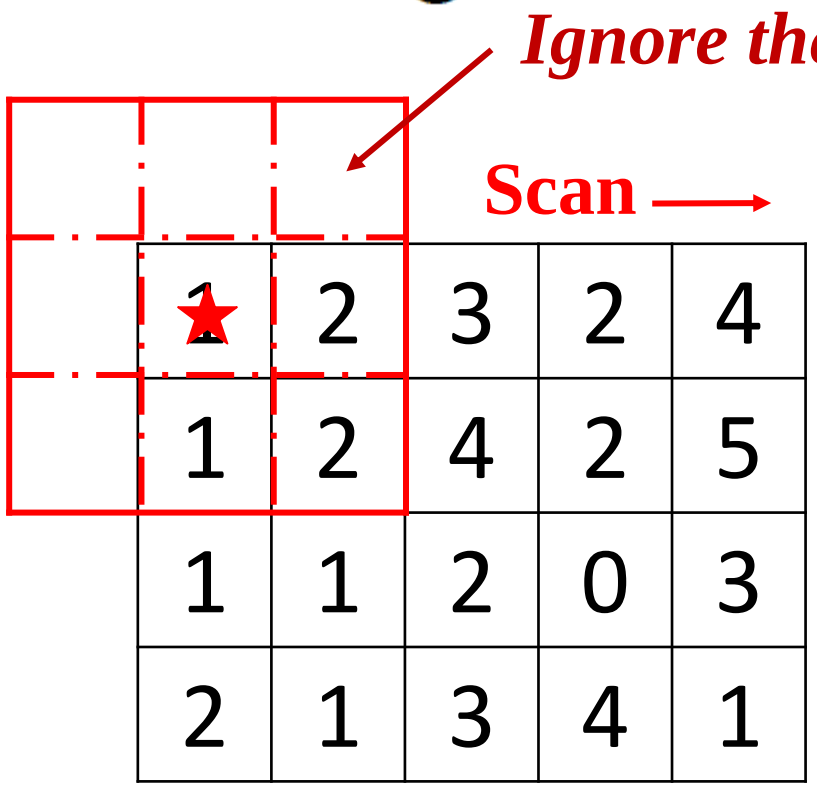


An image of Gray-Level Pixel

Grayscale Morphological Operation (3/18)

Grayscale Morphological Operation (4/18)

- **Dilation** $A \oplus B$



Original Image

2				

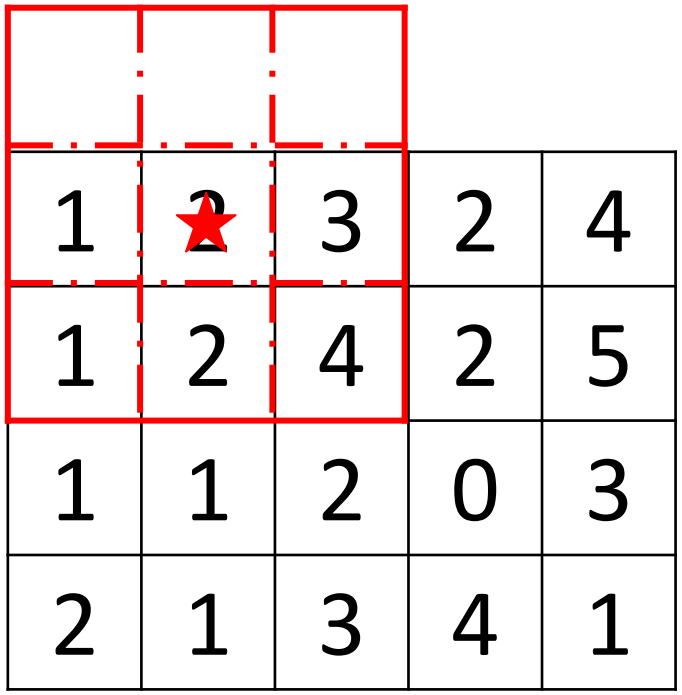
Dilation results

- Anchor pixel is setting to max (= 2)

Grayscale Morphological Operation (5/18)

- **Dilation** $A \oplus B$

Scan →



Original Image

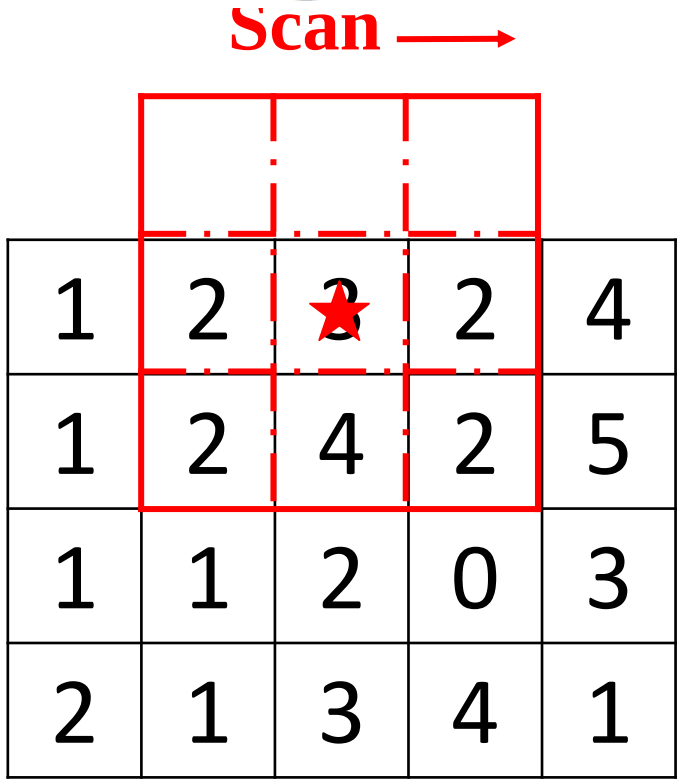
2	4			

Dilation results

- Anchor pixel is setup to max (= 4)

Grayscale Morphological Operation (6/18)

