Computer Vision Basics

- Image Terminology
- Binary Operations
- Filtering
- Edge Operators

Digital Image Terminology:

0	0	0	0	1	0	0
0	0	1	1	1	0	0
0	1	95	96	94	93	92
0	0	92	93	93	92	92
0	0	93	93	94	92	93
0	1	92	93	93	93	93
0	0	94	95	95	96	95

pixel (with value 94)

its 3x3 neighborhood

region of medium intensity

resolution (7x7)

- binary image
- gray-scale (or gray-tone) image
- color image
- multi-spectral image
- range image
- labeled image

The Three Stages of Computer Vision

- low-level

  image → image

- mid-level

  image → features

- high-level

  features → analysis

Low-Level

sharpening

→

←

blurring

Low-Level

Canny →

original image

edge image

Mid-Level

ORT →

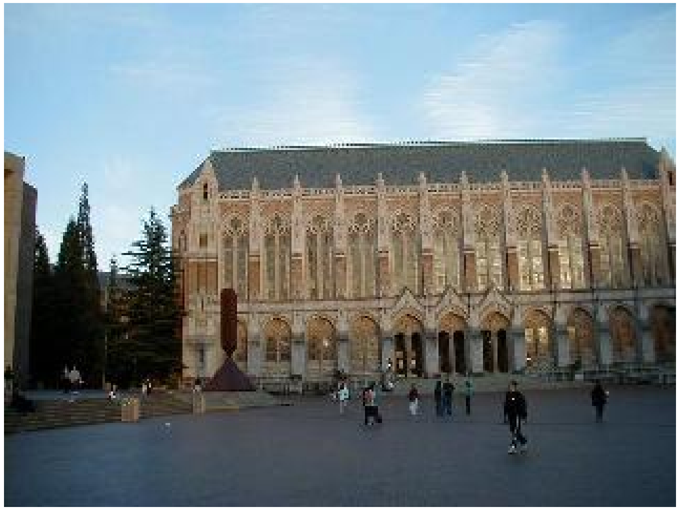
↓

data structure

edge image

circular arcs and line segments

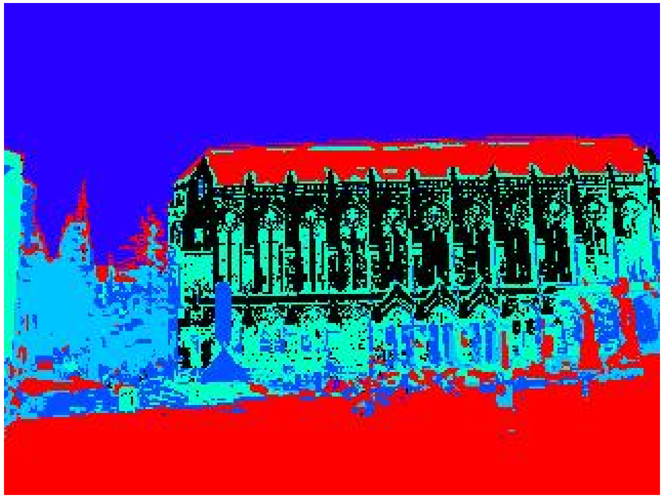
Mid-level



original color image

K-means clustering

(followed by connected component analysis)



