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

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The Three Stages of Computer Vision

- low-level

    image ⟶ image

- mid-level

    image ⟶ features

- high-level

    features ⟶ analysis

Low-Level

sharpening

→

←

blurring

Low-Level

original image

Canny →

edge image
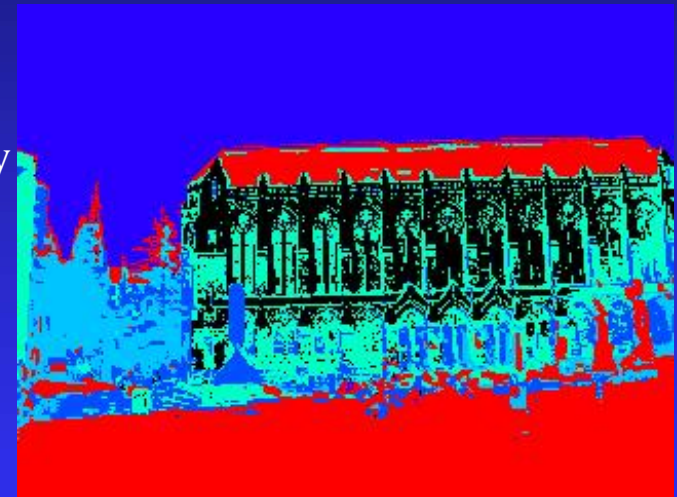
Mid-Level

edge image

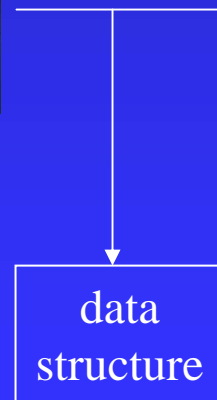ORT →

data structure

circular arcs and line segments

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Mid-level

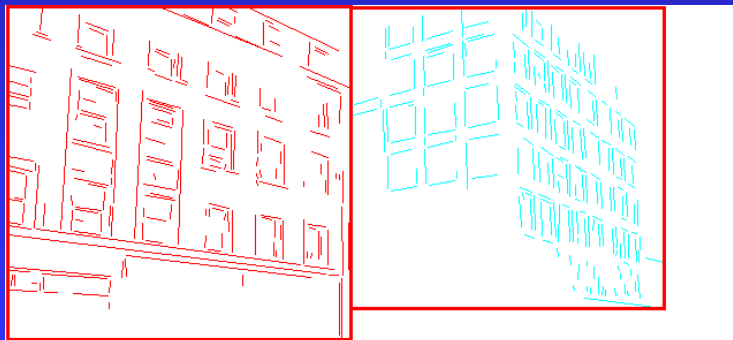K-means
clustering

(followed by
connected
component
analysis)

original color image

regions of homogeneous color

data
structure

Low- to High-Level

low-level →

edge image

mid-level ↓

consistent line clusters

← high-level

Building Recognition

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.

```
000100100001000
000111110001000
000100100001000
```

Example: red blood cell image
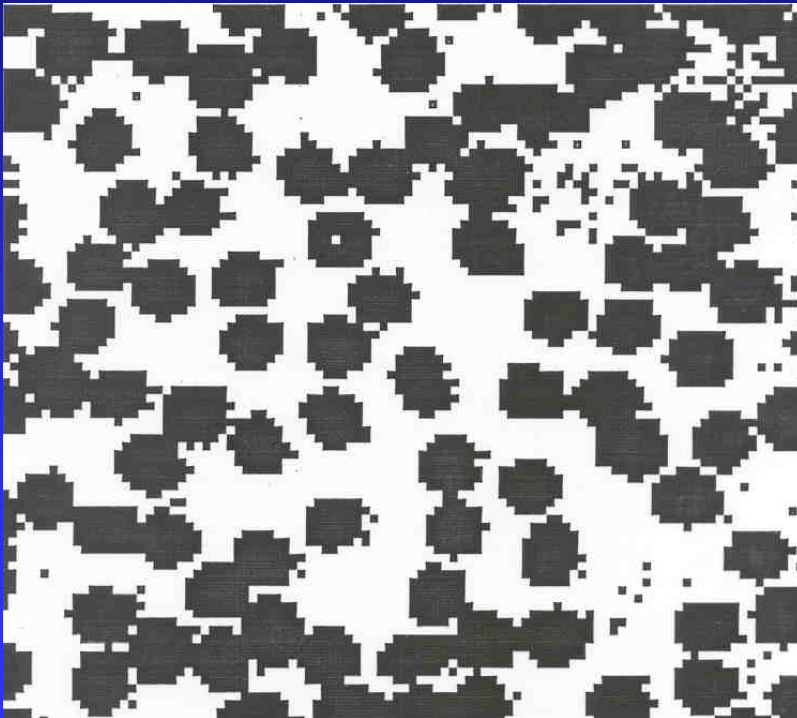
- Many blood cells are separate objects
- Many touch – bad!
- Salt and pepper noise from thresholding
- How useable is this data?
- What operations are needed to clean it up?

