13.4 Segmentation

partion a picture into connection regions which are homogeneous (in some sense) and identified by a unique label.

inclustrually our goal is to locate and identify parts.

13.4.1 Segmentation by thresholding

object brightness ≥ T

background brightness < T

T is called threshold.

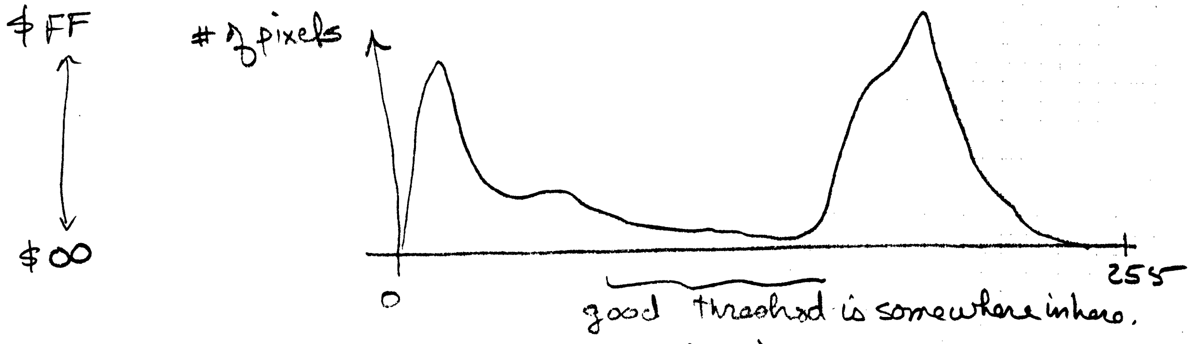
how do you pick threshold?

thresholding is usually local, i.e. a single threshold usually never works over entire image

block thresholding - partition image into thresholds and use different thresholds on each block.

typical block size is 32x32 or. 64x64

<u>choosing a threshold</u>



typical histogram

another strategy pick $i_{avg} + \Delta i$

where i_{avg} is the average and Δi is some small increment

thresholding

if $p(x,y) > T$ set to 1, belongs to object

$p(x,y) < T$ set to ∅, belongs to background

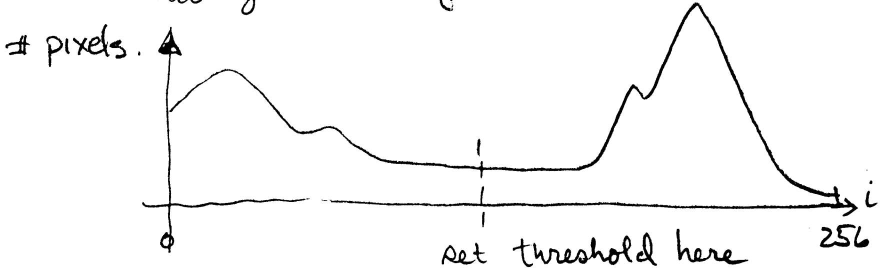
local thresholding

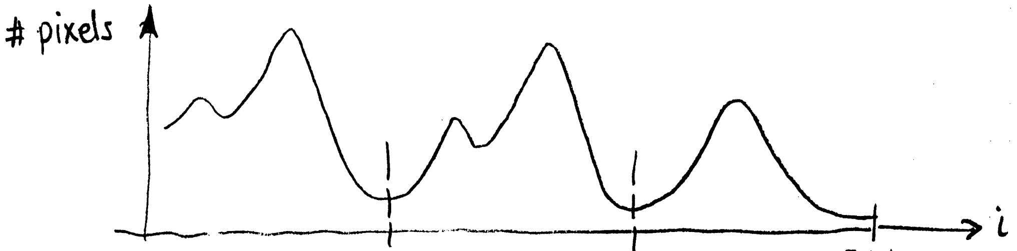
- single T is never good for entire scene
- camera sensitivity drops off due to parabolic distortion, i.e. electron bean not normal to camera face, and vignetting, lenses transmit light more efficiently near the center than near the edges. Usually $I \sim \cos^4\theta$
- block thresholding – partition picture into blocks, say 32 x 32 or 64 x 64 and use varying threshold.

choosing a threshold

simplest scheme average f over block and choose $T = f_{AVG} + \Delta$ where Δ might be $5/256$, i.e. set just a little avove the average.

histogram analysis





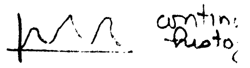
not clear where to set threshold
might want three levels.