regions of homogeneous color

data structure

Low- to High-Level

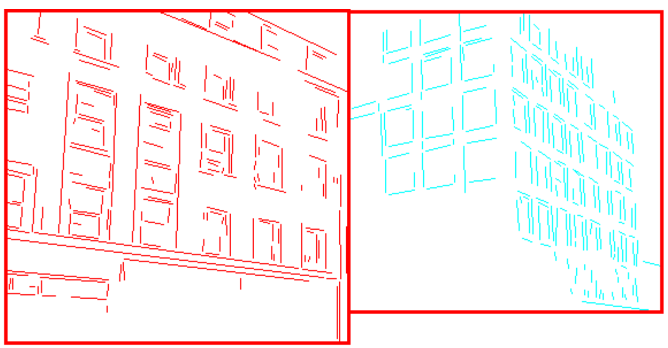
low-level →

edge image

↓ mid-level

consistent line clusters

← high-level



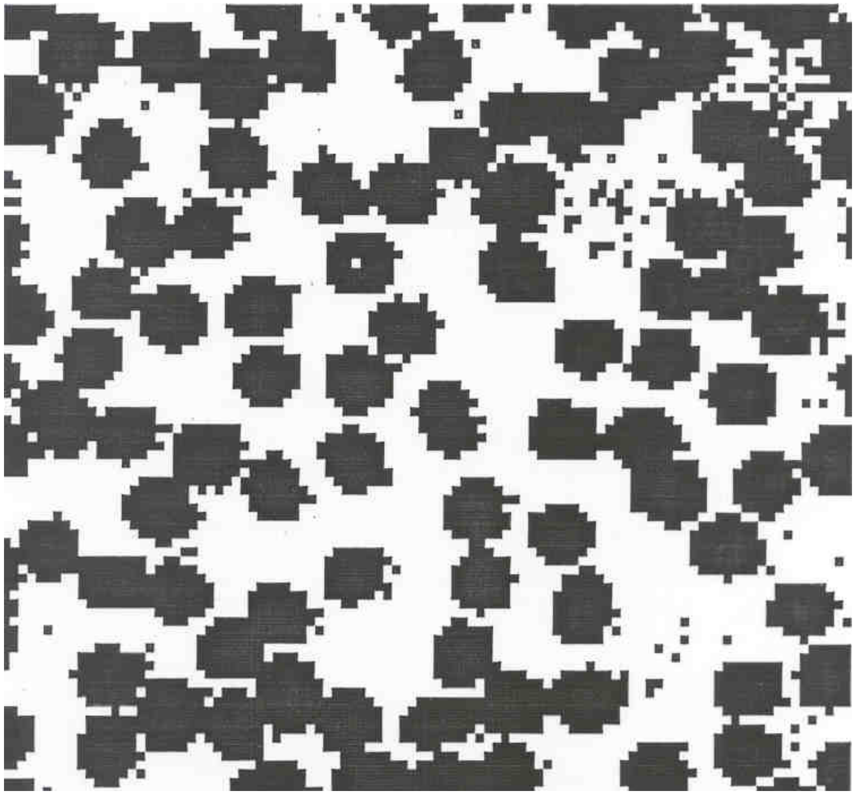
Binary Image Analysis

- used in a variety of applications:
  part inspection
  riveting
  fish counting
  document processing

- consists of a set of image analysis operations that are used to produce or process binary images, usually images of 0's and 1's.

```
0001001000001000
0001111000001000
0001001000001000
```

Example: red blood cell image



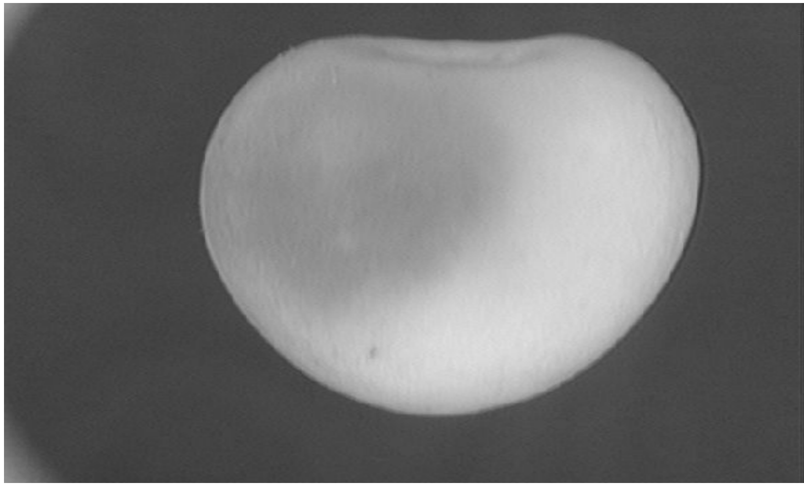
- Many blood cells are separate objects
- Many touch – bad!
- Salt and pepper noise from thresholding
- What operations are needed to clean it up?

