binary machine vision   Chapter 2 Kasturi
Chapter 2 Haralick & Shapiro

2.1 Perform a threshold labeling operation in which each pixel has a high enough value is given the value binary 1; all other pixels are given the value binary ϕ

connected components algorithm (SRI algorithm)

also called signature analysis
- thresholding (labeling operation)
- connected components labeling – segmentation
- region property measurements
- statistical pattern recognition

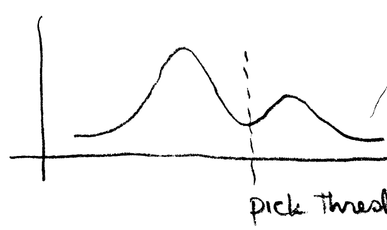
2.2. Thresholding

histogram h $h(m) = \#\{(r,c) \mid I(r,c) = m\}$

counts the number of elements in a set

```
procedure Histogram (I, H).
\* initialize histogram bins to zero *\
 for i:= φ to MAX do H(i):=0;
 \* compute values by accumulation *\
  for r:=1 to ROWSIZE do
   for c:=1 to COLSIZE do
     begin
     grayval:= I(r,c)
     H(gravval):= H(grayval)+1
      end
    end for
  end for
```

This is a global threshold



pick threshold here

8.1.1 The Spatial Transformation

general form $g(x,y) = f(x',y') = f[a(x,y), b(x,y)]$

issues: continuity & connectivity of objects in image

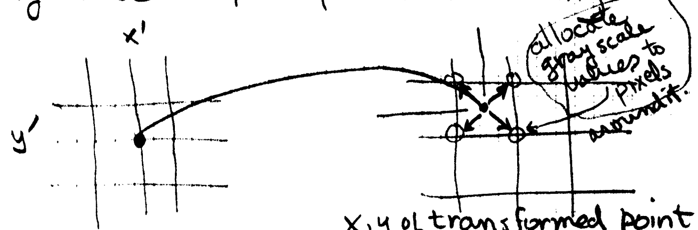
8.1.2. Gray level interpolation

necessary because moving pixels tends to stretch and/or compress them.

integer input pixels map to fractional (non integer) coordinates

8.1.3. pixel carry over (forward mapping) approach.

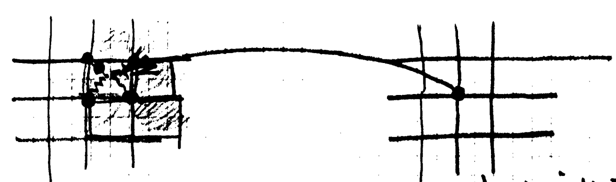
transform input pixel to output and split up among four output pixels according to interpolation rule



x,y of transformed point can be anywhere...

problems
1. pixels mapping to locations outside image
2. multiple addressing of output pixels.
3. missing of output pixel.

pixel-filling (backward mapping) approach



1. each output pixel is determined.

start with the output pixel

generate output pixels one by one

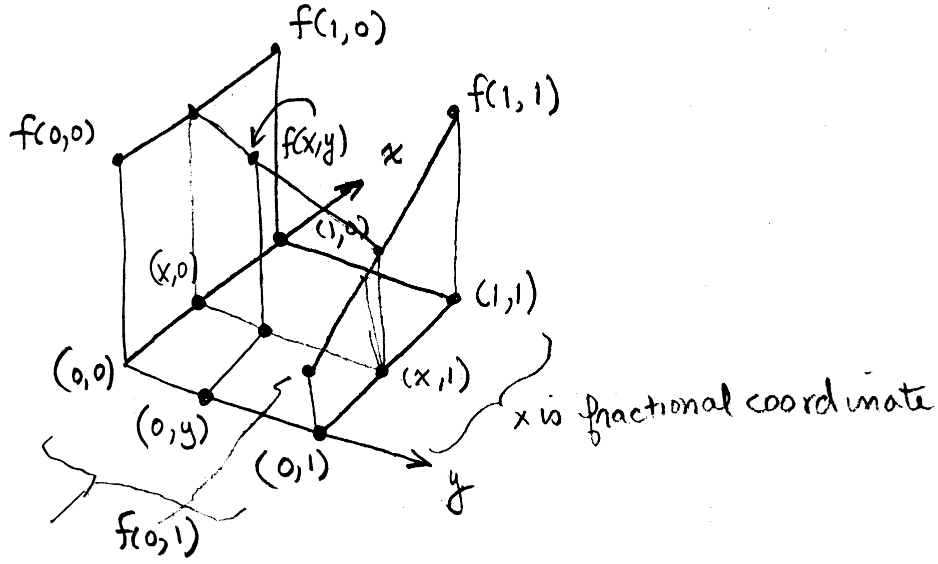
8.2 gray level interpolation

8.2.1. nearest neighbor

gray level of output is that of nearest pixel in input image

can produce edge artifacts where gray levels change rapidly

8.2.2. Bilinear interpolation



can't fit plane through four points

fit hyperbolic paraboloid $\quad f(x,y) = ax + by + cxy + d$

fit to values at each corner by simple algorithm

1) linearly interpolate between upper two points

$$f(x,0) = f(0,0) + x[f(1,0) - f(0,0)] \qquad (1)$$

2) linearly interpolate between lower two points

$$f(x,1) = f(0,1) + x[f(1,1) - f(1,0)] \qquad (2)$$

3) interpolate vertically

$$f(x,y) = f(x,0) + y[f(x,1) - f(x,0)]. \qquad (3)$$

Combine all 3 equations

$$f(x,y) = [f(1,0) - f(0,0)]x + [f(0,1) - f(0,0)]y$$
$$+ [f(1,1) + f(0,0) - f(0,1) - f(1,0)]xy + f(0,0)$$

