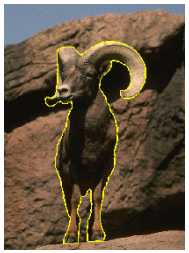
Image Processing

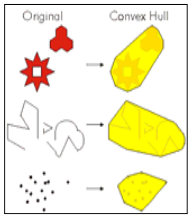
Morphological Image Processing (Part I)

Pattern Recognition and Image Processing Laboratory (Since 2012)

Introduction

Mathematical morphology is a tool for extracting image components, such as boundaries, skeletons, and convex hulls.





Introduction

Morphological techniques include morphological filtering, thinning, and pruning.

Set Theory

Let Z be a set of integers, and Z^2 be a pair of elements from the Cartesian product. If $w = (x, y)$ is an element of A, then we write

$$w \in A$$

Similarly, if w is NOT an element of A, we write

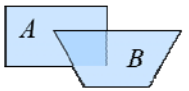
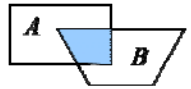
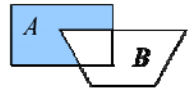
$$w \notin A$$

Set Theory

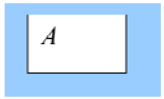
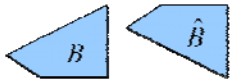
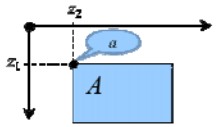
A set B of pixel coordinates that satisfy a particular condition is written as

$$B = \{\omega \mid condition\}$$

Set Theory

Logical Operators	Illustrations
$A \cup B$	
$A \cap B$	
$A - B = \{\omega \mid \omega \in A, \omega \notin B\}$	

Set Theory

Logical Operators	Illustrations
$A^c = \{\omega \mid \omega \notin A\}$	
$\hat{B} = \{\omega \mid \omega = -b, for\ b \in B\}$	
$(A)_z = \{c \mid c = a + z, for\ a \in A\}$ $\Vert$ $(z_1 + z_2)$	

Binary Images, Sets, and Logical Operators

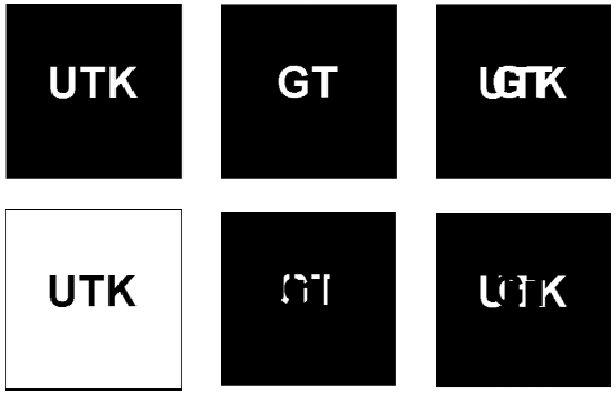
MATLAB Expression for Binary Images

```
>> utk = imread('utk.tif');
>> gt = imread('gt.tif');
>> figure(1); imshow(utk);
>> figure(2); imshow(gt);

>> comp_utk = ~utk;
>> figure(3); imshow(comp_utk);

>> AorB = utk | gt;      % A union B
>> AandB = utk & gt;     % A intersection B
>> AanddifB = utk & ~gt;
>> figure(4); imshow(AorB);
>> figure(5); imshow(AandB);
>> figure(6); imshow(AanddifB);
```

Binary Images, Sets, and Logical Operators



พองขึ้น เหี่ยวลง

Dilation and Erosion

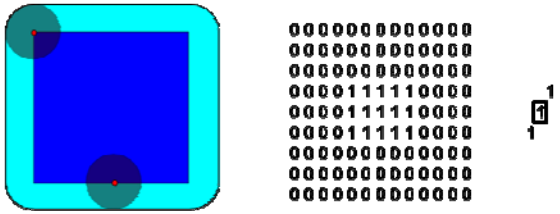
Function: Dilation is an operator that “grows” or “thickens” objects in a binary image.

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

Property: Commutation; $A \oplus B = B \oplus A$

Dilation and Erosion

- **Dilation**



The dilation of the dark-blue square by a disk, resulting in the light-blue square with rounded corners.

Dilation and Erosion

- **IPT function: imdilate**

```
>> A = imread('broken_text.tif');
>> B = [0 1 0;
        1 1 1;
        0 1 0];

>> A2 = imdilate(A, B);
>> figure(1); imshow(A);
>> figure(2); imshow(A2);
```

Dilation and Erosion

- **Structuring Element Decomposition**

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

$\downarrow$ ← **Decomposition**

$(B_1 \oplus B_2)$

Dilation and Erosion

- **Structuring Element Decomposition**

$$\begin{matrix} 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & \boxed{1} & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \end{matrix} \Rightarrow [\,1 \;\; 1 \;\; \boxed{1} \;\; 1 \;\; 1\,] \oplus \begin{bmatrix} 1 \\ 1 \\ \boxed{1} \\ 1 \\ 1 \end{bmatrix}$$

Dilation and Erosion

- **Structuring Element Decomposition**

- IPT function: strel

  se = strel(shape, parameter)

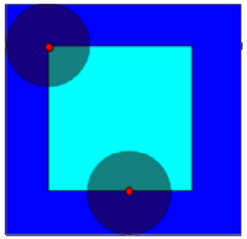
Dilation and Erosion

Function: Erosion is an operator that "shrinks" or "thins" objects in a binary image.

Definition: $A \ominus B = \{z \mid (B)_z \cap A^c \neq \varnothing\}$

Dilation and Erosion

- **Erosion**



The erosion of the dark-blue square by a disk, resulting in the light-blue square.

