Morphology (형태학)

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학습 목표

- Morphology의 의미를 설명할 수 있다.
- Dilation과 Erosion 연산의 용도와 동작을 설명할 수 있다.
- Opening(열림)과 Closing(닫힘) 연산의 용도와 동작을 설명할 수 있다.

모폴로지|Morphology 개요

- 모폴로지 (형태학)
  - 생물학의 한 분야로 동물이나 식물의 모양이나 구조를 다루는 학문

- 수학적 모폴로지|mathematical morphology
  - 관심 객체의 검출을 쉽게 처리할 수 있도록 영상 분할 결과를 단순화하는 방법으로 사용
  - 객체 경계의 단순화, 작은 구멍을 채움, 작은 돌기의 제거 등
  - Binary 영상과 Gray-scale 영상에 적용 가능
  - 모폴로지 필터링morphological filtering
    - 구조적 요소structuring element와 팽창dilation 및 침식erosion 연산 사용

기본 집합 이론Basic Set Theory

Let A and B be sets in Z^2

a is an **element** of A ➡ $a \in A$

a is **not an element** of A ➡ $a \notin A$

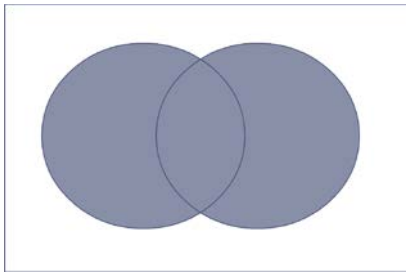
A is a **subset** of B ➡ $A \subseteq B$

The **union** of A and B ➡ $A \cup B = \{x \mid x \in A \text{ or } x \in B\}$

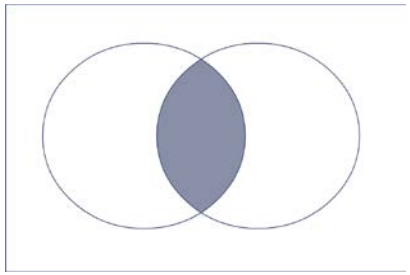
The **intersection** of A and B ➡ $A \cap B = \{x \mid x \in A \text{ and } x \in B\}$

The **complement** of A ➡ $A^c = \{x \mid x \notin A\}$

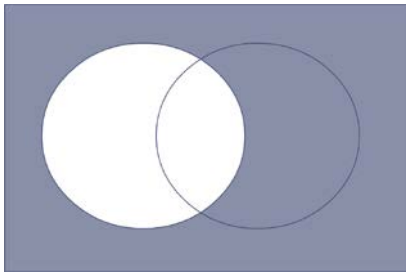
The **difference** of A and B ➡ $A - B = \{x \mid x \in A \text{ and } x \notin B\}$



