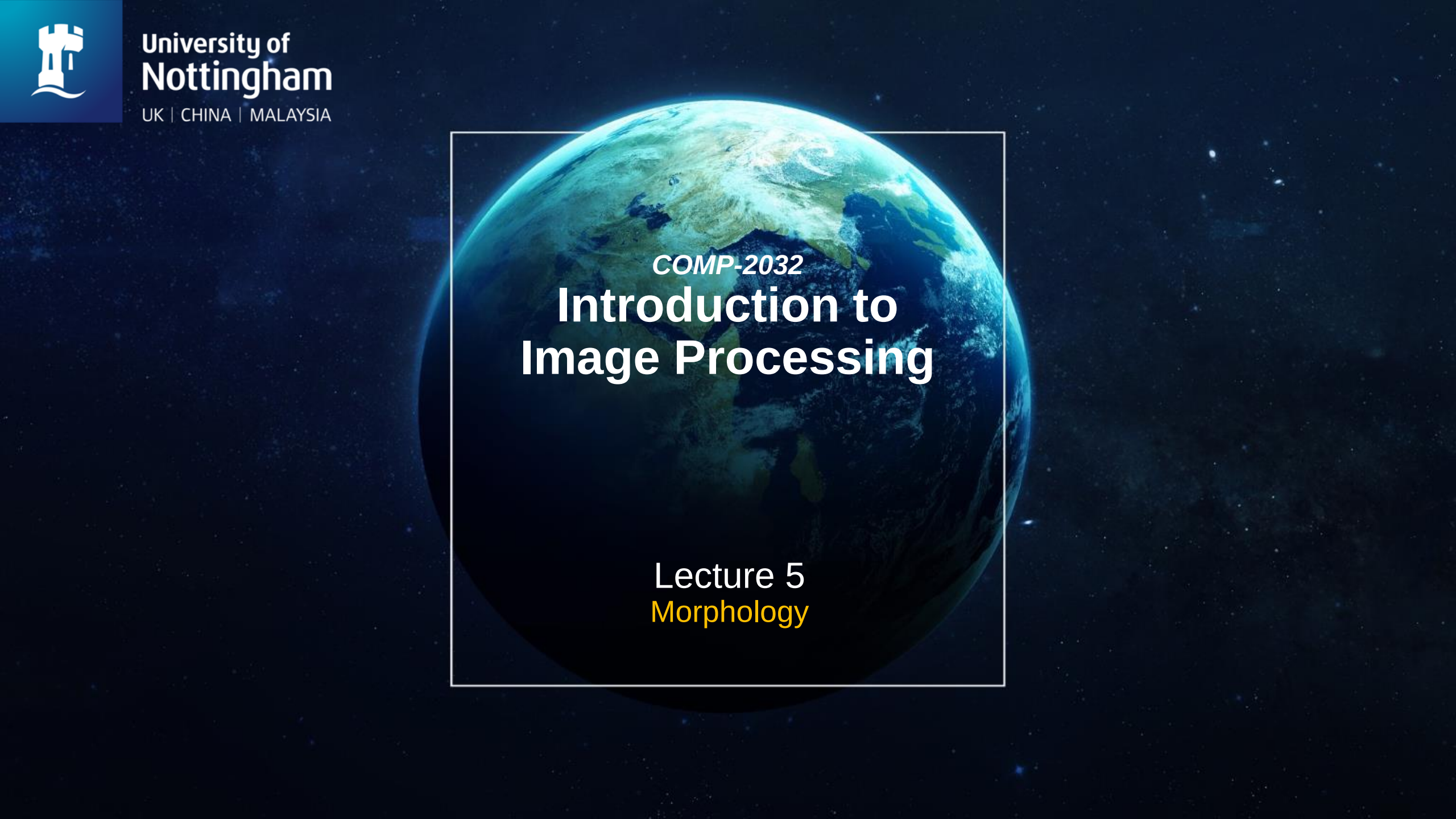
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COMP-2032
Introduction to
Image Processing
Lecture 5
Morphology

COMP2005: Introduction to Image Processing
Week 23 – 10:00am Friday – 01 March 2024

valid for 65 minutes from 9:55am
generated 2024-01-20 03:09

Learning Outcomes

IDENTIFY

1. Connected Components
2. What is Mathematical Morphology
3. Erosion and Dilation
4. Opening and Closing
5. ROIs and Masks