5 Regions and image segmentation (Ballard & Brown)

how to choose threshold

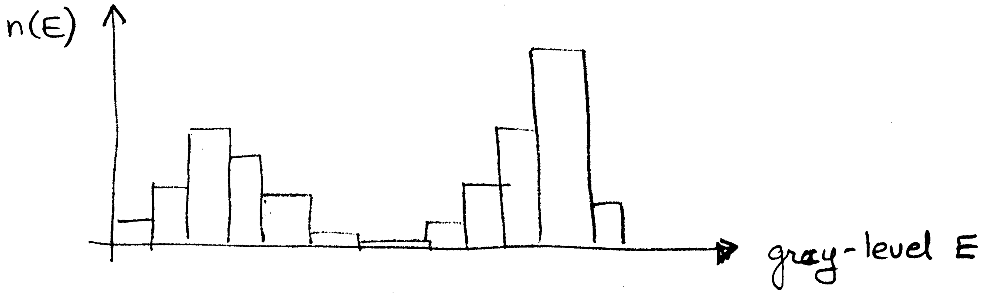
$P(x)$ cumulative brightness distribution

$p(x)$ brightness distribution function

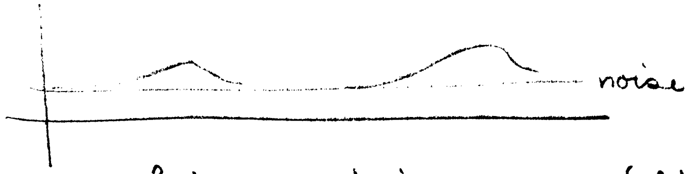


$p(x)\,\delta x$ fraction of the image with brightness in $[x, x+\delta x]$

histogramming



when we are lucky this occurs.



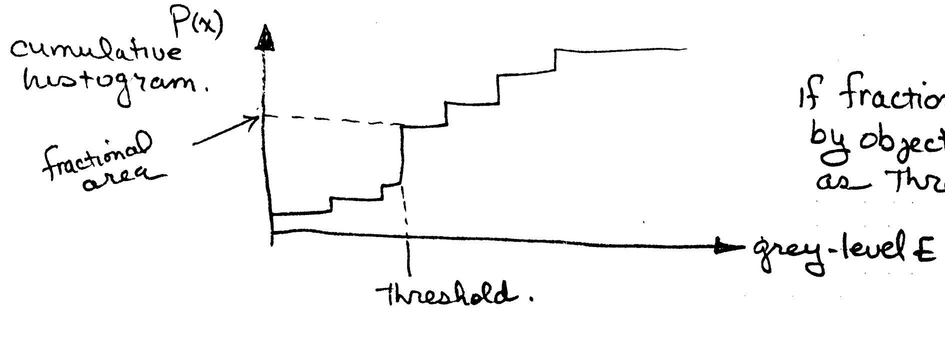
this is a very bad histogram

what we can do is average neighboring cells to reduce noise

this is very difficult to optimize → can also make a coarser histogram by pooling adjacent gray-levels.

problems

- picture cells on edges of object may have intermediate grey levels which confuse histogram
  function of resolution and perimeter/area of object.
- if object or image is too small not enough data to get a peak.



If fraction of area occupied by object is known, set that as threshold.

often best binary images are made from structured lighting or range vision.

Mention triangulation — Consight

5.3 Spatial coherence.

salt & pepper noise can often be removed
— at the grey scale level by filtering

5.4 Image segmentation (region growing)
- break object into regions of like properties for additional processing

can use grey scale
texture
geometry
color.

local technique — pixels are placed in a region on the basis of their properties or the properties of their close neighbors

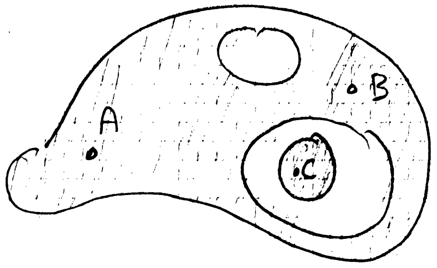
global techniques — pixels are grouped into regions on the basis of the properties of large numbers of pixels distributed throughout the image

split/merge techniques — combine regions using graph structures

Horn

Binary Images: Topological properties

how do we identify individual objects in an image



A is connected to B but not to C

the general idea:

① label a point (anywhere $b_{ij} = 1$)

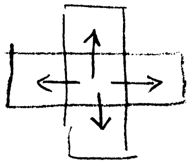
② label its neighbors

③ label the neighbors of the neighbors

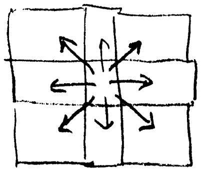
repeat until no more neighbors to be labeled.

can label both objects and holes

what do we mean by neighbors (depends upon tesselation, i.e. area sampling)

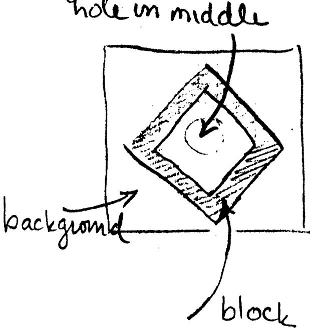


4 connectedness.