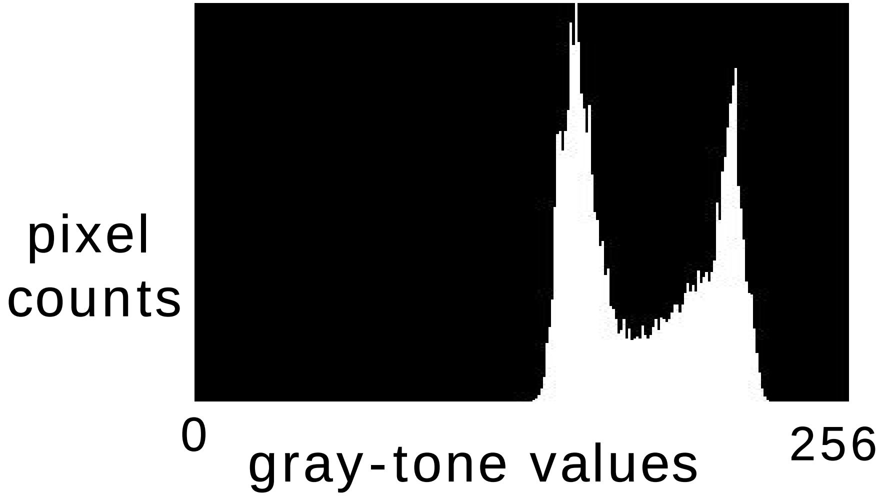
Useful Operations

1. **Thresholding a gray-tone image**
2. **Determining good thresholds**
3. **Filtering with mathematical morphology**
4. **Connected components analysis**
5. **Numeric feature extraction**
   - **location features**
   - **gray-tone features**
   - **shape features ...**

Thresholding

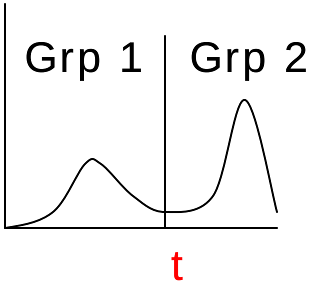
- Background is black
- Healthy cherry is bright
- Bruise is medium dark
- Histogram shows two cherry regions (black background has been removed)





Automatic Thresholding: Otsu's Method

Assumption: the histogram is bimodal



Method: find the threshold t that minimizes the weighted sum of within-group variances for the two groups that result from separating the gray tones at value t.

Works well **if** the assumption holds.

Thresholding Example

original image

pixels above threshold

Mathematical Morphology

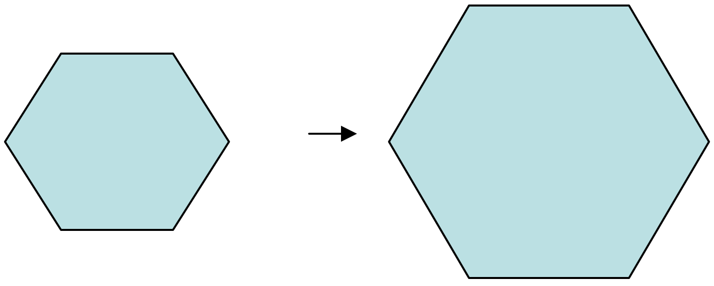
(Dilation, Erosion, Closing, Opening)

• Dilation

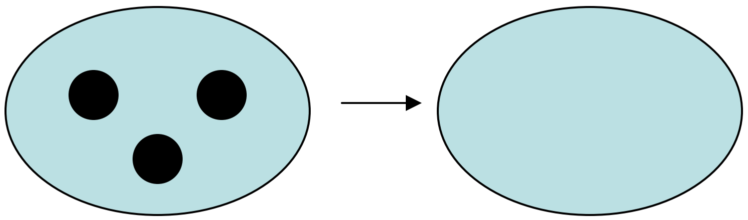
Dilation expands the connected sets of 1s of a binary image.