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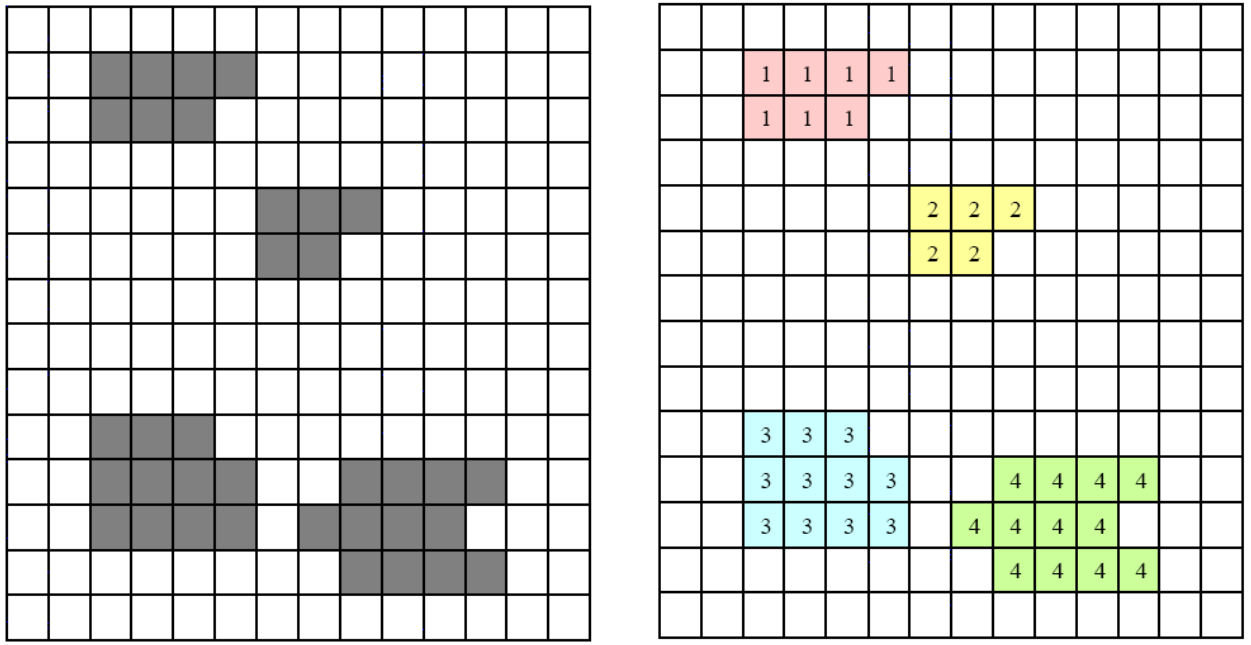
Connected Components

Connected Components

If black pixels are objects & white are background, give each connected set of black pixels a different label



Connected can mean 4- or 8- neighbours **REMEMBER**

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Connected Components

- Connected component algorithms are **slow** and often a **bottleneck**

- Keep a separate output array for labels
- Two passes over the image

A sequential algorithm using 4-neighbours

- Scan image top left to bottom right
- Look at top and left neighbours (already given labels)
- Can we assign either of their labels to the current pixel?

First pass

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Connected Components

- If the current pixel is **foreground**, there are 3 cases:

1. left = top = background → assign current pixel a new label
2. one of left and top is background, the other foreground → assign current pixel the foreground pixel's label
3. Left = top = foreground → assign current pixel one of their labels and note that their labels are equal in an *equivalence table*

- Step 3 detects mergers between two previously separate components

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Connected Components

- Consider each equivalent pair of labels, set all instances of the higher label to the lower

Second pass

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

1st Scan

						a	a	a			b	b		c	c		
				d	d	d		a	a	a	a				c		
	e	e				d	d	d		a	a	a	a	a			

d=a, b=a

d=a

:equivalence table

2nd Scan : Replace b & d by a

						a	a	a			a	a		c	c		
				a	a	a		a	a	a	a				c		
	e	e				a	a	a		a	a	a	a	a			

Using 8 neighbours makes the algorithm (a little) more complex and gives (slightly) different results

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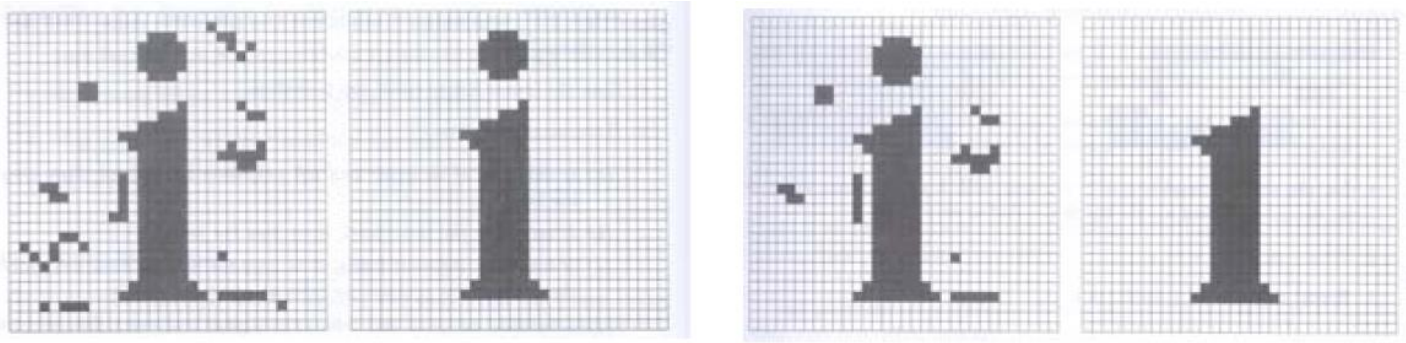
Connected Components

- Can compute features of and apply tests to components to process the underlying image
  - e.g., apply a (size) threshold T to the number of pixels in the component



T=10 T=25

  - Shape is captured by measures like area/boundary length

- Many application-specific features and tests exist

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What is Mathematical Morphology