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
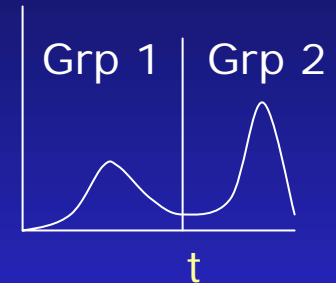- Histogram shows two cherry regions (black background has been removed)
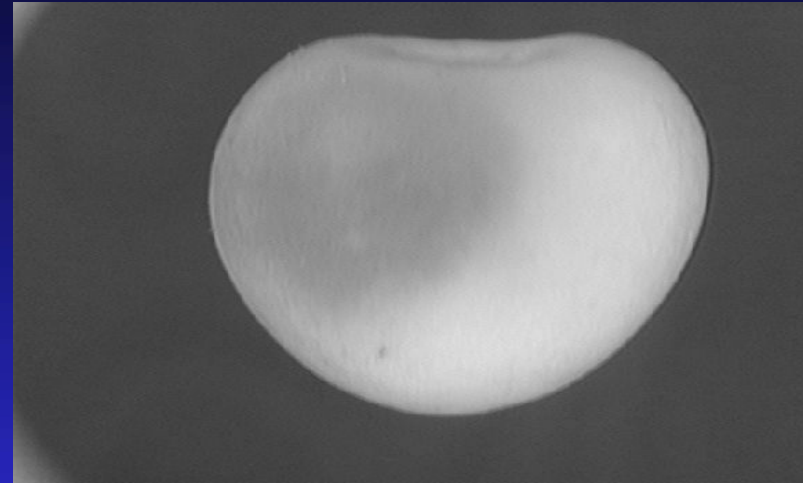
pixel counts
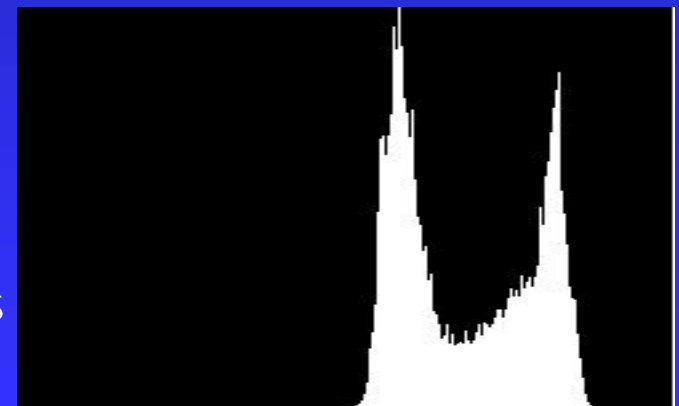
0   gray-tone values   256

Automatic Thresholding: Otsu's Method

Assumption: the histogram is bimodal

Grp 1 | Grp 2
t

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

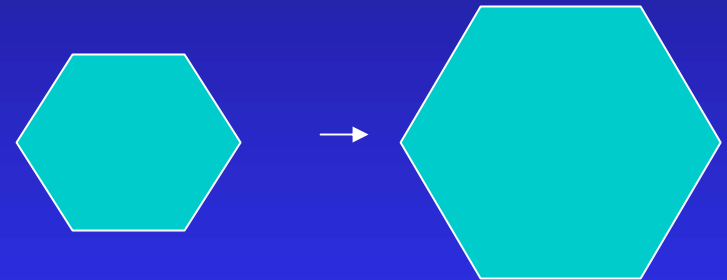pixels above threshold

Mathematical Morphology

(Dilation, Erosion, Closing, Opening)
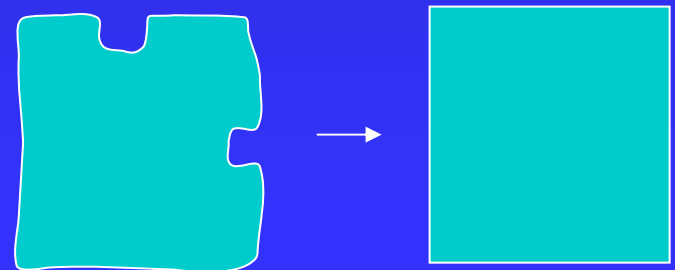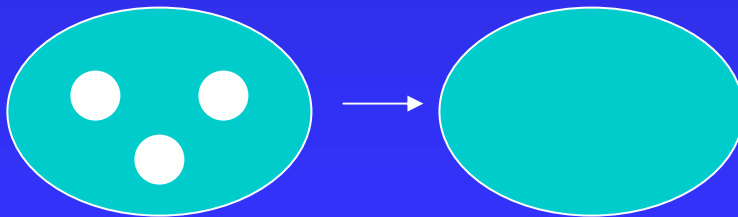
- ## Dilation