- **Dilation** $A \oplus B$



Original Image

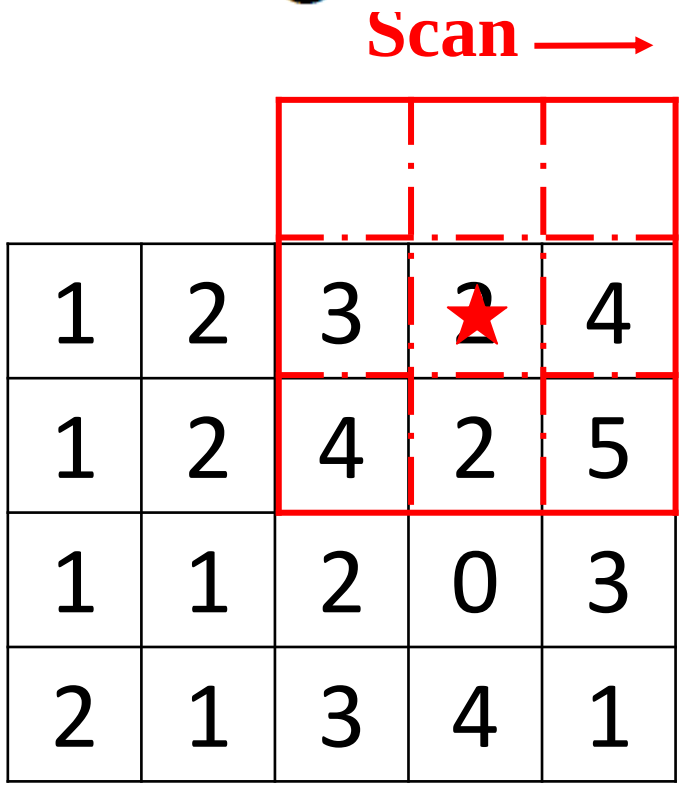
2	4	4		

Dilation results

- Anchor pixel is setup to max (= 4)

Grayscale Morphological Operation (7/18)

- **Dilation** $A \oplus B$



Original Image

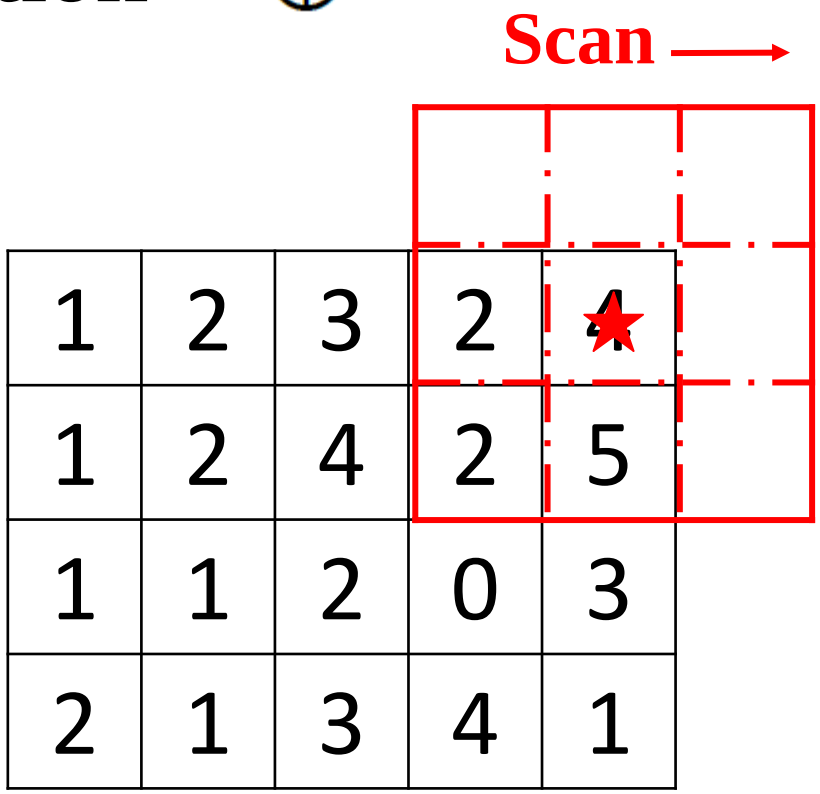
2	4	4	5	

Dilation results

- Anchor pixel is setup to max (= 5)

Grayscale Morphological Operation (8/18)

- **Dilation** $A \oplus B$



Original Image

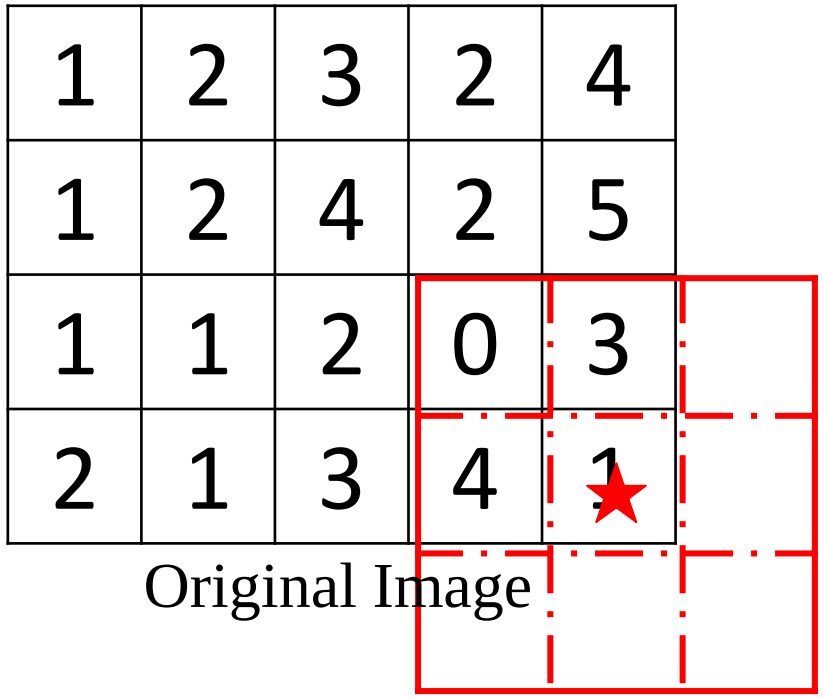
2	4	4	5	5

Dilation results

- Anchor pixel is setup to max (= 5)

Grayscale Morphological Operation (9/18)