Mathematical Morphology

- A branch of image processing which treats images as sets of pixels and uses set theoretic operations to process them
- Developed for binary images, extended to grey level images
- Elements of sets are (x,y) coordinates of black (or white) pixels
- Perform operations by combining two sets:

  - A patch of the binary image to be processed
  - A Structuring Element, similar to the mask in a convolution process

Underlying mathematics is beyond the scope of COMP2032. Instead, we will focus on how they work in practice and what they do

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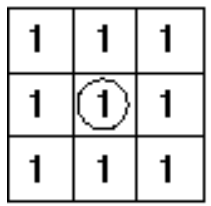
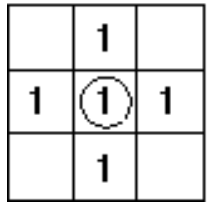
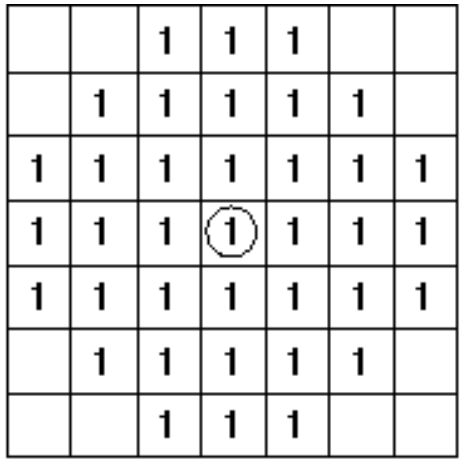
Structuring Elements

- Binary masks, c.f. filter masks but identifying rather than weighting pixels
- Larger structuring elements produce more extreme effects
- Very similar effects can be achieved by repeated operations using a smaller but similarly shaped structuring element
- With larger structuring elements, it is quite common to use an approximately disk-shaped structuring element
- Need not be square, origin need not be in the centre







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Morphological Operations

Dilation

Expands a foreground (or background) object A using structuring element B

Erosion

Shrinks a foreground (or background) object A using structuring element B

- The boundaries between foreground and background are often smoothed in the process
- The amount and the way objects grow and shrink depend upon the choice of the structuring element
- Dilating or eroding without specifying the structural element makes no sense than trying to filter an image without specifying the filter

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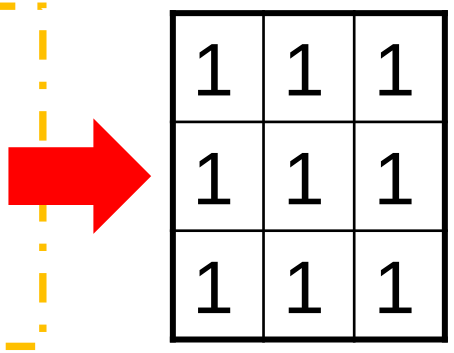
Erosion & Dilation

Dilation

2 inputs

- Binary image to dilate
- Set of points to be considered; a *structuring element*
- Origin is the central element



- The structuring element is superimposed on each of the background pixels such that origin of the structuring element coincides with the input pixel position
- If any of the '1' pixels in the structuring element overlap (intersect) the foreground then the background pixel is also set to foreground

Algorithm (*dilate foreground*)

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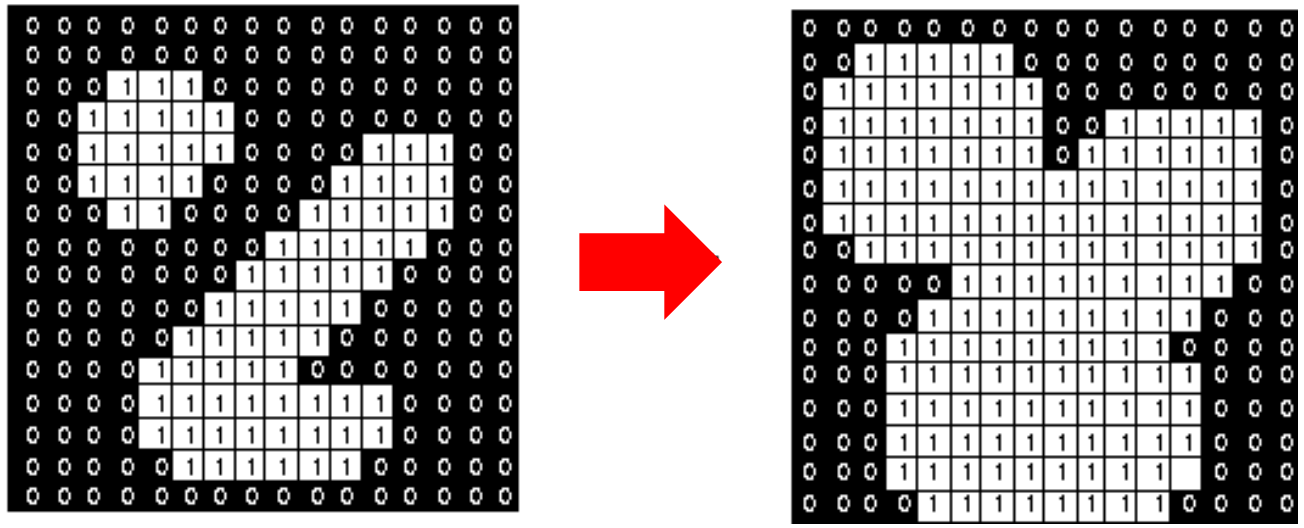
Dilation