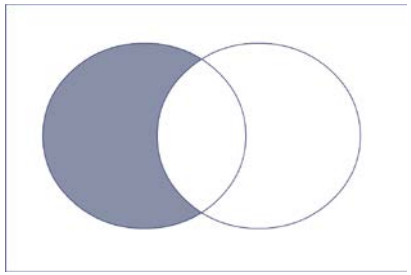
$A \cup B$



$A \cap B$



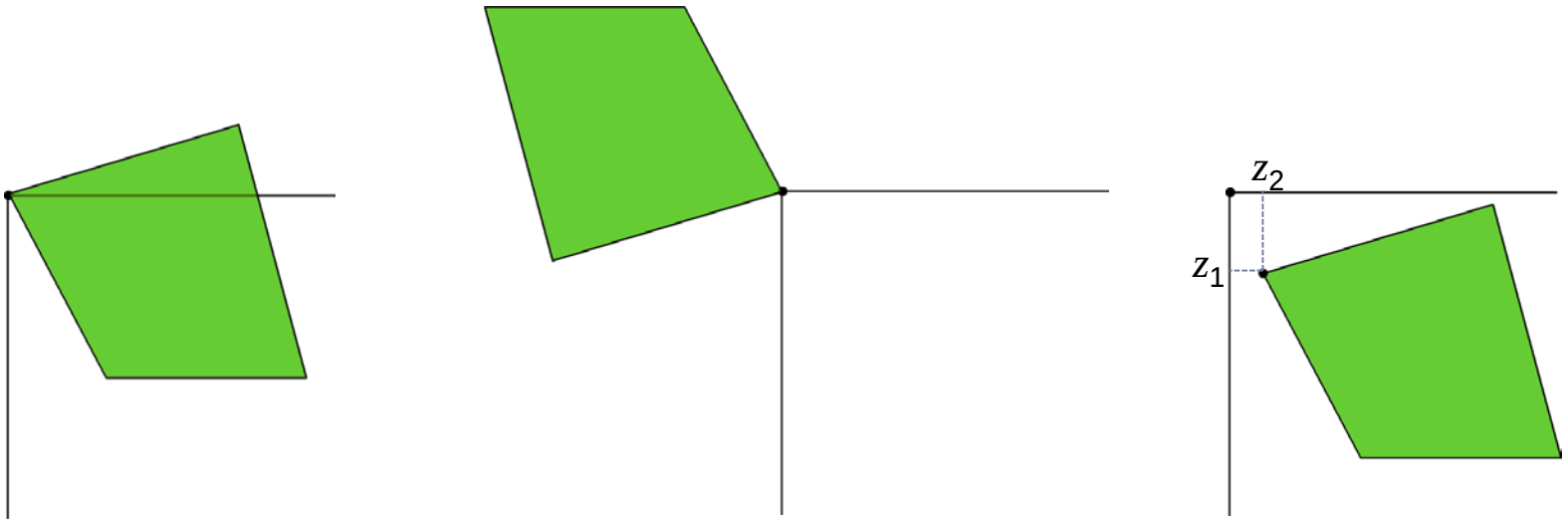
A^c



A-B

The **reflection** of A ➡ $\hat{A} = \{x \mid x = -b, \text{ for } b \in A\}$

The **translation** of A ➡ $(A)_z = \{c \mid c = b + z, \text{ for } b \in A\}$



reflection translation

이진 영상에서의 팽창 연산Dilation operation

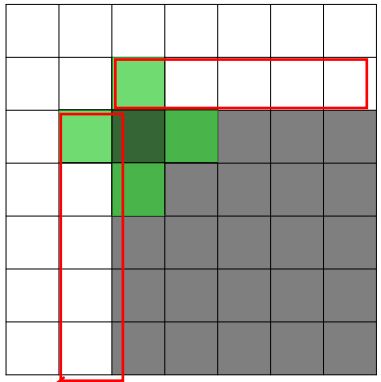
- 객체의 크기를 확장
  - 객체 내부의 작은 구멍을 채움
  - 근접한 위치의 두 객체를 연결

$$A \oplus B = \left\{ z \mid \left(\hat{B}\right)_z \cap A \neq \emptyset \right\}$$

$\boldsymbol{A}$: image
$\boldsymbol{B}$: Structuring element

$$A \oplus B = B \oplus A$$

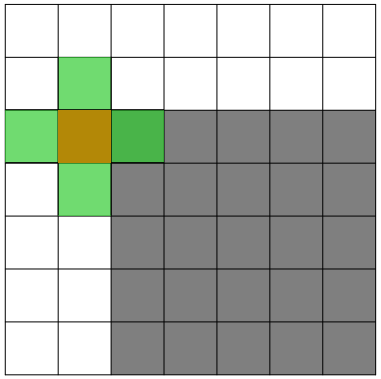
$$A \oplus (B \oplus C) = (A \oplus B) \oplus C$$



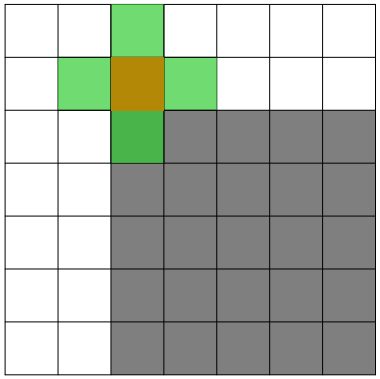
채워짐 결과

팽창

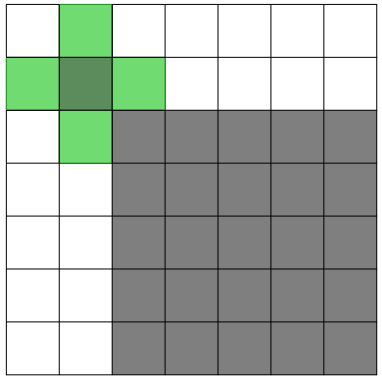
연산 시행
-> anchor point 값들을 1로 변경



연산 시행 X



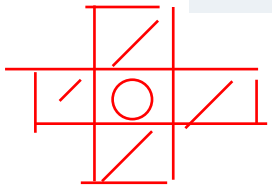
연산 시행 X



연산 시행 X

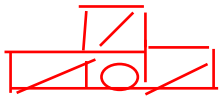
알고리즘

1. 구조적 요소의 중심이 영상의 '0'에 위치하면 다음 위치로 이동
2. 구조적 요소의 중심이 영상의 '1'에 위치하면 구조요소와 영상을 논리적 OR 연산 수행