8 connectedness

problems in handling lines



⇒

0	1	0
1	0	1
0	1	0

by four connectedness ⇒ 4 objects
at least 2 background regions

eight connectedness ⇒ 1 object yet the hole in the center is connected to the background

one solution ⇒ use 8 connectedness for the ob
4 " for the backg

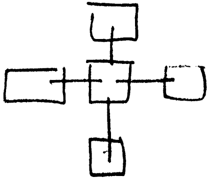
but this is a heuristic

Region Labeling

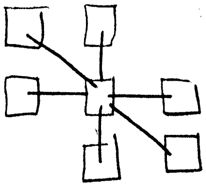
picture is partitioned in pixels of pure black and white

how to connect?

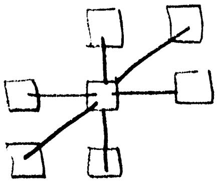
topologically, how do you connect?



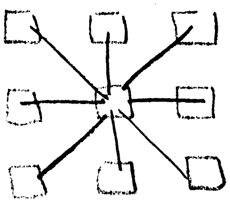
4 connectivity



NW-SE 6 connectivity



NE-SW 6 sonnectivity

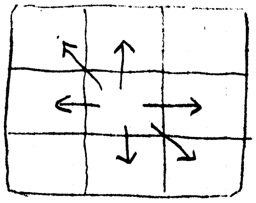


8-connectivity

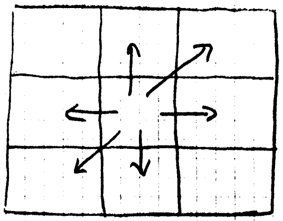
region growing — label a pixel and if a connected pixel has the same property, i.e. is 1, than label that pixel the same, continue recursively another solution symmetry

if A is a neighbor of B ⇒ B is a neighbor of A

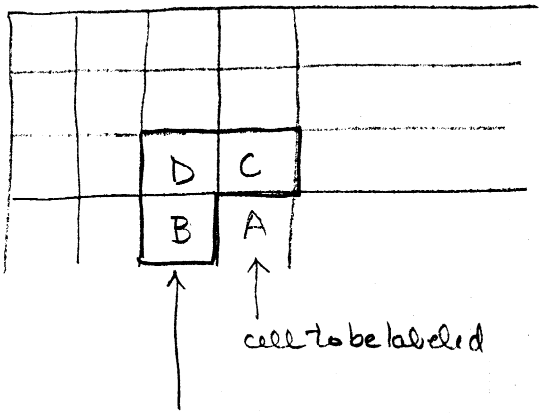
use 6 connectedness



or



<u>sequential</u> labeling

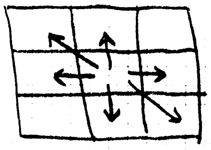


cell to be labeled

have previously been labeled.

scan Left to right
top to bottom

use left hand six-connectedne



if A=0 no labeleng

if A = 1 and D is labeled copy label

" B "

" C "

" and neither D, B,C is labeled new label

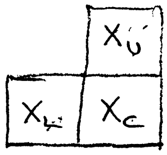
" and B and C have different labels ⇒ labels are really the same.
(NOTE : B and C are **NOT** neighbors)

at end of algorithm update label list removing duplicates, assigning unique labels, etc.

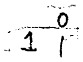
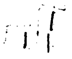
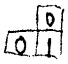
blob coloring

→ given a binary image containing four-connected blobs of 1's on a background of 0's, assign each blob a different label, i.e. color.

Scan the image left to right, top to bottom with the L-shaped template shown below:



Algorithm 5.1 : Blob coloring
Let the initial color, k = 1. Scan L→R, top→bottom.