8 additions plus ~~6 additions~~ 5? multiplications, efficient

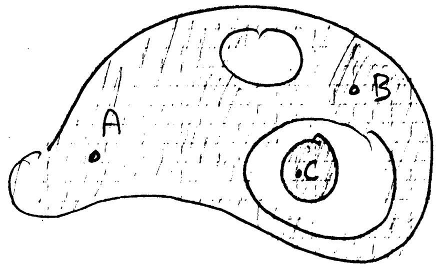
Form of Formula important $ax + by + cxy + d$!

surface produced by bilinear interpolation match in amplitude at neighborhood boundaries, but do not match in slope, $\Rightarrow$ generated surface is continuous but derivatives are discontinuous at boundaries

Horn

Binary Images: Topological properties

how do we identify individual objects in an image



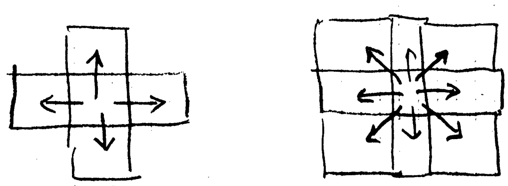
A is connected to B but not to C

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.

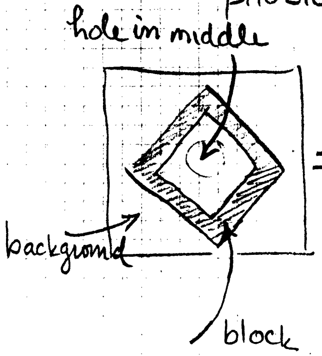
can label both objects and holes

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

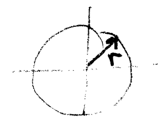
2.4.3 Labeling of connected components

this is actually "blob coloring"

2.4.4 Relations, Equivalence and Transitive Closure (SKIP)

2.4.5. Euclidian distance between p and q.

$$D_e(p,q) = [(x-s)^2 + (y-t)^2]^{\frac{1}{2}}.$$



$$D_4(p,q) = |x-s| + |y-t|$$

(city block distance).

		2		
	2	1	2	
2	1	0	1	2
	2	1	2	
		2		

$$D_8(p,q) = \max\left(|x-s|, |y-t|\right).$$

2	2	2	2	2
2	1	1	1	2
2	1	0	1	2
2	1	1	1	2
2	2	2	2	2

2.4.6 Arithmetic/Logic Point operations

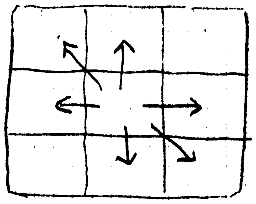
Addition ——— $p+q$
Subtraction ——— $p-q$
Multiplication ——— $p*q$
Division ——— $p \div q$

AND — p AND q.
OR — p OR q.
COMPLEMENT — NOT q.

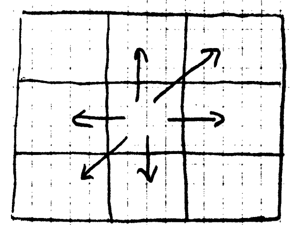
another solution asymmetry

if A is a neighbor of B $\Rightarrow$ B is a neighbor of A

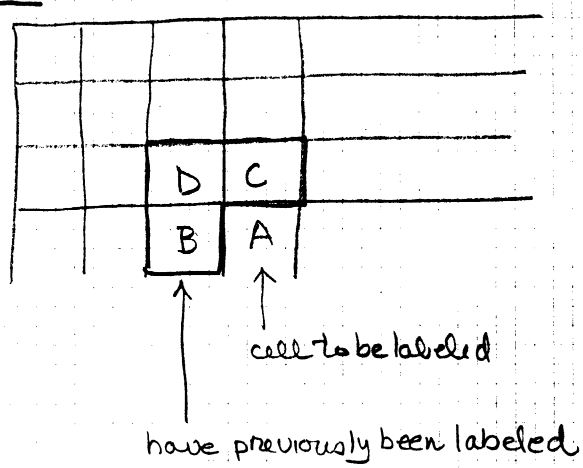
use 6 connectedness



or

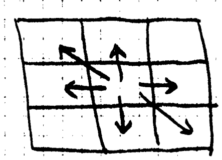


<u>sequential</u> labeling (6 connected blob coloring).



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 $\Rightarrow$ labels are really the same.