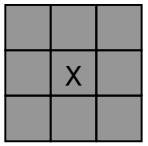
anchor point
<- 4 연결성

8 연결성

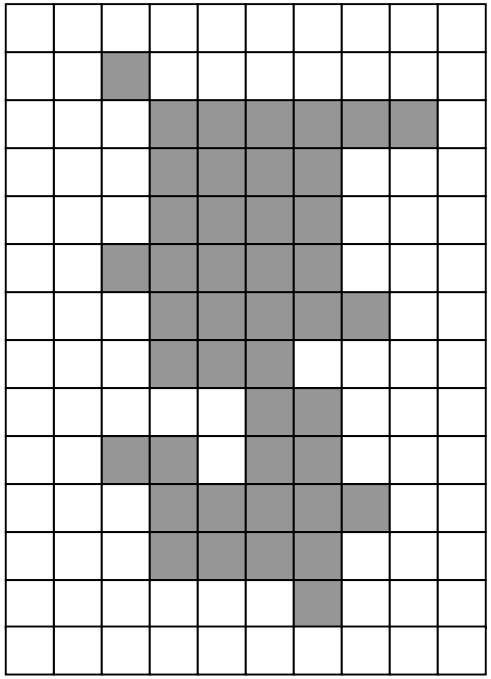


3 연결성

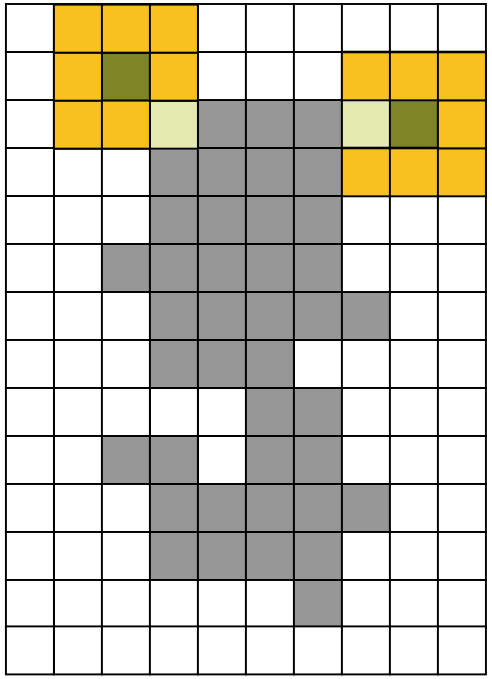
example



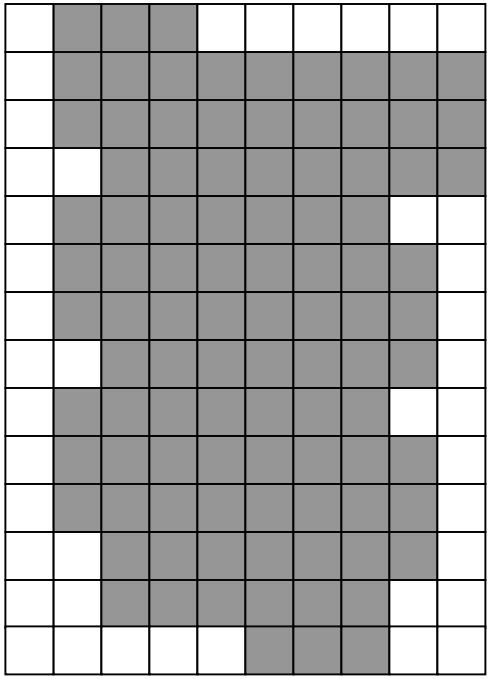
Structuring Element



Original Image



중간 결과



After Dilation

Original image

Structuring element

Dilation with SE
of rectangle (7x7)

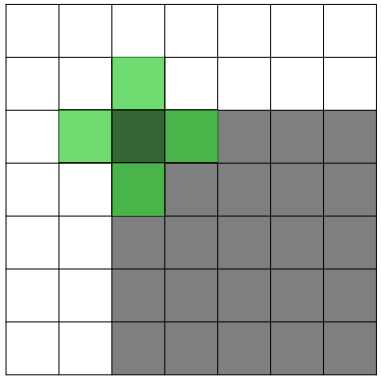
Dilation with SE
of circle (7x7)

이진 영상에서의 침식 연산Erosion operation

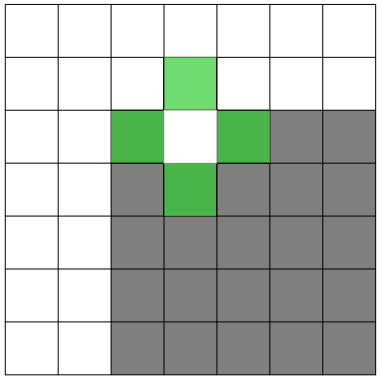
- 객체의 크기를 축소
  - 객체 경계를 침식
  - 작은 돌기를 제거

$$A \ominus B = \{z \mid B_z \subseteq A\}$$

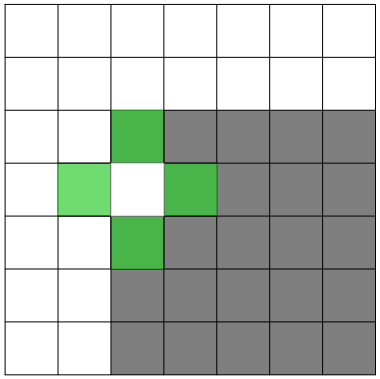
$\boldsymbol{A}$: image
$\boldsymbol{B}$: Structuring element