- **Dilation** $A \oplus B$



Original Image

2	4	4	5	5
2	4	4	5	5
2	4	4	5	5
2	4	4	4	4

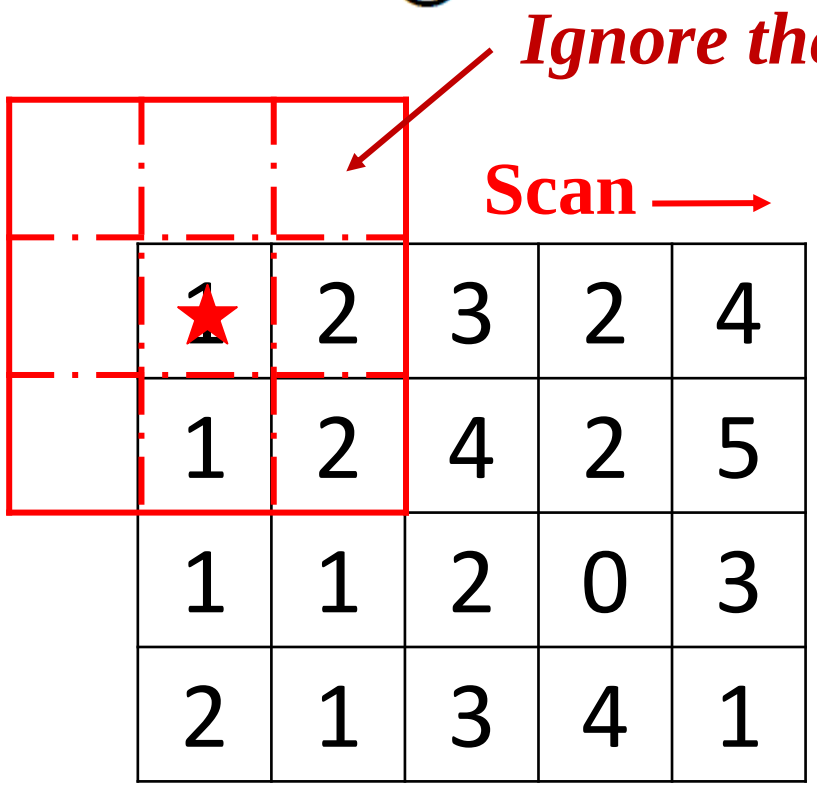
Dilation results

✓ After scanning throughout the image, the result is a grayscale image.

Grayscale Morphological Operation (10/18)

Grayscale Morphological Operation (11/18)

- **Erosion** $A \ominus B$



Original Image

1				

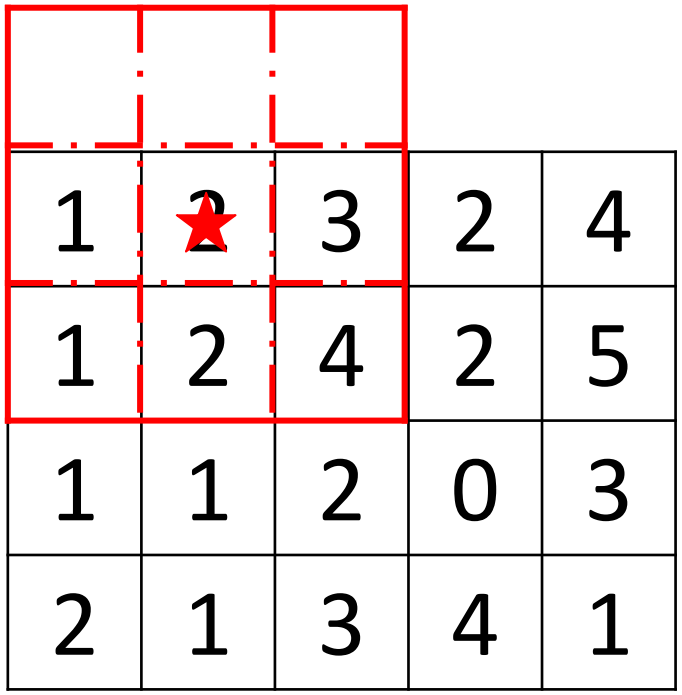
Dilation results

- Anchor pixel is setting to min (= 1)

Grayscale Morphological Operation (12/18)

- **Erosion** $A \ominus B$

Scan →



Original Image

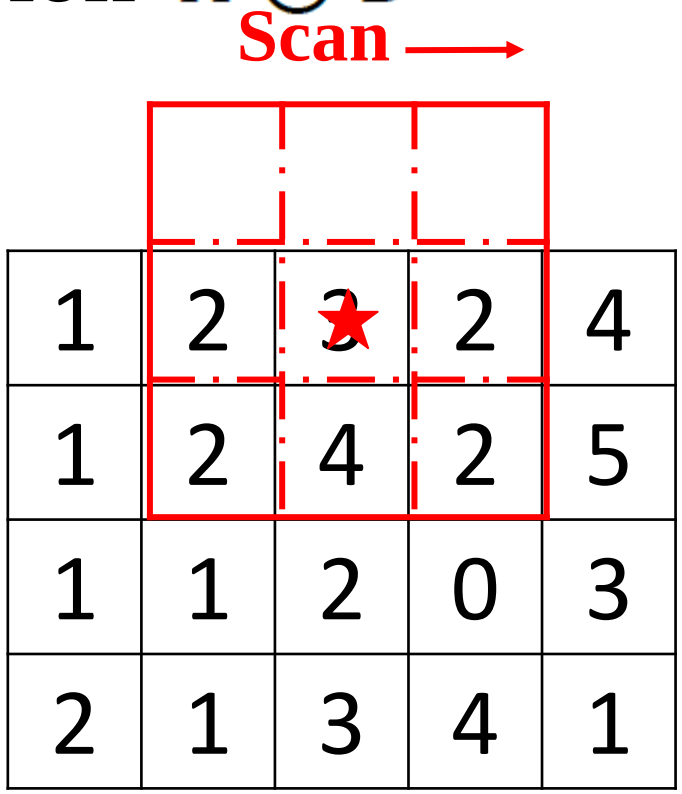
1	1			

Dilation results

- Anchor pixel is setting to min (= 1)

Grayscale Morphological Operation (13/18)

- **Erosion** $A \ominus B$



Original Image

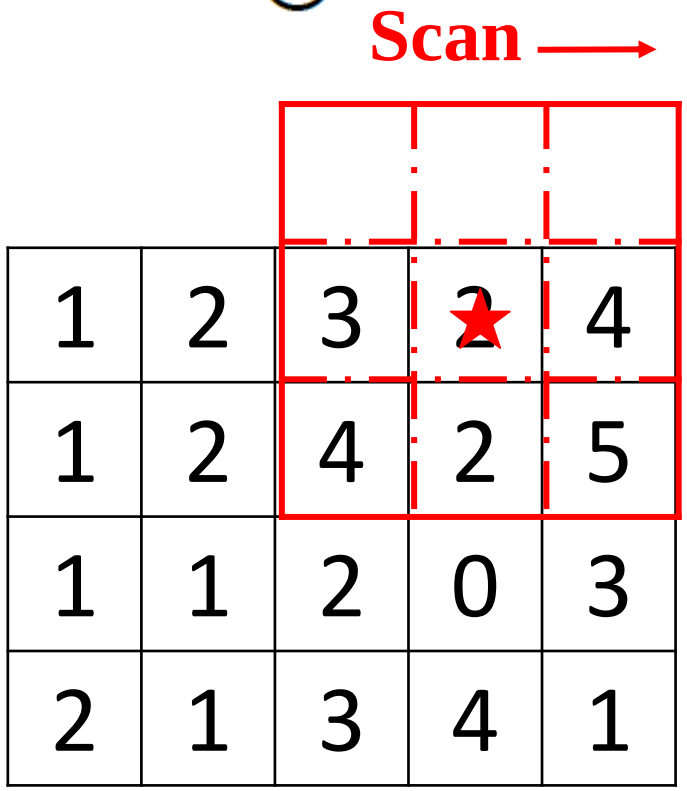
1	1	2		

Dilation results

- Anchor pixel is setting to min (= 2)