- Gradually enlarges the boundaries of regions of foreground pixels (i.e., white pixels, typically)
- Areas of foreground pixels grow in size while holes within those regions become smaller



Result of dilation with a square 3 x 3 structuring element

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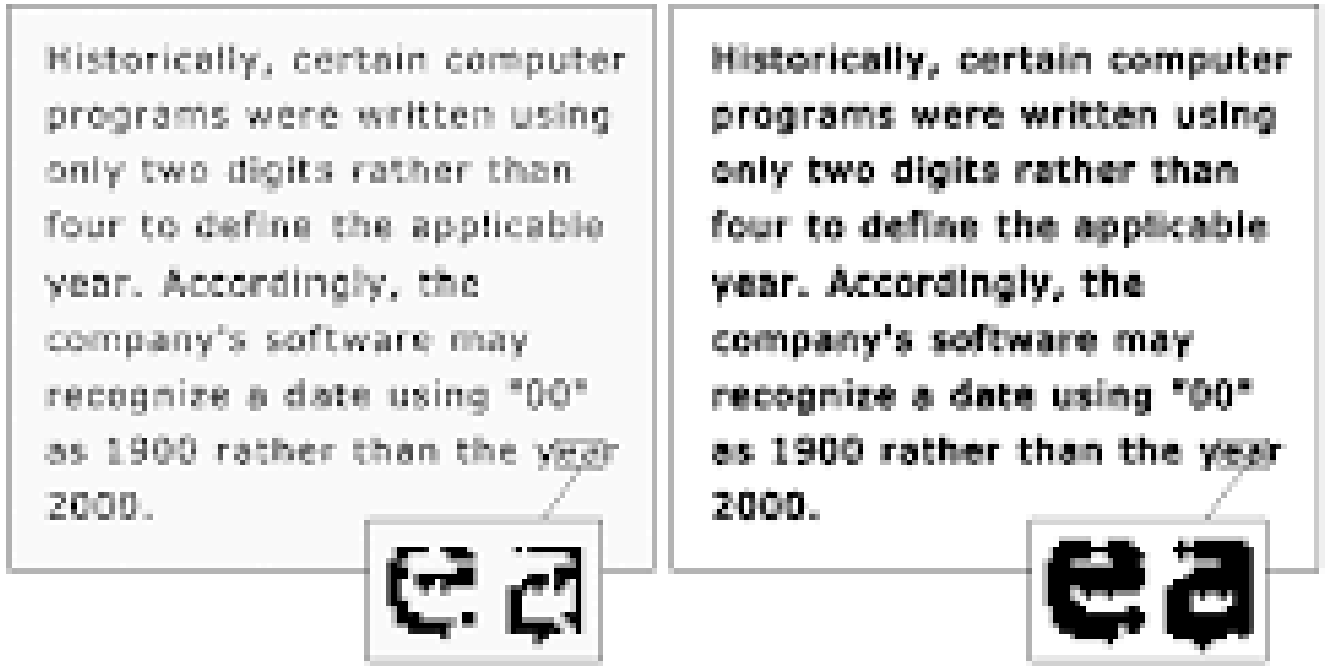
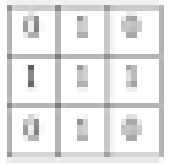
A More interesting Example



a c
b

FIGURE 9.5
(a) Sample text of poor resolution with broken characters (magnified view). (b) Structuring element. (c) Dilation of (a) by (b). Broken segments were joined.



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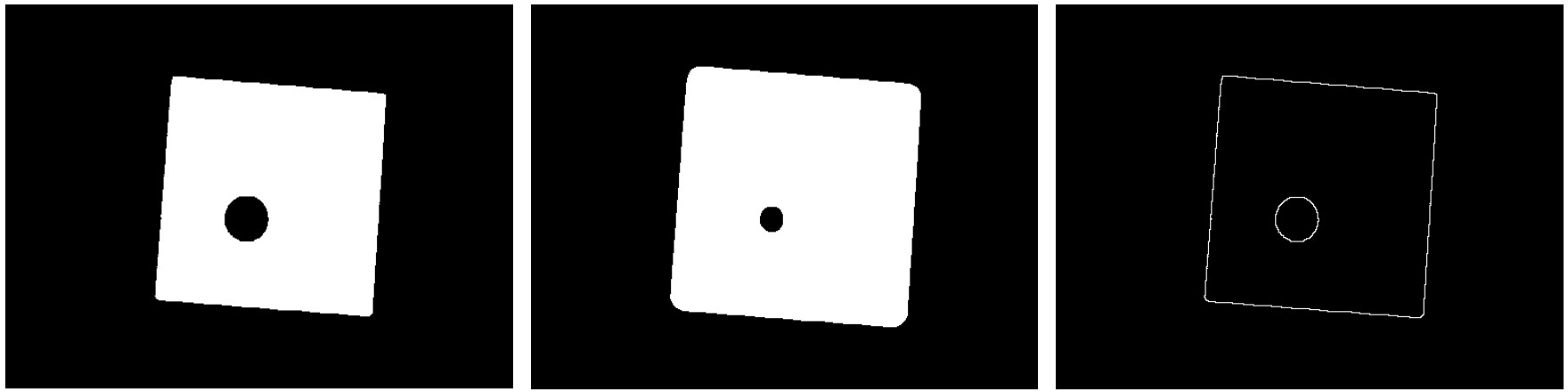
Edge Detection by Dilation