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

It can be used for
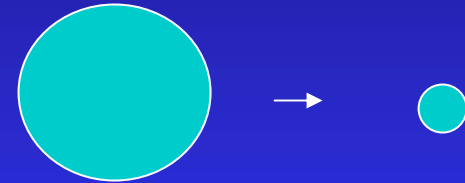
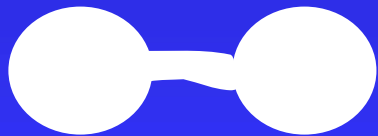1. growing features

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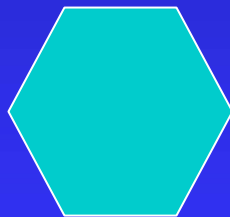
A **structuring element** is a shape mask used in the basic morphological operations.

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

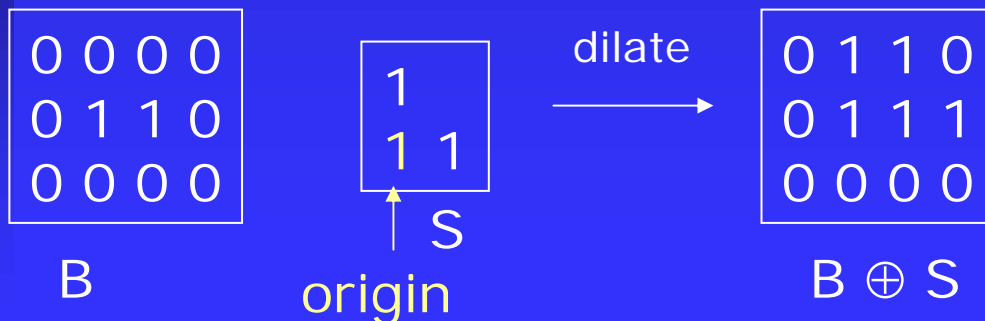box

hexagon

disk

something

box(length,width)

disk(diameter)

Dilation with Structuring Elements

The arguments to dilation and erosion are

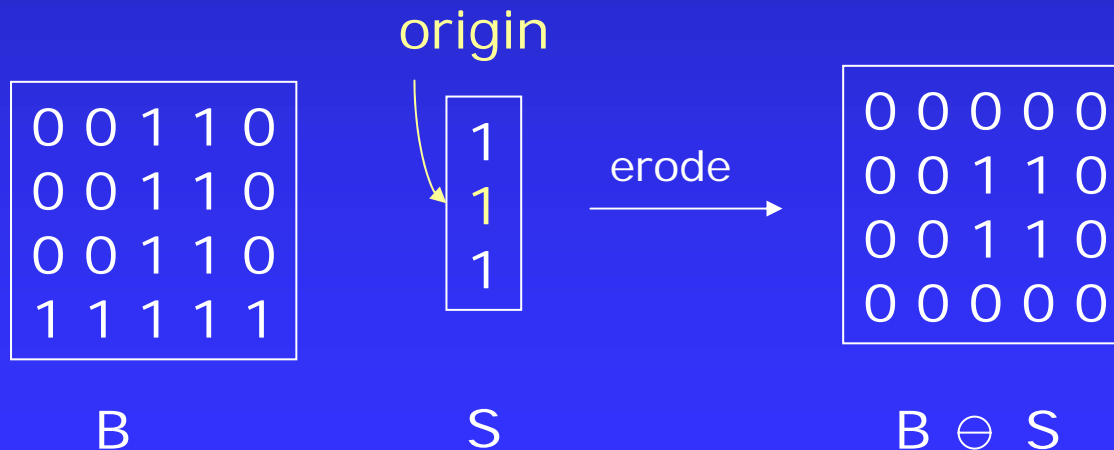1. **a binary image B**
2. **a structuring element S**

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.

```
0 0 0 0          1            0 1 1 0
0 1 1 0          1 1    dilate 0 1 1 1
0 0 0 0                  →     0 0 0 0
```