Grayscale Morphological Operation (14/18)

- **Erosion** $A \ominus B$



Original Image

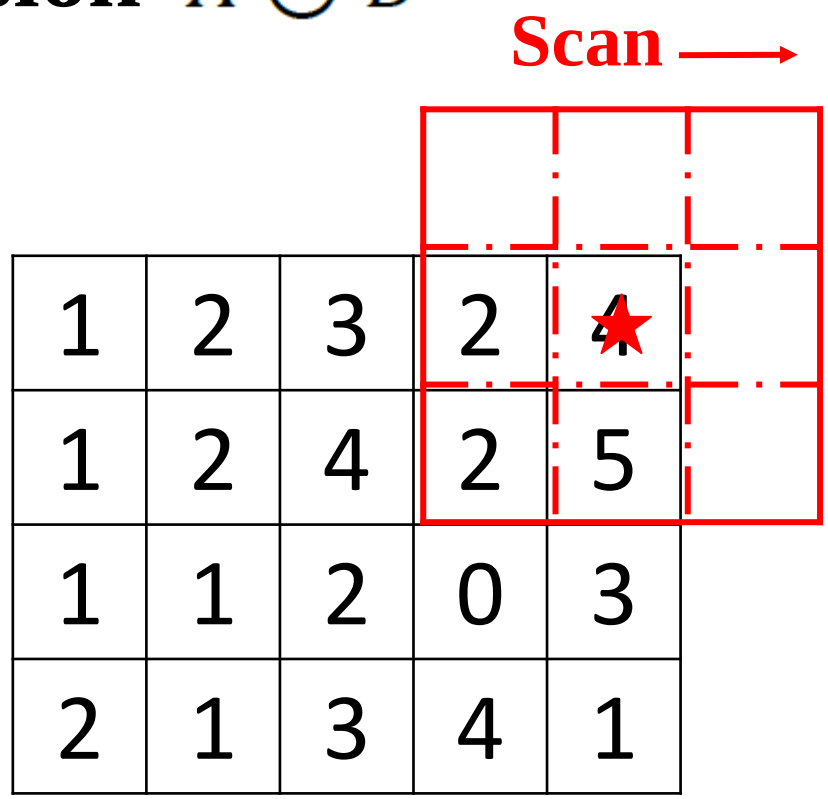
1	1	2	2	

Dilation results

- Anchor pixel is setting to min (= 2)

Grayscale Morphological Operation (15/18)

- **Erosion** $A \ominus B$



Original Image

1	1	2	2	2

Dilation results

- Anchor pixel is setting to min (= 2)

Grayscale Morphological Operation (16/18)

- **Erosion** $A \ominus B$

1	2	3	2	4
1	2	4	2	5
1	1	2	0	3
2	1	3	4	1

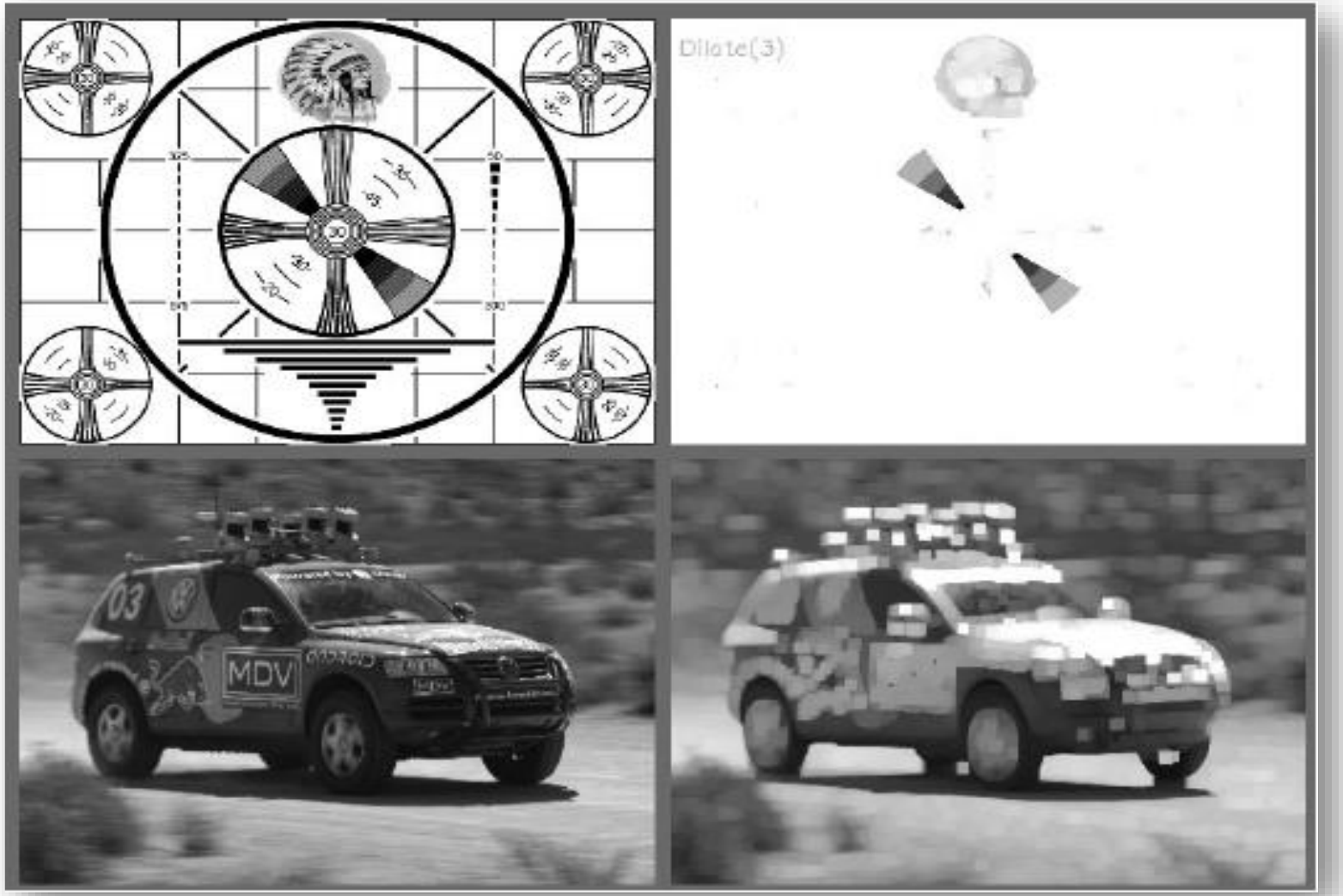
Original Image

1	1	2	2	2
1	1	0	0	0
1	1	0	0	0
1	1	0	0	0

Dilation results

✓ After scanning throughout the image, the result is a grayscale image.