Dilation and Erosion

- **IPT function: imerode**

```
>> A = imread('wirebond_mask.tif');
>> se1 = strel('disk', 10);
>> A1 = imerode(A, se1);
>> se2 = strel('disk', 5);
>> A2 = imerode(A, se2);
>> se3 = strel('disk', 20);
>> A3 = imerode(A, se3);
>> figure(1);
>> subplot(2, 2, 1); imshow(A);
>> subplot(2, 2, 2); imshow(A1);
>> subplot(2, 2, 3); imshow(A2);
>> subplot(2, 2, 4); imshow(A3);
```

Combining Dilation and Erosion

- **Opening and Closing**

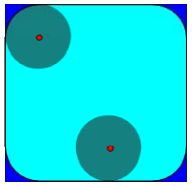
Function: Morphological opening is a operator that smoothes object contours, breaks thin connections, and removes thin protrusion.

Definition: $A \circ B = (A \oplus B) \oplus B$

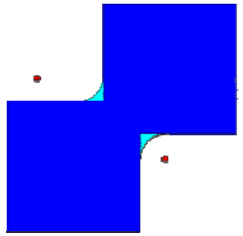
$$A \circ B = \bigcup \{(B_z) \mid (B_z) \subseteq A\}$$

Combining Dilation and Erosion

- **Opening and Closing**



The opening of the dark-blue square by a disk, resulting in the light-blue square with round corners.



The closing of the dark-blue shape (union of two squares) by a disk, resulting in the union of the dark-blue shape and the light-blue areas.

Combining Dilation and Erosion

- **Opening and Closing**

Function: Morphological closing is a operator that joints narrow breaks, fills long thin gulfs, and fills holes smaller than the structuring element.

Definition: $A \bullet B = (A \oplus B) \oplus B$

$$A \bullet B = \bigcup \{(B_z) \mid (B_z) \subseteq A^c\}$$

Combining Dilation and Erosion

- **Opening and Closing**

ITP function: opening and closing

```
>> f = imread('noisy_fingerprint.tif');
>> se = strel('square', 3);

>> fo = imopen(f, se);
>> foc = imclose(fo, se);

>> figure(1);
>> subplot(1, 3, 1); imshow(f);
>> subplot(1, 3, 2); imshow(fo);
>> subplot(1, 3, 3); imshow(foc);
```

Combining Dilation and Erosion

- **The Hit-or-Miss Transformation**

Function: It is useful to identify specified configurations of pixels, such as isolated foreground pixels, or pixels that are end points of line segments.

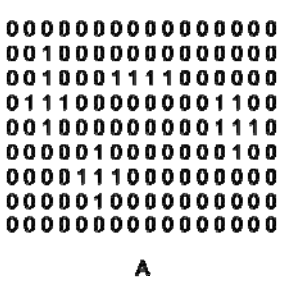
ต้องเป็น erosion

Definition: $A \otimes B = (A \oplus B_1) \cap (A^c \oplus B_2)$

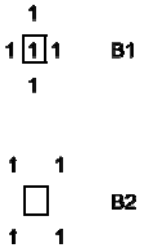
Structuring elements

Combining Dilation and Erosion

- **The Hit-or-Miss Transformation**



A



Combining Dilation and Erosion

- **The Hit-or-Miss Transformation**

```
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 0 0 0 0 0 0 0 0
0 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 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 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 0 0
```

$$(A \ominus B_1)$$

```
1 0 1 0 1 1 1 1 1 1 1 1 1 1 1 1
1 0 1 0 1 0 0 0 0 0 0 1 1 1 1 1
0 0 0 0 0 1 1 1 1 1 1 0 0 0 0 1
1 0 1 0 1 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 1 0 1 1 1 1 0 0 0 0 1
1 0 1 0 0 0 0 0 1 1 1 0 0 0 0 0
1 1 1 1 0 1 0 1 1 1 1 1 0 1 0 1
1 1 1 0 0 0 0 0 1 1 1 1 1 1 1 1
1 1 1 1 0 1 0 1 1 1 1 1 1 1 1 1
```

$$(A^C \ominus B_2)$$

Combining Dilation and Erosion

- **The Hit-or-Miss Transformation**

```
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 0 0 0 0 0 0 0 0
0 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 0 0 0 0 0
0 0 0 0 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 0 0
```

$$A \otimes B = (A \ominus B_1) \cap (A^c \oplus B_2)$$

Combining Dilation and Erosion

- **The Hit-or-Miss Transformation**

ITP function: bwhitmiss

```
>> f = imread('small_squares.tif');
>> figure(1); imshow(f);

>> B1 = strel([0 0 0; 0 1 1; 0 1 0]);
>> B2 = strel([1 1 1; 1 0 0; 1 0 0]);
>> g = bwhitmiss(f, B1, B2);
>> figure(2); imshow(g, []);
```

Combining Dilation and Erosion

- **The Hit-or-Miss Transformation**

ITP function: bwmorph

```
>> f = imread('noisy_fingerprint.tif');
>> se = strel('square', 3);
>> fo = imopen(f, se);
>> foc = imclose(fo, se);
>> g1 = bwmorph(foc, 'thin', 1);
>> g2 = bwmorph(foc, 'thin', 2);
>> ginf = bwmorph(foc, 'thin', Inf);
>> figure(1);
>> subplot(2, 2, 1); imshow(f);
>> subplot(2, 2, 2); imshow(foc);
>> subplot(2, 2, 3); imshow(g1);
>> subplot(2, 2, 4); imshow(g2);
>> figure(2); imshow(ginf);
```


The end of
part I