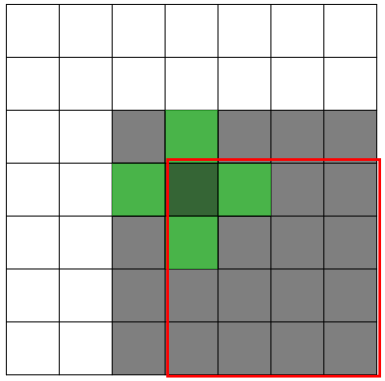
연산 시행 X



연산 시행
anchor point
만 없앰



연산 시행

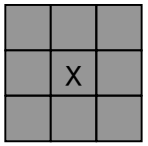


Anchoring
point가
다 겹치면 살
림
결과

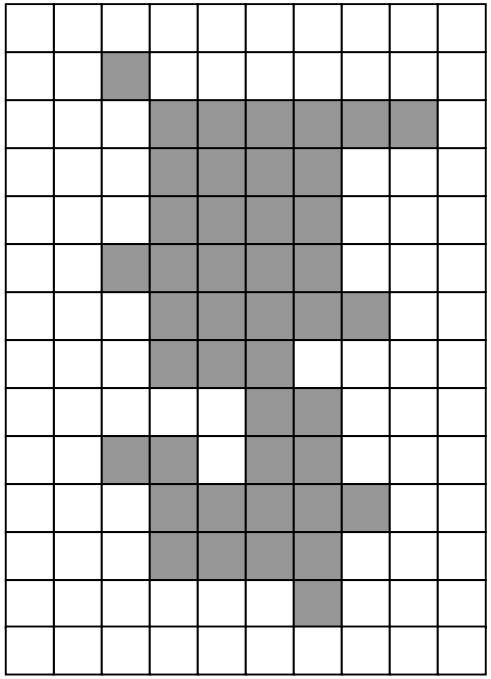
알고리즘

1. 구조적 요소의 중심이 영상의 ‘0’에 위치하면 다음 위치로 이동
2. 구조적 요소의 중심이 영상의 ‘1’에 위치하면 구조요소에서 ‘1’ 위치가 하나라도 객체를 벗어나면 그 위치는 ‘0’으로 변경

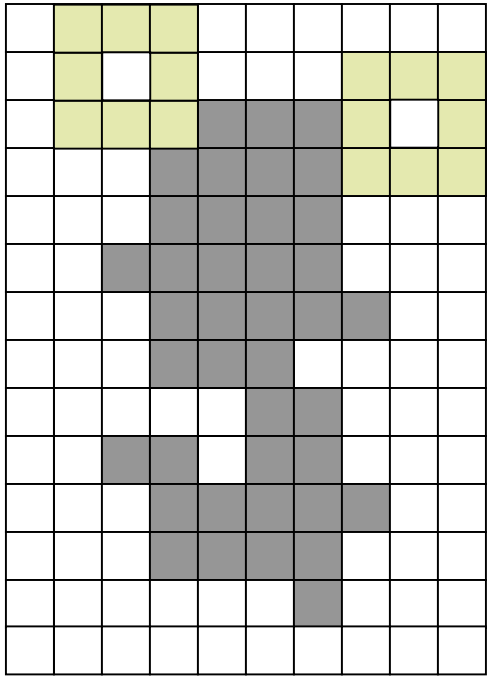
example



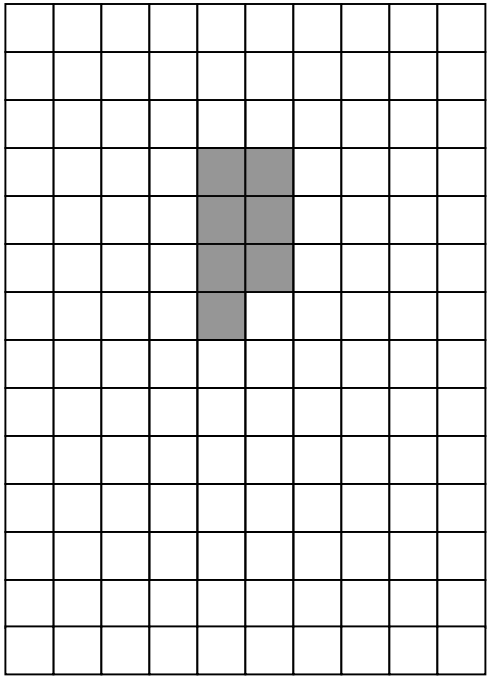
Structuring Element



Original Image



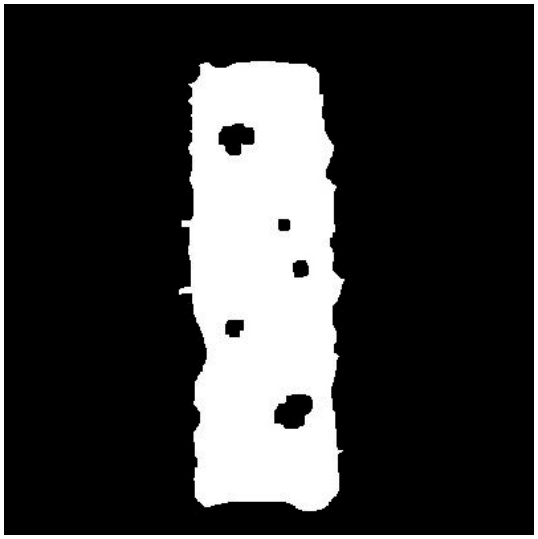
중간 결과



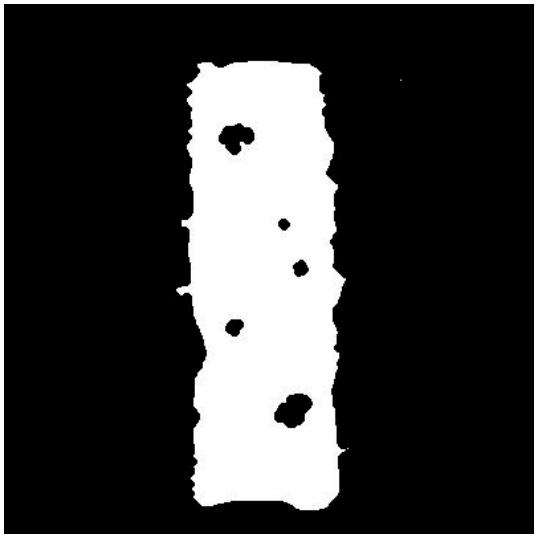
After Erosion

침식(erosion

Original image



Erosion with SE
of rectangle (7x7)