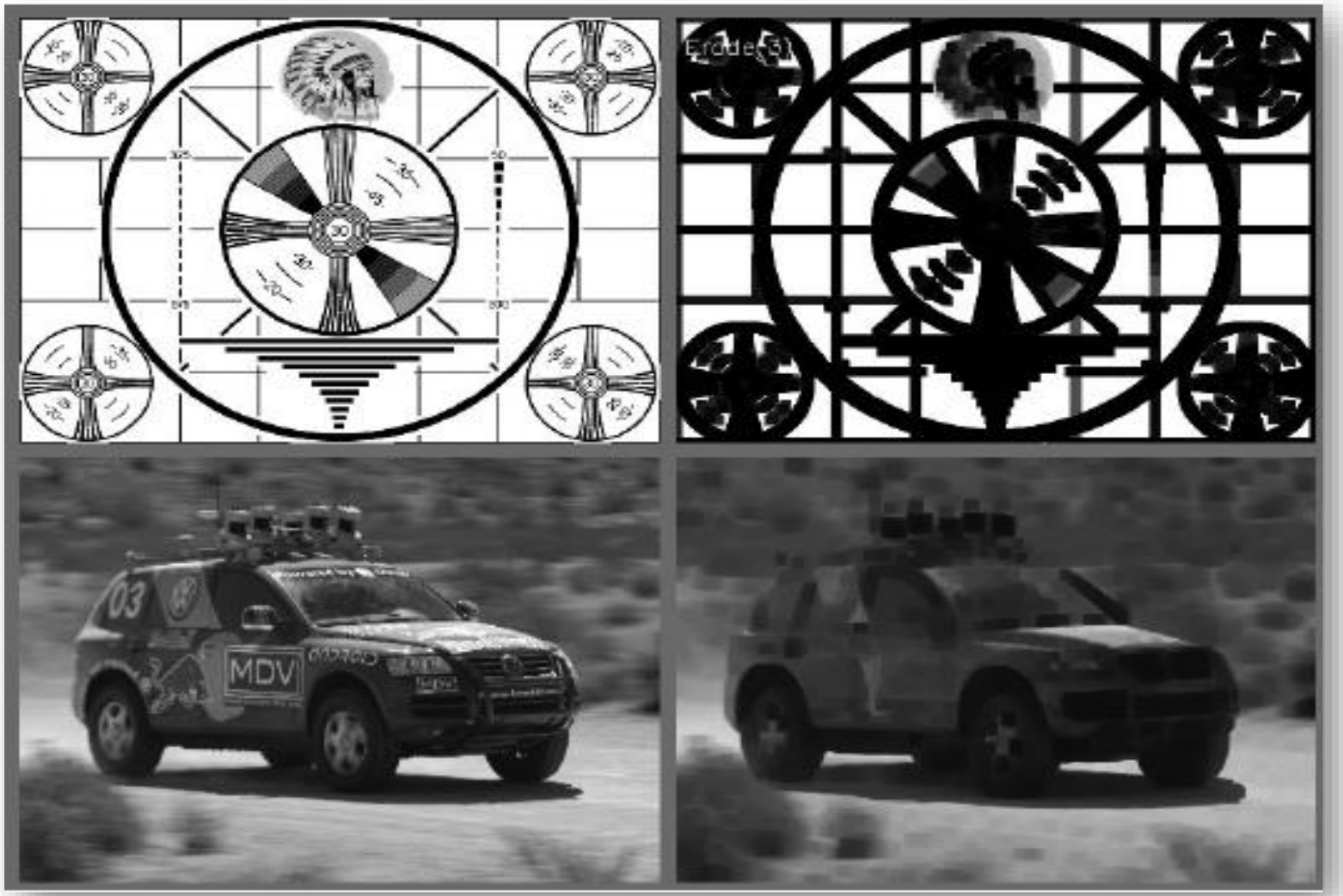
Grayscale Morphological Operation (17/18)



- **Dilation Results in grayscale images.**

- As we can see, many black line and black regions disappear.
- The results looks brighter than before.

Grayscale Morphological Operation (18/18)



- **Erosion Results in grayscale images.**

- The black holes and black lines become bigger.
- So, the image seems darker.

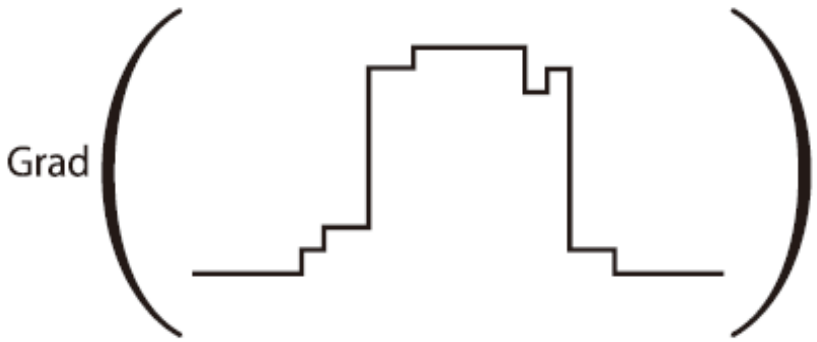
Morphological Gradient (1/4)

$$\text{Gradient(src)} = \text{Dilate(src)} - \text{Erode(src)}$$

- ✓ Dilation and erosion can be used in combination with image subtraction to obtain morphological gradient.
- ✓ Dilation thickens regions in the image, and erosion shrinks them.

Morphological Gradient (2/4)

- Their difference emphasizes the boundaries between regions.



Dilate Erode

Example is used to explain the utility of morphological **gradient.**
The operator has its highest values where grayscale image is changing most rapidly.