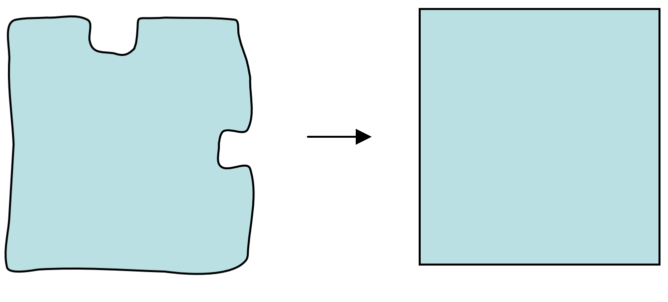
It can be used for

1. growing features



2. filling holes and gaps



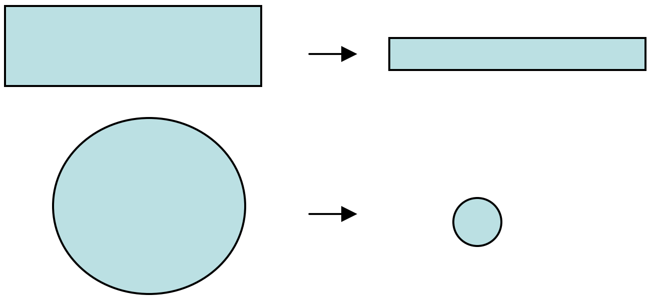


• Erosion

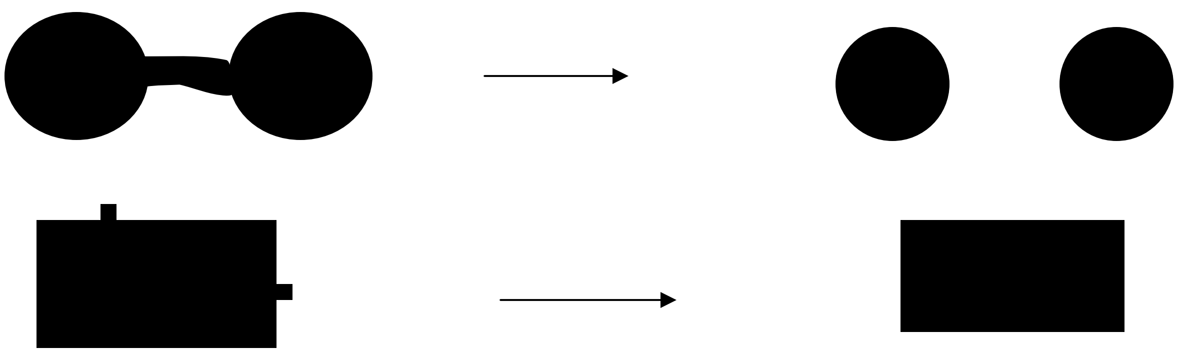
Erosion shrinks the connected sets of 1s of a binary image.

It can be used for

1. shrinking features



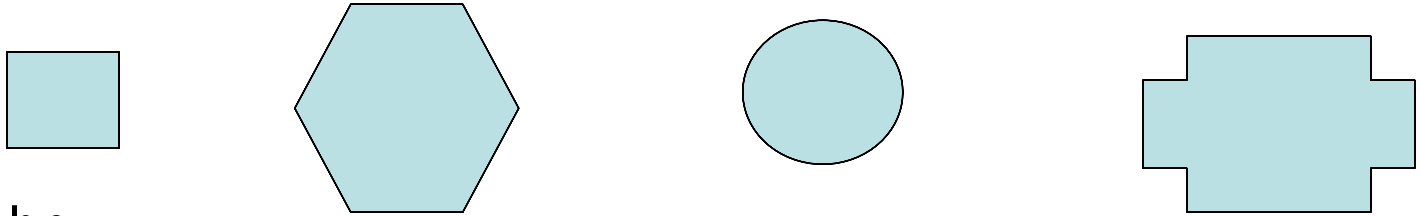
2. Removing bridges, branches and small protrusions



Structuring Elements

A structuring element is a shape mask used in the basic morphological operations.

They can be any shape and size that is digitally representable, and each has an origin.



box hexagon disk something

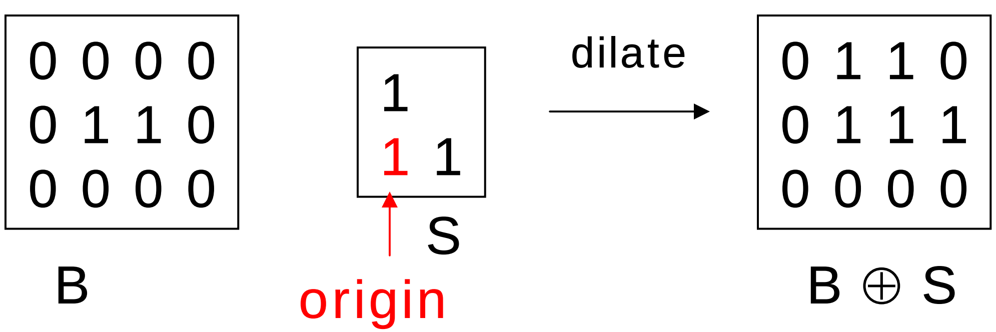
box(length,width) disk(diameter)

Dilation with Structuring Elements

The arguments to dilation and erosion are

1. **a binary image B**
2. **a structuring element S**

dilate(B,S) takes binary image B, places the origin of structuring element S over each 1-pixel, and ORs the structuring element S into the output image at the corresponding position.