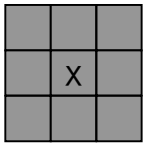
Erosion with SE
of circle (7x7)

열림 연산Opening operation

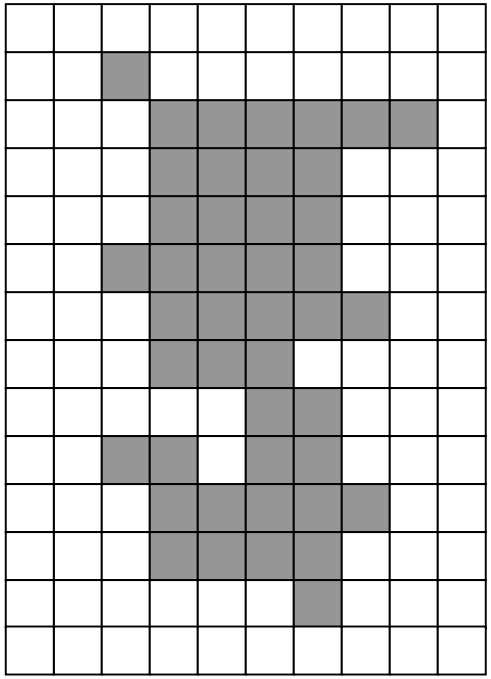
- 침식Erosion 연산을 수행한 후 다시 팽창Dilation 연산 적용
- 작은 크기의 객체에 포함되는 픽셀들을 제거

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

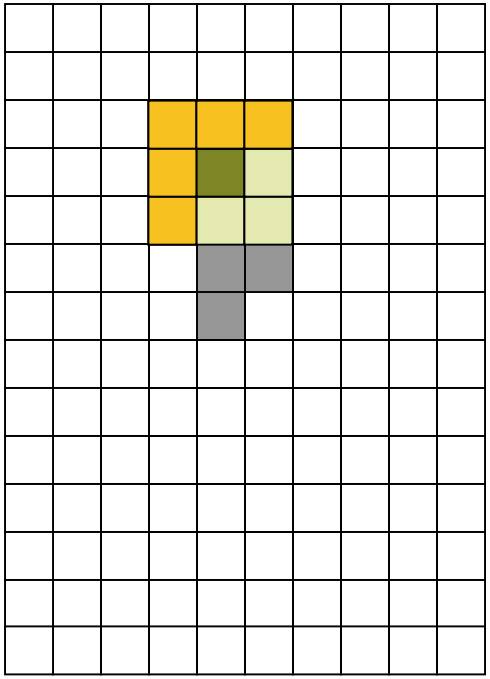
example



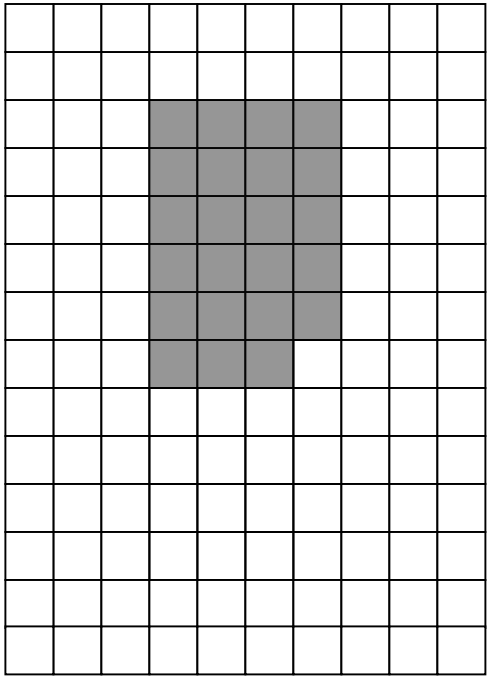
Structuring Element



Original Image



After Erosion



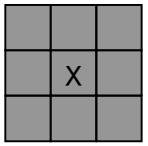
After Opening

닫힘 연산Closing operation

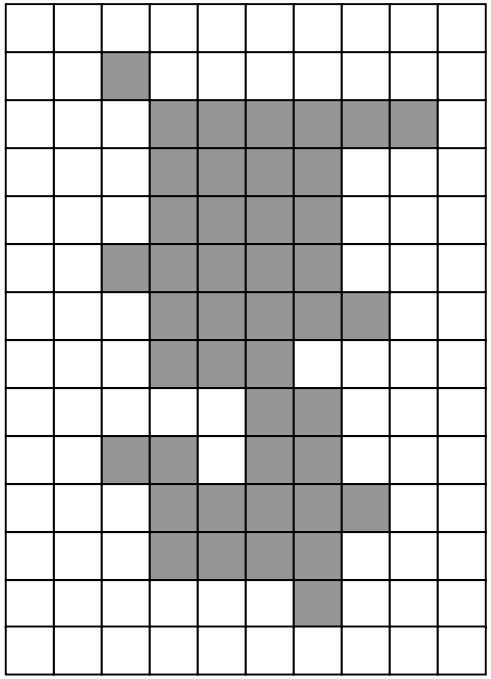
- 팽창Dilation 연산을 수행한 후 다시 침식Erosion 연산 적용
- 객체 내부의 작은 구멍hole이나 간격gap을 채움