- Dilation input image (*note rounding of corners*)
- Subtract from original
- Edges remain (*pixels on the outside of the boundary*)



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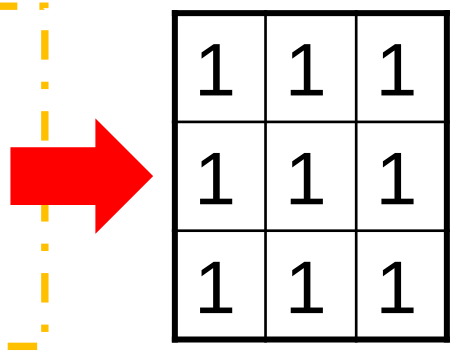
Erosion

2 inputs

- Binary image to erode
- Set of points to be considered; a *structuring element*
- Origin is the central element



- The structuring element is superimposed on each of the foreground pixels such that origin of the structuring element coincides with the input pixel position
- If any of the '1' pixels in the structuring element overlap (intersect) the background then the foreground pixel is also set to background

Algorithm (*erode foreground*)

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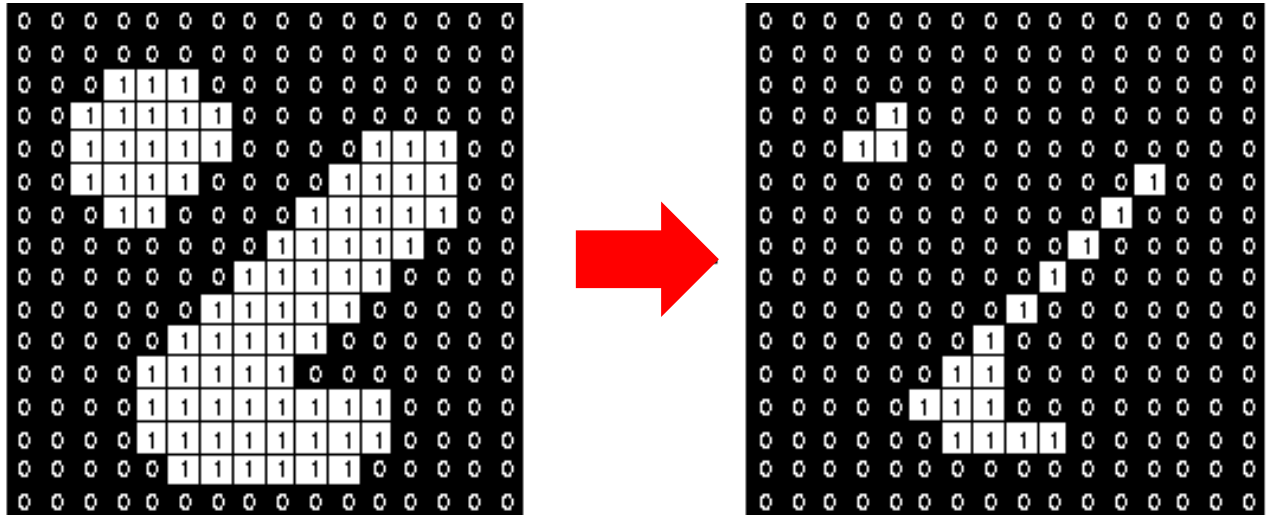
Erosion



Result of erosion with a square 3 x 3 structuring element

- Erosion is the *dual* of dilation, *i.e.,* eroding foreground pixels is equivalent to dilating the background pixels with the same structuring element

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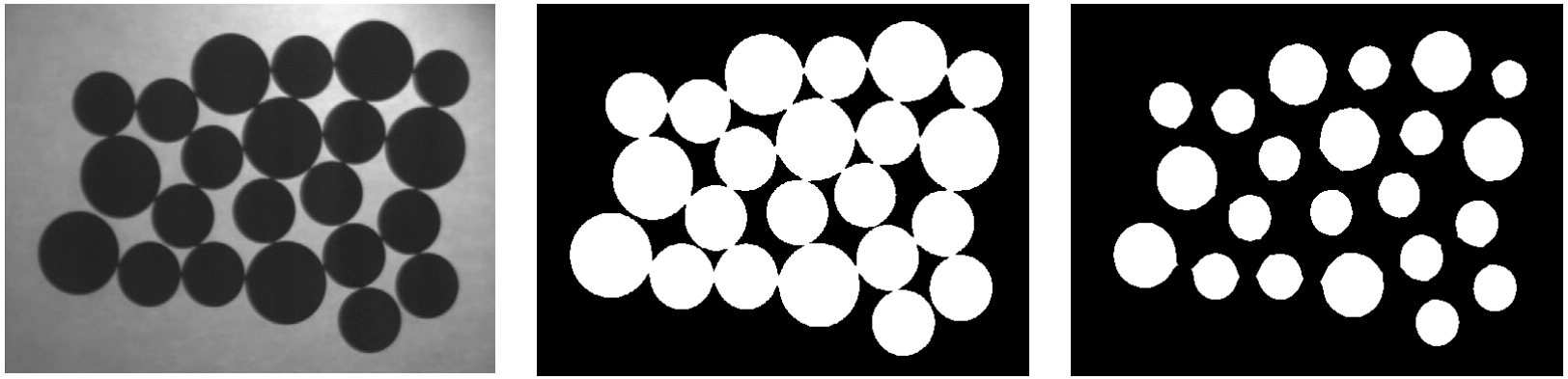
Erosion