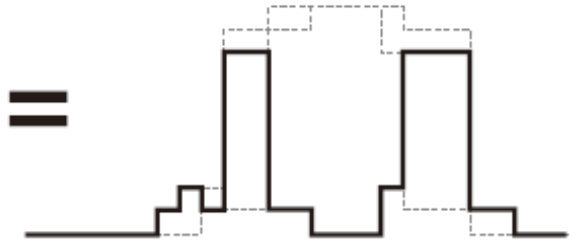
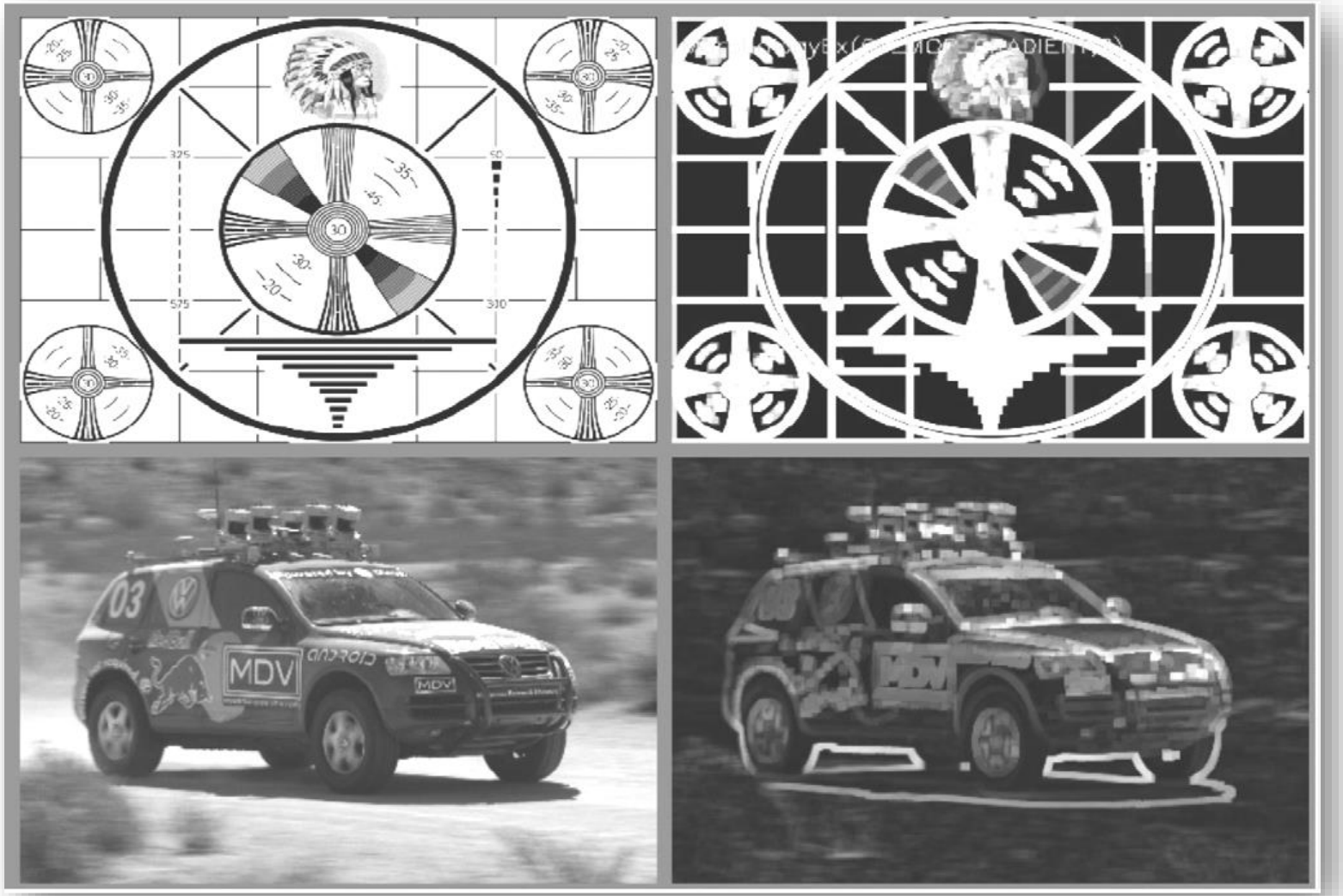


Figure 5-14. Morphological gradient applied to a grayscale image: as expected, the operator has its highest values where the grayscale image is changing most rapidly

Morphological Gradient (3/4)



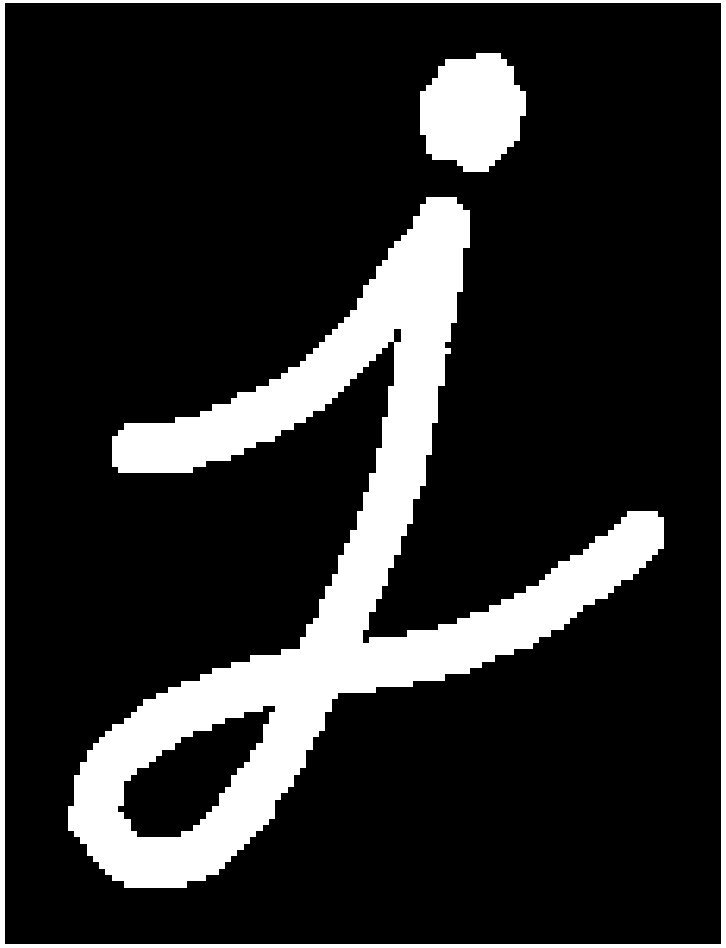
Gradient(src) =
Dilate(src) - Erode(src)

The operator has its highest values where grayscale image is changing most rapidly.