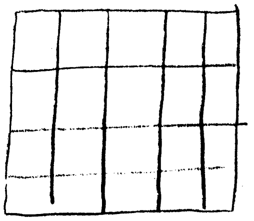
```
If $f(x_c)=0$ then continue
else
    begin
    if $f(X_u)=1$ and $f(X_L)=0$ then color $(X_c) :=$ color $(X_u)$
    if $f(X_L)=1$ and $f(X_u)=0$ then color $(X_c) :=$ color $(X_L)$
    if $f(X_L)=1$ and $f(X_u)=1$ then
        begin
        color $(X_c) :=$ color $(X_L)$
        color $(X_c)$ is equivalent to color $(X_u)$        ← key
        end

    if $f(X_L)=0$ and $f(X_u)=0$
    then color $(X_c) = k$ ; $k := k+1$
     comment : new color

    end.
```

parallel, local algorithms

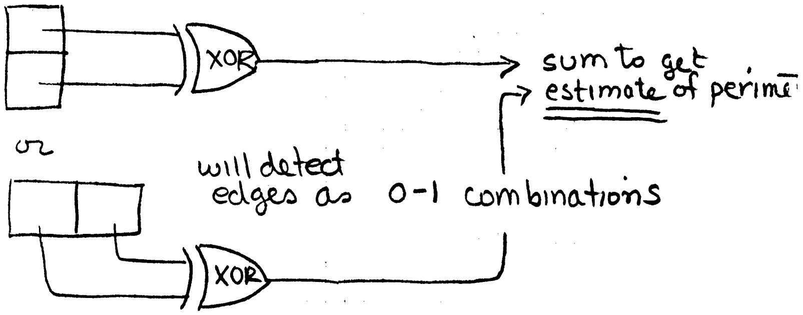
- all at once
- recursive



$\Longrightarrow$ local processor

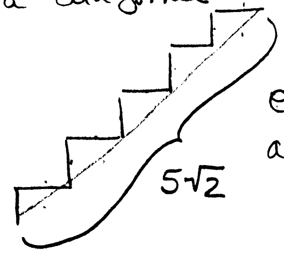
single cell ⟶ sum to get area

pattern recognition of edges for perimeter


XOR
sum to get estimate of perime
or
will detect edges as 0-1 combinations
XOR

Trick: in general the perimeter will be overestimated because it has become ragged due to spatial quantization so divide by some estimate of overestimation.

Consider a diagonal line.



estimate is 10
actual is $5\sqrt{2}$

ratio of estimate to actual is $\sqrt{2}$
so divide by $\sqrt{2}$ to get better estimate

Repeat for all angles and average to get average overestimation of $\frac{4}{\pi} \approx 1.27$

Local counting

$$\underset{\substack{\uparrow \\ \text{can be} \\ \text{computed} \\ \text{locally}}}{\text{Euler \#}} = \underbrace{\text{\# of objects} - \text{\# of holes.}}_{\text{cannot be computed locally.}}$$

3. Binary Machine Vision

regions (produced by labeling algorithm) }
segment (signature segmentation) } — compute global properties

↓

classification of property vectors using statistical pattern recogniti

3.2 Region properties

labeling operator ⟶ property measurements

- histogram of gray level values
- mean gray level value
- variance, skewness, kurtosis *
- co-occurrence *
- gray level second moments — way a region is sha and orientation
- area
- bounding rectangle
- extremal points
- second central moments
- orientation
- shape property — area, number of holes, length of perimeter, length of major and minor axes of best fitting ellipse, orientation of major axis

shape descriptors (developed at SRI about 1960).

average grey value
maximum grey value
minimum grey value
} before thresholding

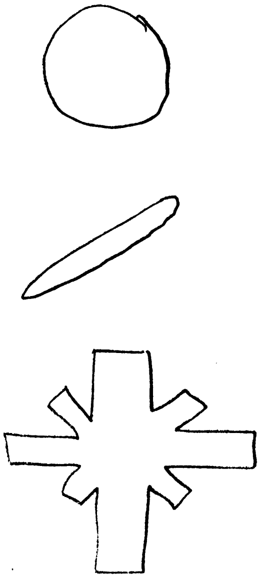
A area = # of pixels in region (after thresholding)

P perimeter = # of pixels in a region that are adjacent to a pixel not in a region.

D diameter = maximum chord, distance between most distant points on a boundary.

thinness $T_A = \frac{P^2}{A}$

$T_B = \frac{D}{A}$



T_A	T_B	
small	large.	(alr depenc upon wheti objec larg or si
↑		
large	large	
↓		
large	small	

(Scale is vertical NOT horizontal)

↑

more intuitive measure.