- Counting objects (cells, coins) can be difficult if they touch
- Erosion can separate them



- Erosion can be used for edge detection too – giving pixels on the inside of the boundary

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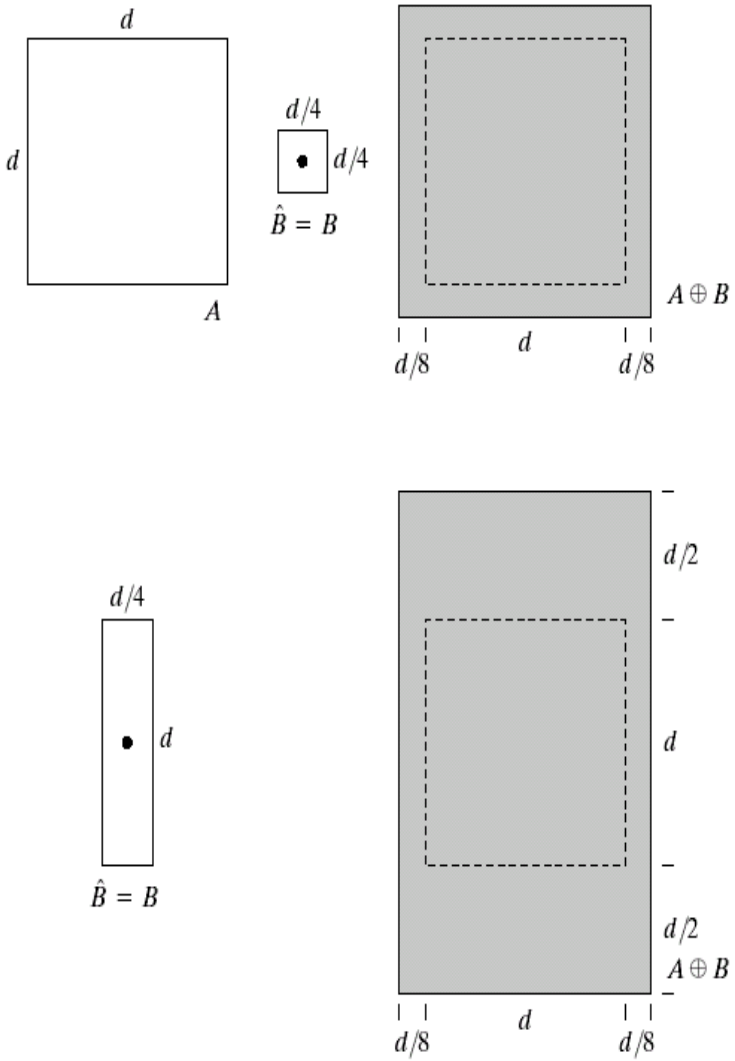
Asymmetric Structuring Elements

a b c
d e

FIGURE 9.4
(a) Set A.
(b) Square structuring element (dot is the center).
(c) Dilation of A by B, shown shaded.
(d) Elongated structuring element.
(e) Dilation of A using this element.



Dilation

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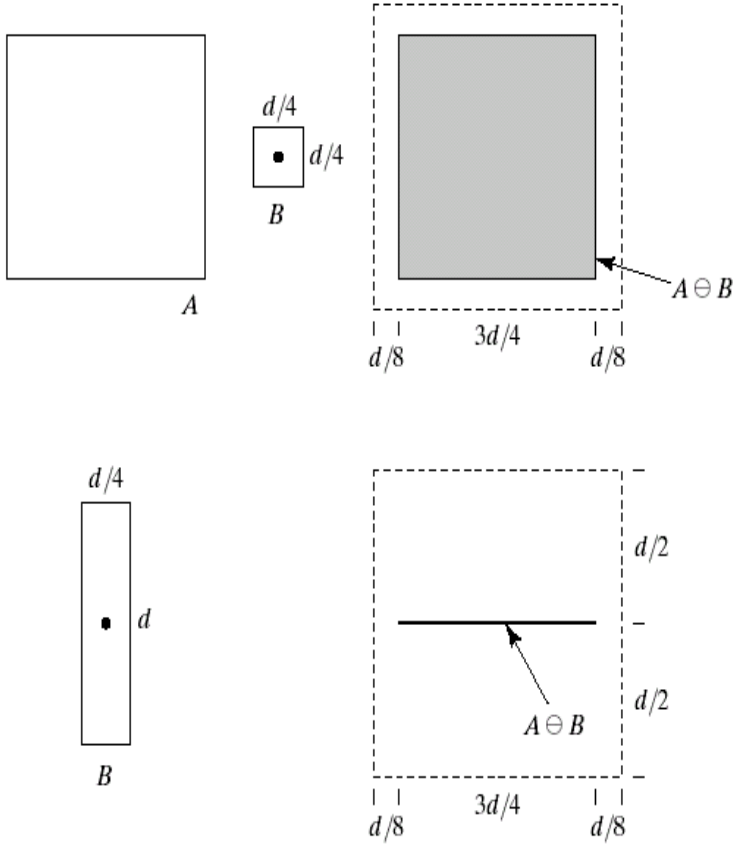
Asymmetric Structuring Elements



a b c
d e

FIGURE 9.6 (a) Set A. (b) Square structuring element. (c) Erosion of A by B, shown shaded. (d) Elongated structuring element. (e) Erosion of A using this element.