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

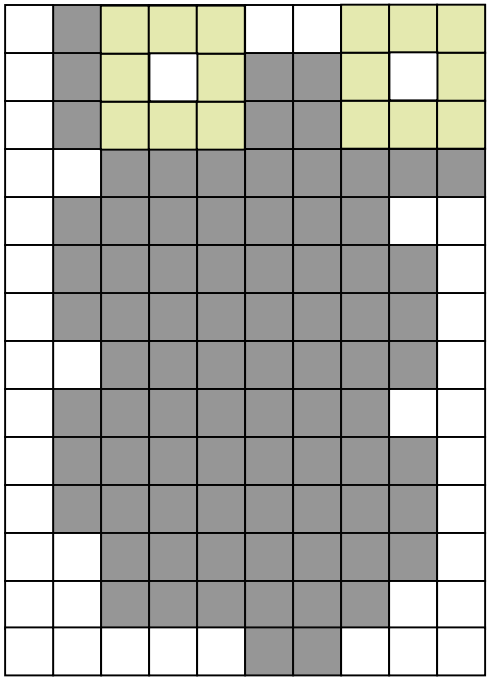
example



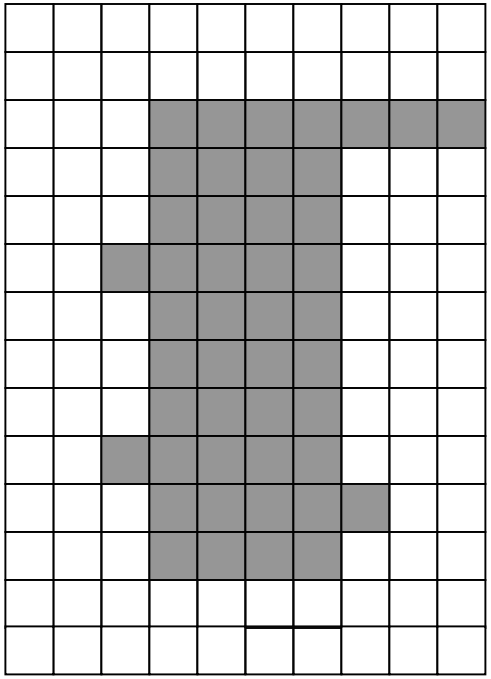
Structuring Element



Original Image

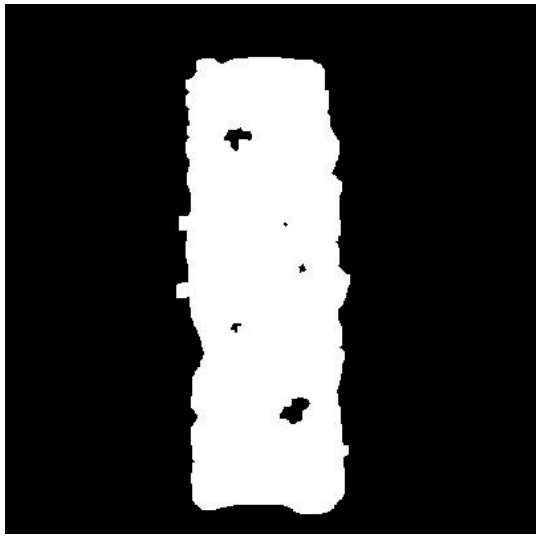


After Dilation



After Closing

Original image

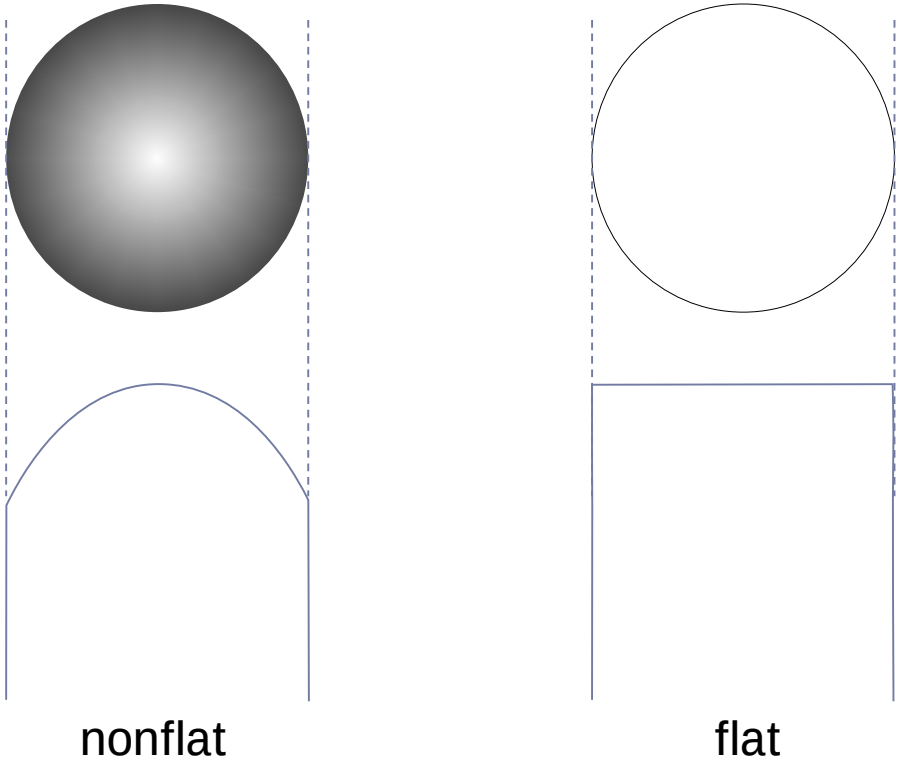


Opening with SE
of rectangle (7x7)