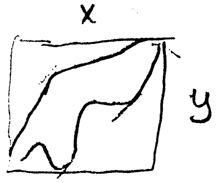
center of gravity (actually first moment)

$$m_x = \frac{1}{N}\sum x \longrightarrow \frac{\iint x\, b(x,y)\, dx\, dy}{\iint b(x,y)\, dx\, dy}.$$

$$m_y = \frac{1}{N}\sum y$$

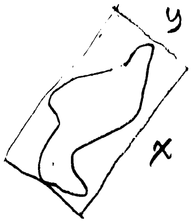
X-Y aspect ratio

length / width ratio of bounding rectangle



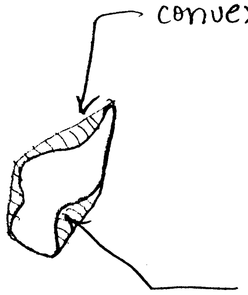
aspect ratio = $\frac{y}{x}$

minimum aspect ratio $= \frac{y}{x}$



muchharder to compute
since you have to minimize function.

convex hull



convex hull

convex discrepancy is the area between the object and its convex hull.

moments:

$$m_{pq} = \sum x^p y^q$$

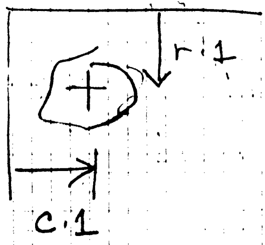
there are invariant moments - i.e. invariant to translation, rotation & scale change.

center of gravity $m_x = \frac{m_{10}}{m_{00}}$ $m_y = \frac{m_{01}}{m_{00}}$

$$m_{00} = \text{area.}$$

first invariant moment: $\dfrac{m_{00}\, m_{20} - m_{10}^2 + m_{00}\, m_{02} - m_{01}^2}{m_{00}^3}$

Area $A = \sum_{(r,c) \in R} 1$

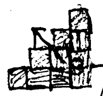


Centroid $\bar{r} = \frac{1}{A} \sum_{(r,c) \in R} r$

$$\bar{c} = \frac{1}{A} \sum_{(r,c) \in R} c$$

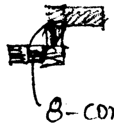
perimeter

No holes



when
connected is used for connectivity (labeling)
perimeter pixels are four connected

when 4-connectivity is used,
perimeter pixels are eight connected.



8-connectivity

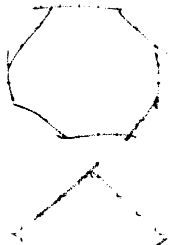
$$P_4 = \{(r,c) \in R \mid N_8(r,c) - R \neq 0\}$$

$$P_8 = \{(r,c) \in R \mid \underbrace{N_4(r,c) - R \neq 0}_{\text{connectivity to external region}}\}$$

$$|P| = \# \underbrace{\{k \mid (r_{k+1} c_{k+1}) \in N_4(r_k, c_k)\}}_{\text{the sum of straight segments}} + \sqrt{2}\, \# \underbrace{\{k \mid (r_{k+1}, c_{k+1}) \in N_8(r_k, c_k) - N_4(r_k}_{\text{the sum of diagonal components.}}$$

8 connected — four conned boundary pixels

$\frac{\|P\|}{A}$ sometimes used as measure of shape's compactness or circularity



$\#\{$neighboring 4-connected pixels$\}$?

length of border ?

common properties

- radius of circumscribing circle
- radius of maximum inscribed circle
- mean distance μ_R from centroid to shape boundary
- standard deviation σ_R of distance from centroid to shape boundary

$$\mu_R = \frac{1}{K} \sum_{k=0}^{K-1} \| (r_k, c_k) - (\bar{r}, \bar{c}) \|$$

$$\sigma_R^2 = \frac{1}{K} \sum_{k=0}^{K-1} \left[\| (r_k, c_k) - (\bar{r}, \bar{c}) \| - \mu_R \right]^2$$

1. as shape becomes more circular $\frac{\mu_R}{\sigma_R}$ increases

2. $\frac{\mu_R}{\sigma_R}$ similar for digital and similar continuous shapes

⇒ 3. orientation and area independent

# of sides to a regular digital polygon N estimated by.

$$N \cong 1.4111 \left(\frac{\mu_R}{\sigma_R} \right)^{0.4724}$$

first order properties

avg. gray level $\mu = \frac{1}{A} \sum_{(r,c) \in R} I(r,c)$

gray level variance

$$\sigma^2 = \frac{1}{A} \sum_{(r,c) \in R} \left[I(r,c) - \mu \right]^2 \overset{?}{=} \left[\frac{1}{A} \sum_{(r,c) \in R} I(r,c) \right]^2 - \mu^2$$