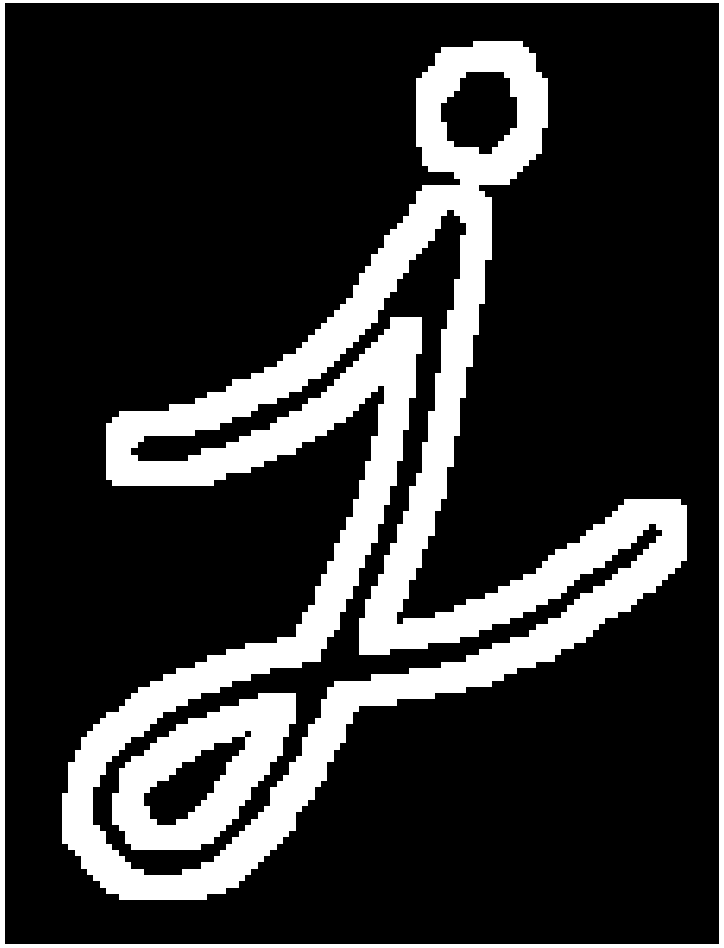
- Bright perimeter edges are identified.

Source: Morphological Operation - Chen Hua-Tsung

Morphological Gradient (4/4)



Before



After

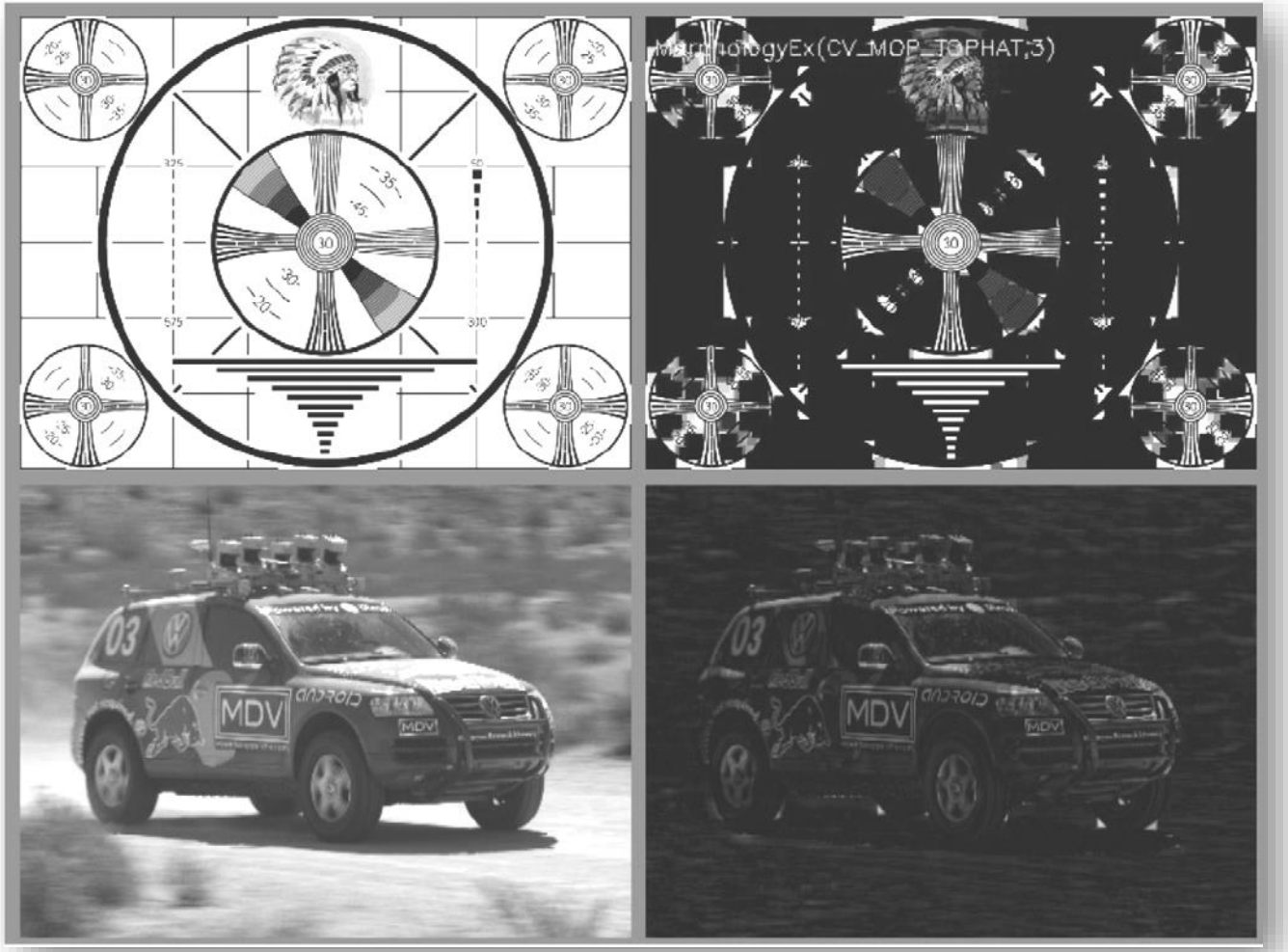
Morphological application methods (1/3)

➢ Top Hat

TopHat(src)

= src – Open(src)

✓ Bright local peaks are isolated.