S
↑
origin

B

B ⊕ S

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          1              0 0 0 0 0
0 0 1 1 0          1    erode     0 0 1 1 0
0 0 1 1 0          1   ------>    0 0 1 1 0
1 1 1 1 1                         0 0 0 0 0
```

B   S   B ⊖ S

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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)

a) Binary image B

b) Structuring Element S

c) Dilation $B \oplus S$

d) Erosion $B \ominus S$

e) Closing $B \bullet S$

f) Opening $B \circ S$

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Application: Gear Tooth Inspection
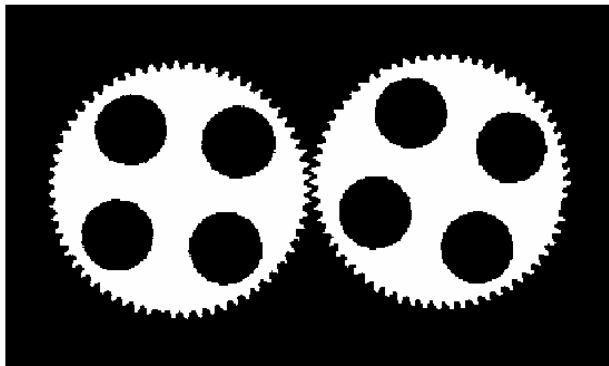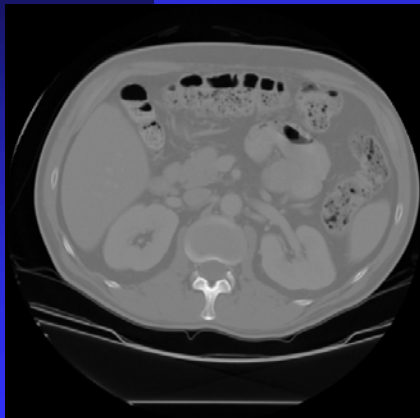
original binary image
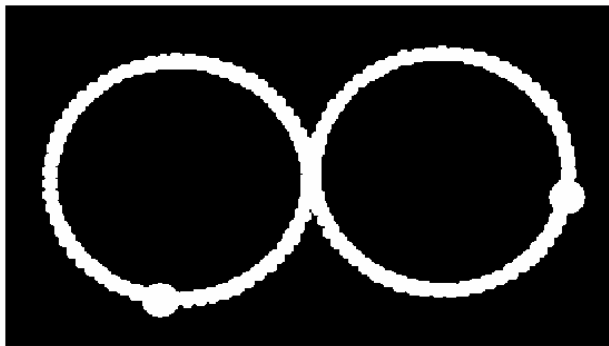
detected defects

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
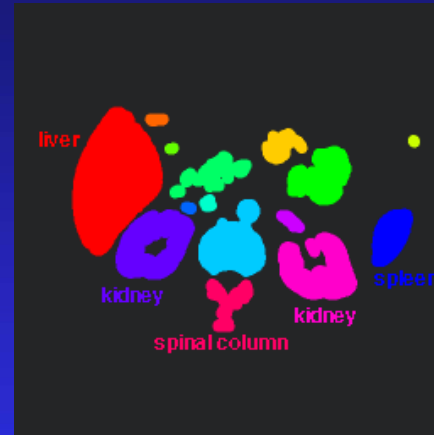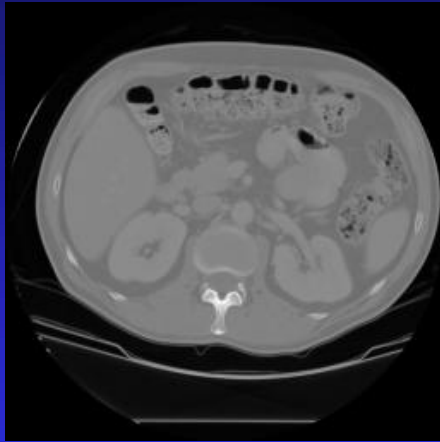
connected
components
of 1's from
cleaned,
thresholded
image
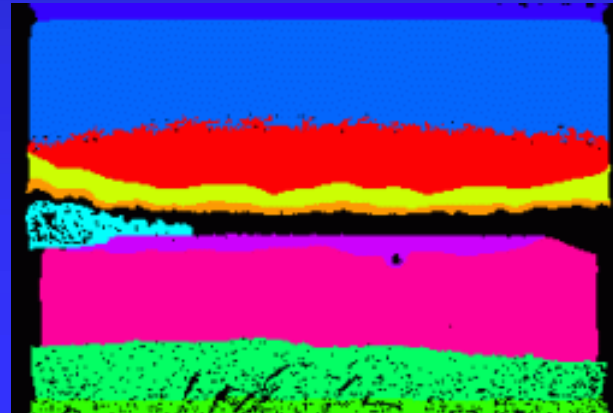
connected
components
of cluster
labels