Closing with SE
of rectangle (7x7)

Operations for gray-scale images

Two types of a structuring element



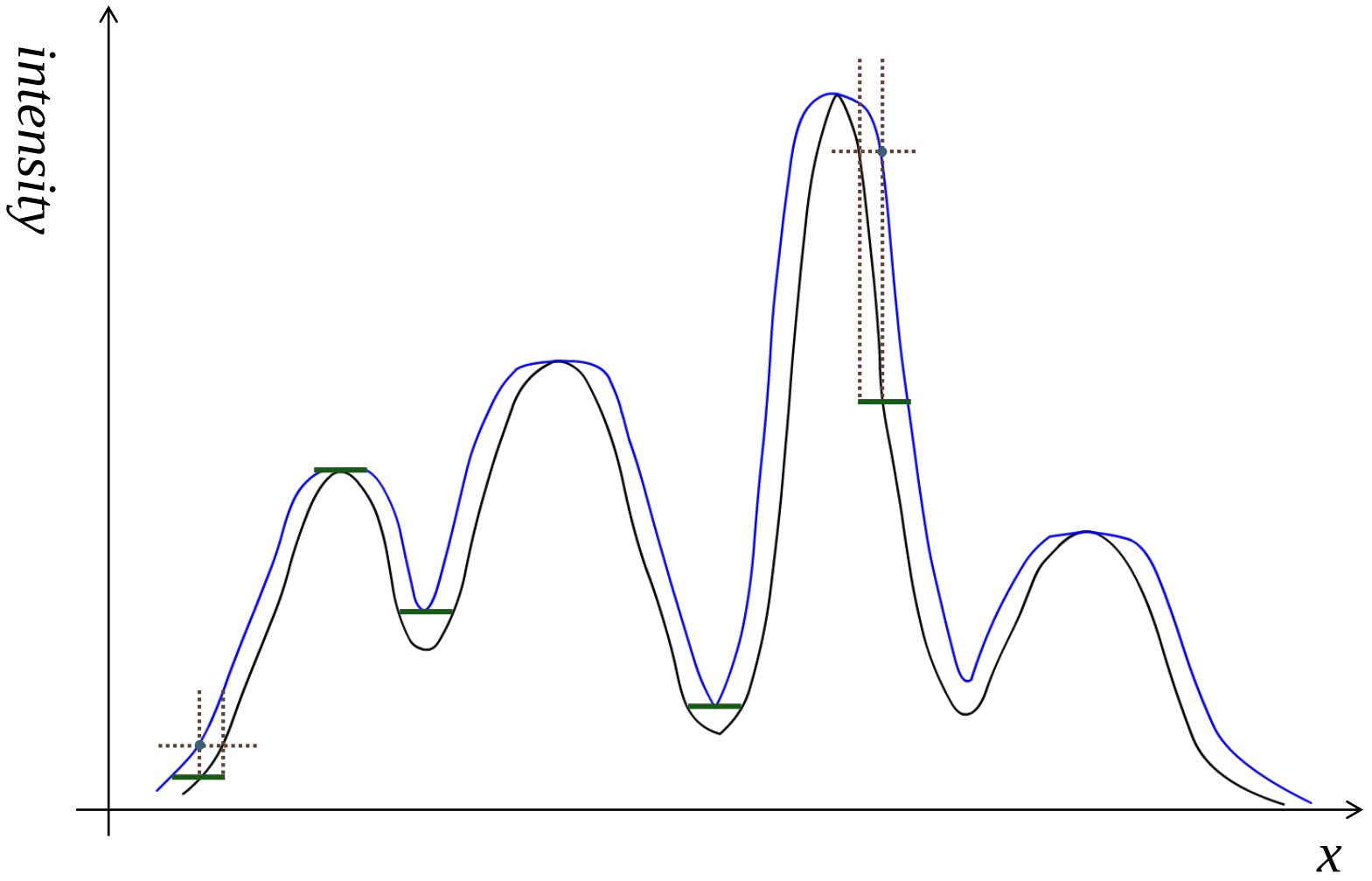
Dilation of f by k

$$(f \oplus k)(s,t) = \max_{(s,t)\in D_k} \{f(x-s, y-t) + k(s,t)\}$$

Erosion of f by k

$$(f \ominus k)(s,t) = \min_{(s,t)\in D_k} \{f(x+s, y+t) - k(s,t)\}$$

Dilation with a flat structuring element



OpenCV를 사용한 Morphological operations 구현

```
Mat   getStructuringElement( … )
void  dialte(  …  )
void  erode(  …  )
void  morphologyEx(  …  )
```

```
Mat getStructuringElement(
      int shape,
      Size ksize,
      Point anchor=Point(-1,-1)
)
```

shape

- MORPH_RECT: a rectangular structuring element
- MORPH_ELLIPSE: an elliptic structuring element,