Erosion

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Break

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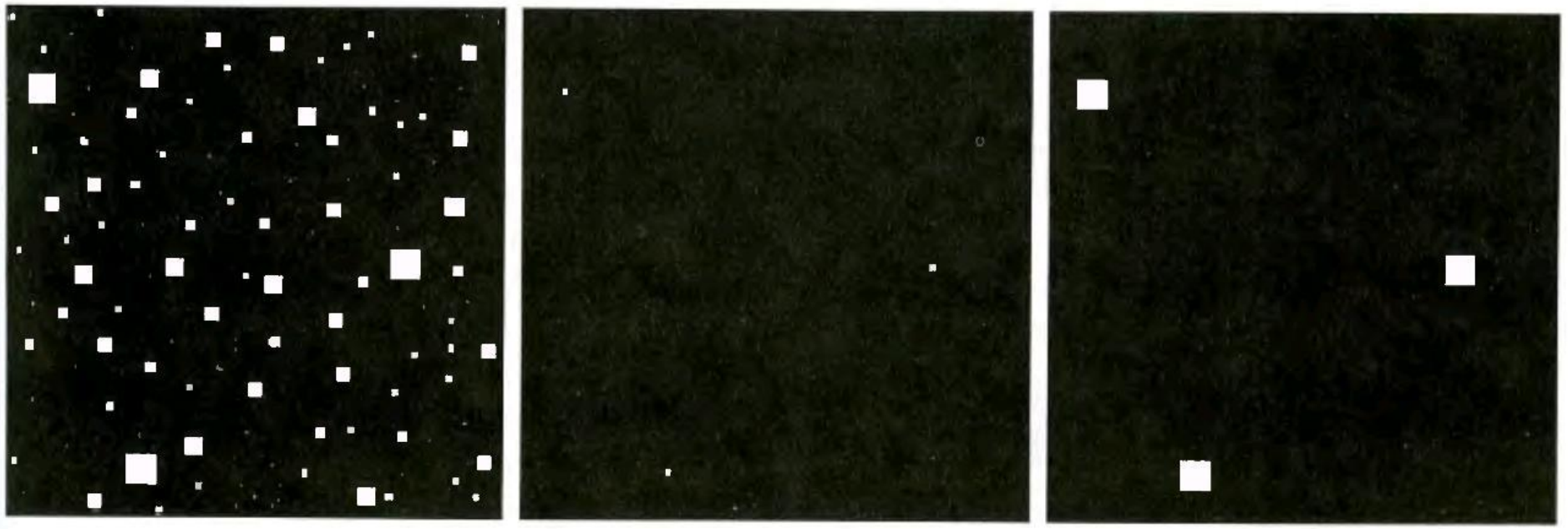
Opening & Closing

Combining Dilation and Erosion

Its rare to need only erosion and dilation, and they are much more useful when combined



a b c

FIGURE 9.7 (a) Image of squares of size 1, 3, 5, 7, 9, and 15 pixels on the side. (b) Erosion of (a) with a square structuring element of 1's, 13 pixels on the side. (c) Dilation of (b) with the same structuring element.

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Opening and Closing

Opening

- First erode A with B, then dilate A with B
- Smoothes contours, eliminates protrusions

Closing

- First dilate A with B, then erode A with B
- Smoothes sections of contours, fuses narrow breaks and long thin gulfs, eliminates small holes and fill gaps in contours

- These operations are dual to each other
- These operations can be applied multiple times, but have an effect only once (*the first time*)