Erosion with Structuring Elements

erode(B,S) takes a binary image B, places the origin of structuring element S over every pixel position, and ORs a binary 1 into that position of the output image only if every position of S (with a 1) covers a 1 in B.

origin

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

B

1
1
1

S

erode →

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

$B \ominus S$

Opening and Closing

- Closing is the compound operation of dilation followed by erosion (with the same structuring element)

- Opening is the compound operation of erosion followed by dilation (with the same structuring element)

1	1	1	1	1	1	1	
			1	1	1	1	
			1	1	1	1	
		1	1	1	1	1	
			1	1	1	1	
		1	1				

a) Binary image B

1	1	1
1	1	1
1	1	1

b) Structuring Element S

1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1
	1	1	1	1	1	1	1
	1	1	1	1	1	1	1
	1	1	1	1	1	1	1
	1	1	1	1	1	1	1
	1	1	1	1			

c) Dilation $B \oplus S$

				1	1		
				1	1		
				1	1		

d) Erosion $B \ominus S$

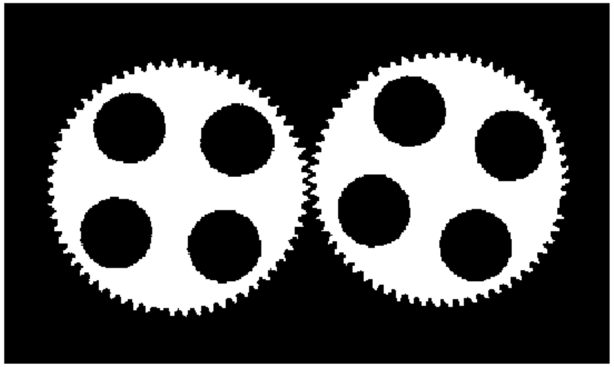
	1	1	1	1	1	1	
		1	1	1	1	1	
		1	1	1	1	1	
		1	1	1	1	1	
		1	1	1	1	1	
		1	1				

e) Closing $B \bullet S$

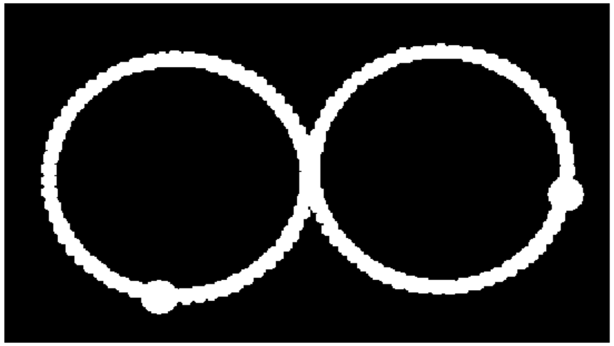
			1	1	1	1	
			1	1	1	1	
			1	1	1	1	
			1	1	1	1	
			1	1	1	1	

f) Opening $B \circ S$

Application: Gear Tooth Inspection



original binary image



detected defects

Connected Components Labeling

Once you have a binary image, you can identify and then analyze each **connected set of pixels**.

The connected components operation takes in a binary image and produces a **labeled image** in which each pixel has the integer label of either the background (0) or a component.

original

thresholded

opening+closing

components

Methods for CC Analysis

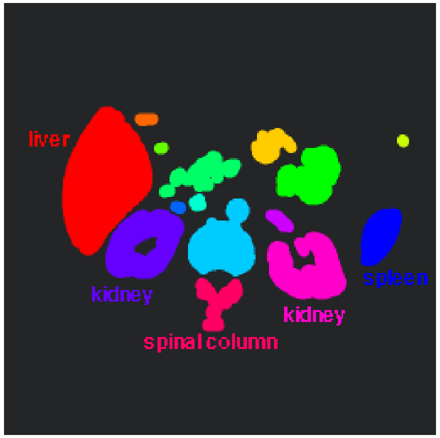
1. Recursive Tracking (almost never used)
2. Parallel Growing (needs parallel hardware)
3. Row-by-Row (most common)

   a. propagate labels down to the bottom, recording equivalences

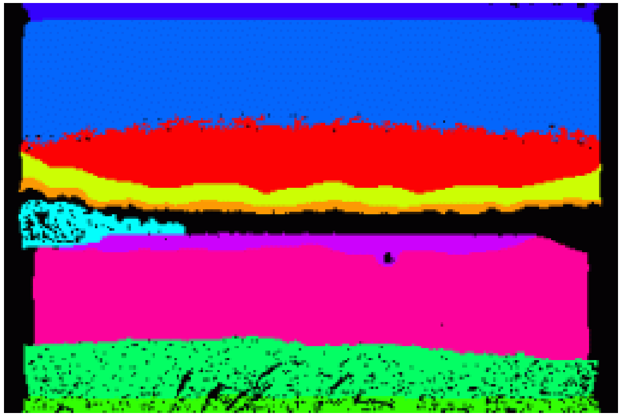
   b. Compute equivalence classes

   c. Replace each labeled pixel with the label of its equivalence class.

Labelings shown as Pseudo-Color



connected components of 1's from cleaned, thresholded image



connected components of cluster labels