  Rect(0, 0, ksize.width, ksize.height)
- MORPH_CROSS: a cross-shaped structuring element
- CV_SHAPE_CUSTOM: custom structuring element

```
void dilate(
      InputArray src,
      OutputArray dst,
      InputArray kernel,
      Point anchor=Point(-1,-1),
      int iterations=1,
      int borderType=BORDER_CONSTANT,
      const Scalar& borderValue =
                        morphologyDefaultBorderValue()
)
```

```
void erode(
      InputArray src,
      OutputArray dst,
      InputArray kernel,
      Point anchor=Point(-1,-1),
      int iterations=1,
      int borderType=BORDER_CONSTANT,
      const Scalar& borderValue =
                        morphologyDefaultBorderValue()
)
```

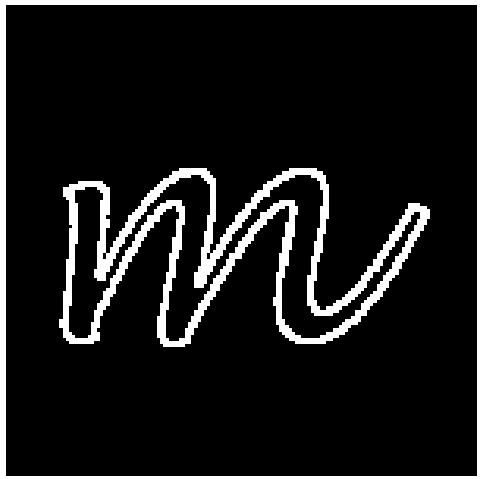
```
void morphologyEx(
      InputArray src,
      OutputArray dst,
      int op,
      InputArray kernel,
      Point anchor=Point(-1,-1),
      int iterations=1,
      int borderType=BORDER_CONSTANT,
      const Scalar& borderValue =
                  morphologyDefaultBorderValue()
)
```

op

- MORPH_OPEN - an opening operation
- MORPH_CLOSE - a closing operation
- MORPH_GRADIENT - a morphological gradient
  $(f \oplus b) - (f \ominus b)$
- MORPH_TOPHAT - “top hat” $f - (f \circ b)$
- MORPH_BLACKHAT - “black hat” $(f \bullet b) - f$

dilation

erosion



gradient

dilation

erosion

```
void Dilation( const Mat &image, Mat &result, int type=0, int size=3 );
void Erosion( const Mat &image, Mat &result, int type=0, int size=3 );
void Morphology( const Mat &image, Mat &result, int op, int type=0, int size=3 );

int main(void){
     Mat image = imread( "text_m.bmp", -1 );
     if( image.data == NULL ) return -1;

     Mat dilation;
     Dilation( image, dilation );

     Mat erosion;
     Erosion( image, erosion );

     Mat morphology;
     Morphology( image, morphology, 2 );

     // Display the images
     namedWindow( "Image" );
     namedWindow( "Dilation" );
     namedWindow( "Erosion" );
     namedWindow( "Morphology" );
     imshow( "Image", image );
     imshow( "Dilation", dilation );
     imshow( "Erosion", erosion );
     imshow( "Morphology", morphology );

     waitKey();

     return 0;
}
```

```
void Dilation( const Mat &image, Mat &result, int type, int size )
{
        // allocate if necessary
       result.create( image.size(), image.type() );

       int dilation_type;
       if( type == 0 )
              dilation_type = MORPH_RECT;
       else if( type == 1 )
              dilation_type = MORPH_CROSS;
       else if( type == 2)
              dilation_type = MORPH_ELLIPSE;

       Mat element = getStructuringElement(
                        dilation_type, Size(size, size) );

       // Apply the dilation operation
       dilate( image, result, element );
}
```

```
void Erosion( const Mat &image, Mat &result, int type, int size )
{
        // allocate if necessary
       result.create( image.size(), image.type() );

       int erosion_type;
       if( type == 0 )
                erosion_type = MORPH_RECT;
       else if( type == 1 )
                erosion_type = MORPH_CROSS;
       else if( type == 2)
                erosion_type = MORPH_ELLIPSE;

       Mat element = getStructuringElement(
                        erosion_type, Size(size, size) );

       // Apply the dilation operation
       erode( image, result, element );
}
```

```
void Morphology( const Mat &image, Mat &result, int op,
 int type, int size ) {
     // allocate if necessary
    result.create( image.size(), image.type() );

    int operation;
    switch( op )
    {
    case 0:
        operation = MORPH_OPEN;
        break;
    case 1:
        operation = MORPH_CLOSE;
        break;
    case 2:
        operation = MORPH_GRADIENT;
        break;
    case 3:
        operation = MORPH_TOPHAT;
        break;
    case 4:
        operation = MORPH_BLACKHAT;
        break;
    }
```

```
        int mor_type;
        if( type == 0 )
                mor_type = MORPH_RECT;
        else if( type == 1 )
                mor_type = MORPH_CROSS;
        else if( type == 2)
                mor_type = MORPH_ELLIPSE;

        Mat element = getStructuringElement( mor_type,
                Size(size, size) );

        // Apply the specified morphology operation
        morphologyEx( image, result, operation, element );
}
```

Reference

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