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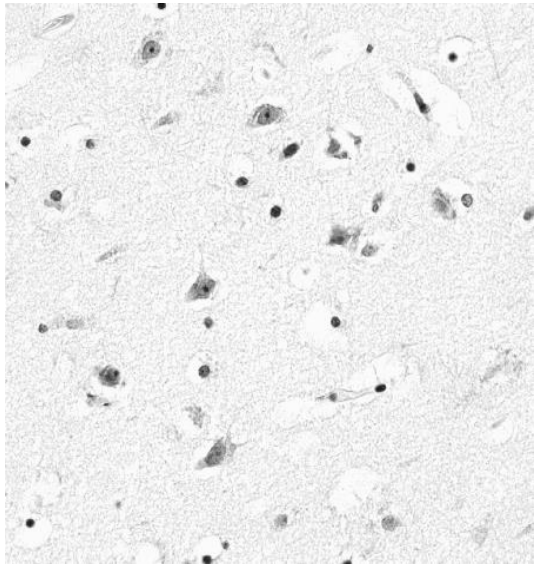
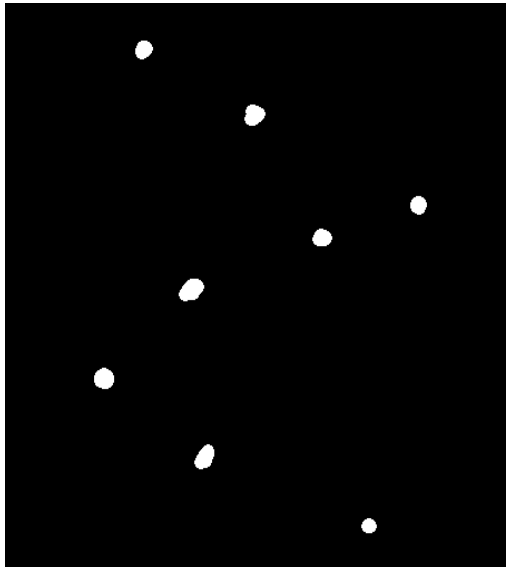
Opening

(a) Contains two kinds of cells: small, black ones and larger, grey ones. Thresholding with a value of *210* yields (b). Opening (b) using an *11* pixel circular structuring elements yields (c)



(a)

(b)



(c)

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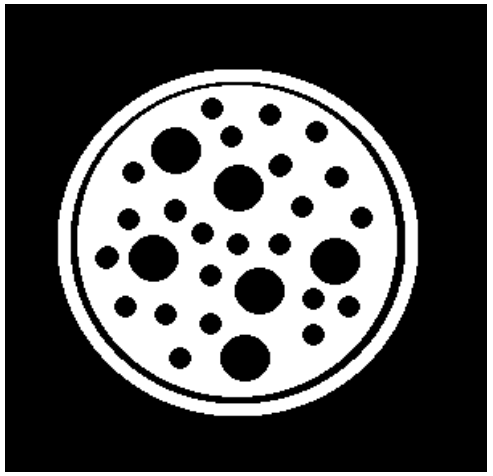
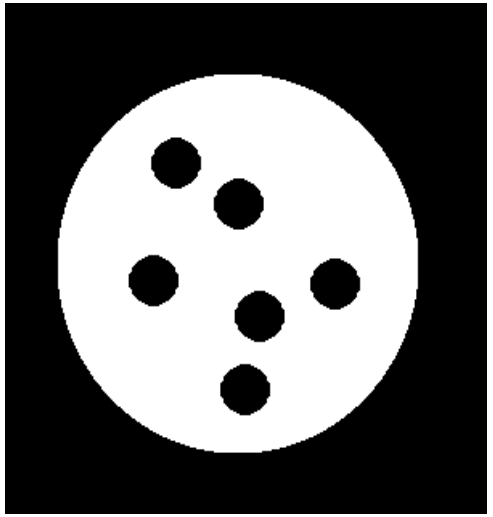
Closing



To retain only the large holes, we can simply perform a closing with a disk-shaped structuring element with a diameter larger than the smaller holes, but smaller than the large holes



The result of a closing with a 22 pixel diameter disk

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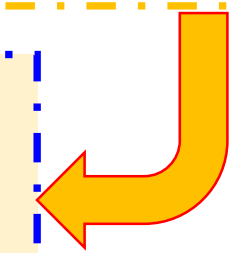
ROIs & Masks

The Whole Image

- All our examples so far have applied processes to the whole image – or section of image – input
- The tools we have become more powerful if we can apply them to selected pixels, and more powerful still if the selection can be automatic

OpenCV supports *Region of Interest Processing* through NumPy array slicing

- ROI Object Creation and Modification
- Mask creation
- ROI filtering



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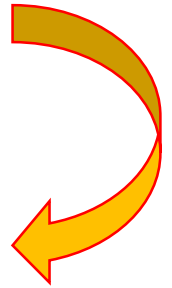
Python OpenCV

Supports filtering and inpainting of:



- Manually defined rectangular ROIs
- Interactively drawn bounding box ROIs
- ROIs defined by any appropriately sized binary image
- ROIs defined by colour

The concept of ROIs is very powerful; code can be written to allow the output of one process to determine where another is applied

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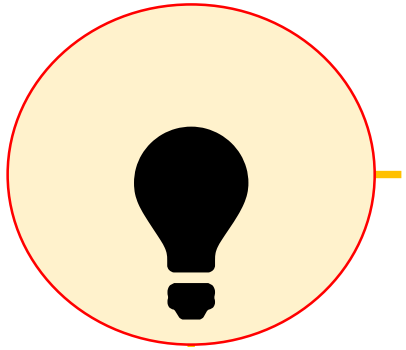
Summary



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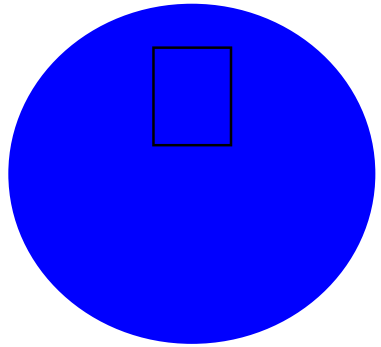

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NEXT:
Derivates and Edges