Source: **Morphological Operation - Chen Hua-Tsung**

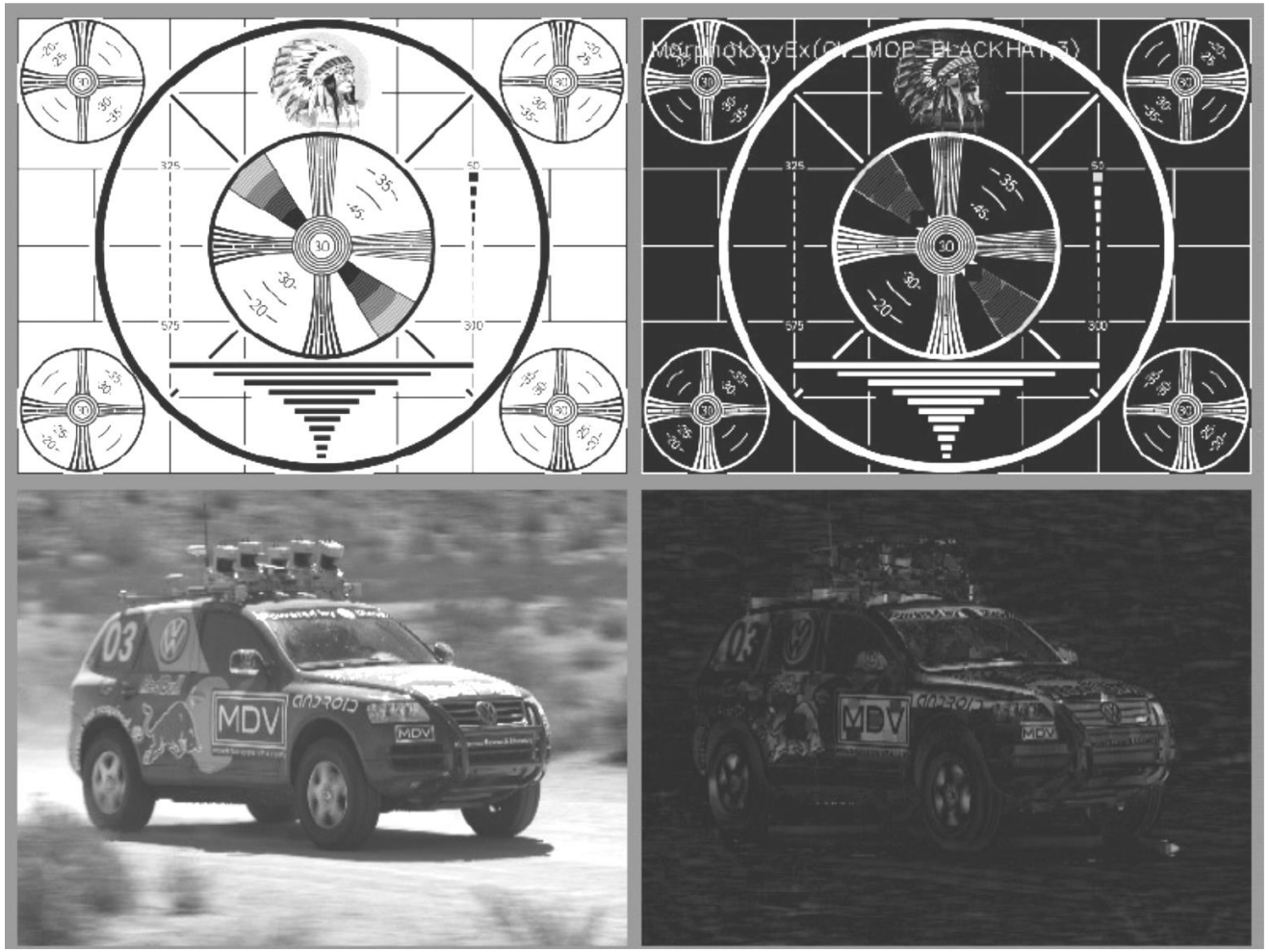
Morphological application methods (2/3)

➢ Black Hat

BlackHat(src)

= Close(src) – src

✓ Dark holes are isolated.



Source: Morphological Operation - Chen Hua-Tsung

Morphological application methods (3/3)

Syntax:

morphologyEx(src, dst, operation, kernel, iterations, borderType, borderValue)

MORPH_OPEN – An opening operation
MORPH_CLOSE – A closing operation
MORPH_GRADIENT – A morphological gradient
MORPH_TOPHAT – "Top Hat"
MORPH_BLACKHAT – "Black Hat"

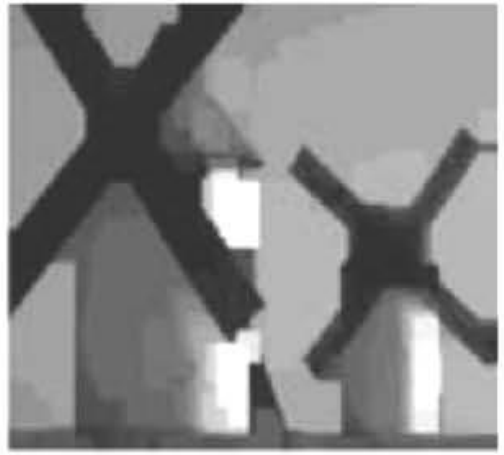
Grayscale Morphological Operations Summary

Image I

Erosion $I \ominus B$

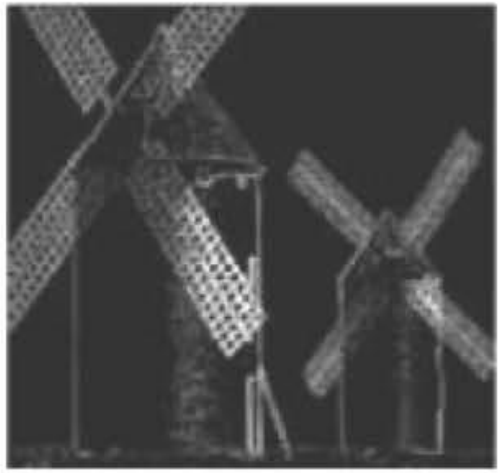
Dialation $I \oplus B$

Opening $I \circ B = (I \ominus B) \oplus B$

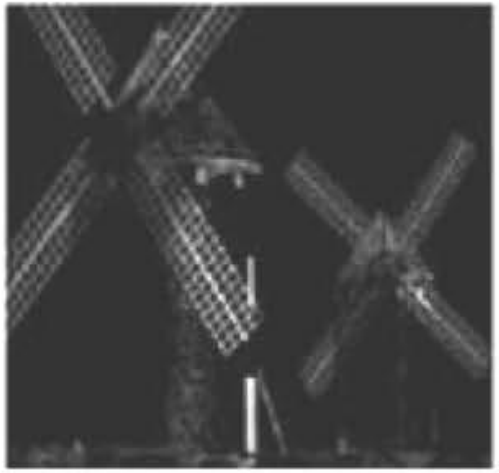


Closing $I \bullet B = (I \oplus B) \ominus B$

Grad(I)= $(I \oplus B) - (I \ominus B)$



TopHat(I)= $I - (I \ominus B)$



BlackHat(I)= $(I \ominus B) - I$

Source: Morphological Operation - Chen Hua-Tsung

Practice

Exercise #4

Please choose any color image to complete the following operations:

1. **Grayscale – Dilation**
2. **Grayscale – Erosion**
3. **Boundary extraction**

- **LibreStock**
- **Pixabay**

✓ **Note:** ***.sln & *.ppt(or *.pptx)*** are necessary and compress in a *.rar file.

Thanks!

Any questions?