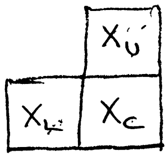
(NOTE : B and C are <u>NOT</u> neighbors)

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.

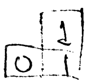
Scan the image left to right, top to bottom with the L-shaped template shown below:



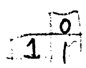
4connected blob coloring

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

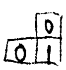


if $f(X_u) = 1$ and $f(X_L) = 0$ then color $(X_c) := $ color (X_u)



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.

8.2.3. Higher order interpolation

bilinear gray level interpolation
- smooths image losing fine level detail
- slope discontinuities may cause undesirable effects

higher order functions
- cubic splines
- Legendre functions
- $\sin(\alpha x)/\alpha x$

8.3.2 General transformations

show geometric transform of Ranger spacecraft camera.

8.3.3. Specification by control points

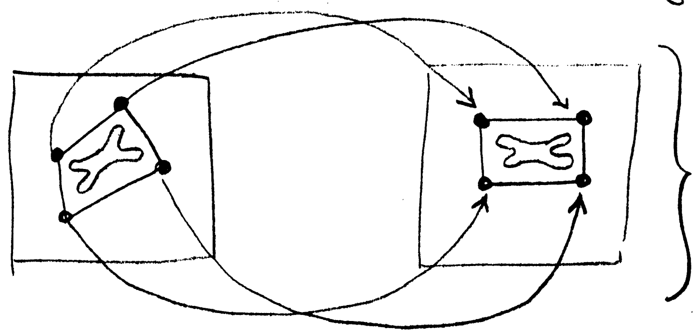
specify the spatial transform as a series of displacement values for selected <u>control points</u> in the image. Displacement of non-control points determined by interpolation

often use polynomials up to 5th degree.

sometimes need more complex transformations

break picture into polygons and use

piecewise bilinear mapping functions



control grid interpolation

8.3.4. Polynomial warping

# of control points = # of terms in polynomial — linear equations

# of control points > # of terms in polynomial

use fitting techniques

8.3.5 Control grid interpolation

Bilinear interpolation

$$G(x,y) = F(x',y') = F(\underline{ax+by+cxy+d},\ \underline{ex+fy+gxy+h})$$

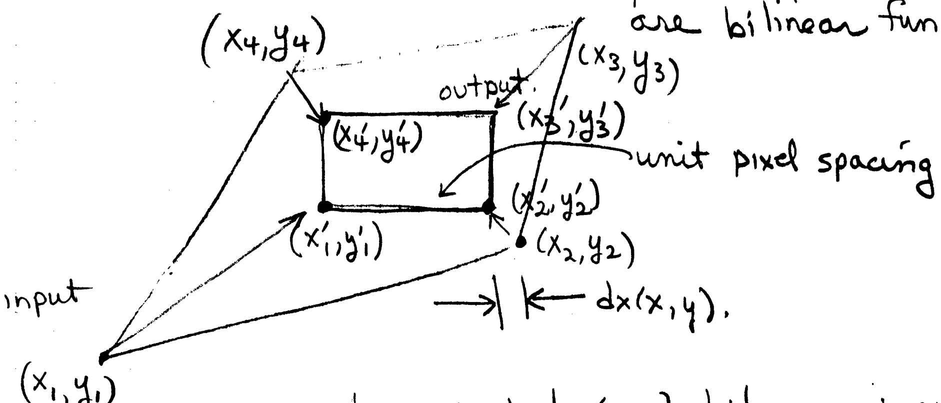
transform defined by a through h

if a quadrilateral maps to a quadrilateral
specifying vertices gives 2 sets of 4 linear equations in four unknowns.

Better way to define it

$$G(x,y) = F\left[x + dx(x,y),\ y + dy(x,y)\right].$$

pixel displacements that are bilinear functions of x and y.



dx(x,y) & dy(x,y) bilinear in x & y.
$\Rightarrow$ linear in x <u>along</u> each horizontal line in output

for each output line $\quad dx(x+1,y) = dx(x,y) + \Delta x$
where Δx varies for each line

basically do a curve fit: four x's map to four x''s.

i.e.
$$x_1' = ax_1 + by_1 + cx_1y_1 + d$$
$$x_2' = ax_2 + by_2 + cx_2y_2 + d$$
$$x_3' = ax_3 + by_3 + cx_3y_3 + d$$
$$x_4' = ax_4 + by_4 + cx_4y_4 + d$$

$$\begin{bmatrix} x_1' \\ x_2' \\ x_3' \\ x_4' \end{bmatrix} = \begin{bmatrix} x_1 & y_1 & x_1y_1 & 1 \\ x_2 & y_2 & x_2y_2 & 1 \\ x_3 & y_3 & x_3y_3 & 1 \\ x_4 & y_4 & x_4y_4 & 1 \end{bmatrix} \begin{bmatrix} a \\ b \\ c \\ d \end{bmatrix}$$

and solve for $\begin{bmatrix} a \\ b \\ c \\ d \end{bmatrix}$

2.5 Imaging Geometry. Read 2.4 NOT 2.4.4, 2.5, NOT 2.6

PROBLEMS 2.16, 2.17, 2.20.