CHAPTER 2

PIXEL RELATION

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Pixel Relationship

- Pixel
- Pixel Neighbourhood and Type of Neighbourhood
- Pixel Connectivity
- Connected Component
- Different Distance Measure Techniques
- Arithmetic/Logical Operator
- Neighborhood Operation

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What is Pixel?

- After sampling we get no. of analog samples and each sample have intensity value which can be Quantized as final step of digitization
- Quantized to discrete label
- 8bit for black and white image
- 24bit for colour image
- A matrix element is called pixel.
- For 8 bit a pixel can have value between 0 to 256

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Neighbourhood

- A pixel p at location (x,y) has 2 horizontal and 2 vertical neighbour. In total a pixel p has four neighbour.

	(x-1, y)	
(x, y-1)	P (x, y)	(x, y+1)
	(x+1, y)	

- This set of four pixel is called 4 neighbour of p = $N_4(p)$
- Each of this neighbour is at a unit distance from p
- If p is a boundary pixel then it will have less neighbours.

Neighbourhood Cont..

- Boundary Pixel

p		

Boundary pixel has only two neighbour

- A pixel p has four diagonal neighbour $N_D(p)$

(x-1, y-1)		(x-1, y+1)
	P (x, y)	
(x+1, y-1)		(x+1, y+1)

- The point of $N_4(p)$ and $N_D(p)$ together are called 8 neighbourof p

$$N_8(p) = N_D(p) \cup N_D(p)$$

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Pixel Connectivity

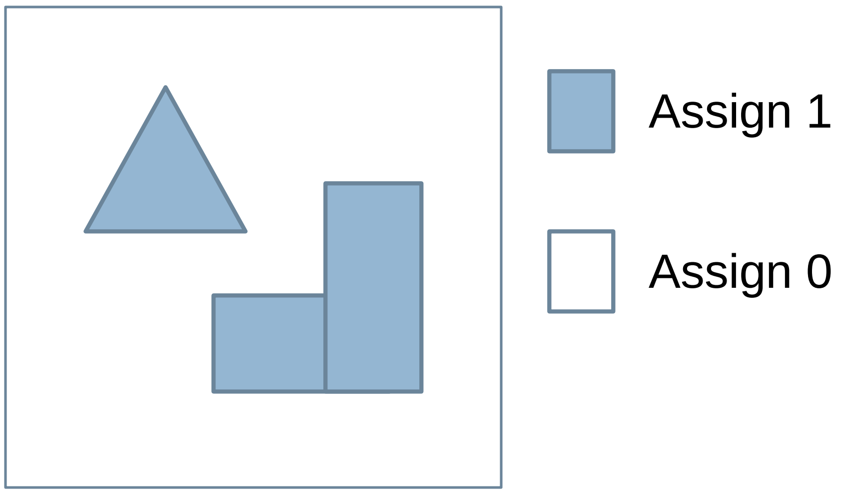
- Pixel connectivity is very useful for establishing object boundary and defining image component/ region etc.

If f(x,y) > Th (threshold)

(x,y) є object

else

(x,y) є background



Here pixel connected to 1 belongs to one object

Pixel Connectivity Cont..

- Two pixel are said to be connected if they are adjacent in same sense
  - They are neighbour (N_4 N_D or N_8) and
  - Their intensity value (gray level) are similar
  - Example: For a binary image B two points p and q will be connected if q є N(p) are p є N(q) and B(p) = B(q)

P		
	q	

	p	
	q	

	p	q

Here p and q are connected iff their intensity value are same

Define Connectivity in Gray Level

- Let v be the set of gray level used to define connectivity for two points (p,q) є V
- Three type of connectivity are defined
  - 4 connectivity $\rightarrow$ p,q є v & p є $N_4(q)$
  - 8 connectivity $\rightarrow$ p,q є v & p є $N_8(q)$
  - M connectivity (Mixed Connectivity) p,q є v are m connected if
    - q є $N_4(p)$ or
    - q є $N_D(p)$ and $N_4(p) \cap N_D(p) = \phi$

Mixed Connectivity

- Mixed connectivity is modification of 8 connectivity
  - Only inclusion of concept is eliminating the multiple path often arises with 8 connectivity
  - Example V = {1}

Multiple path

0	1	1
0	1	0
0	0	0

4 connected

0	1	1
0	1	0
0	0	1

8 connected

0	1	1
0	1	0
0	0	1

M connected

$N_4(p) \cap N_D(p) = \phi$ so $N_D(p)$ is not taken

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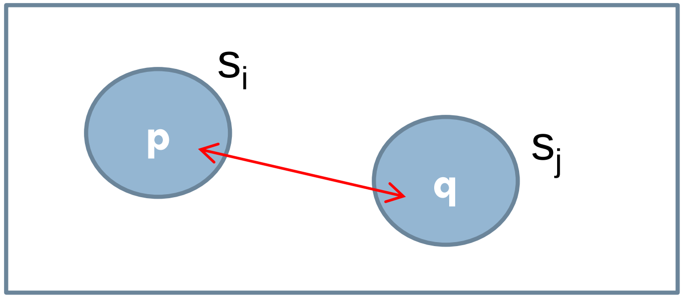
Connected Component

- **Adjacency** : Two pixel p & q are adjacent if they are connected
  - 4 adjacency
  - 8 adjacency
  - M adjacency
- Depending on type of connectivity used two image subset s_i and s_j are adjacent If $p \in s_i$ and $q \in s_j$ such that p and q are adjacent



Connected Component

- **Path :** A path from p(x,y) to q(s,t) is a sequence of distinct pixel

  (x_0,y_0), (x_1,y_1), …… , (x_n,y_n)

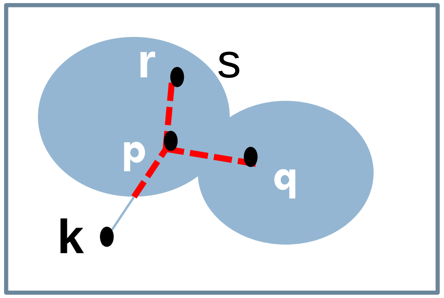
  Where $(x_0,y_0) = (x,y)$ and $(x_n,y_n) = (s, t)$

  (x_i,y_i) is adacent to (x_{i-1}, y_{i-1}) for $1 \leq I \leq n$

  here n is the length of path

Connected Component

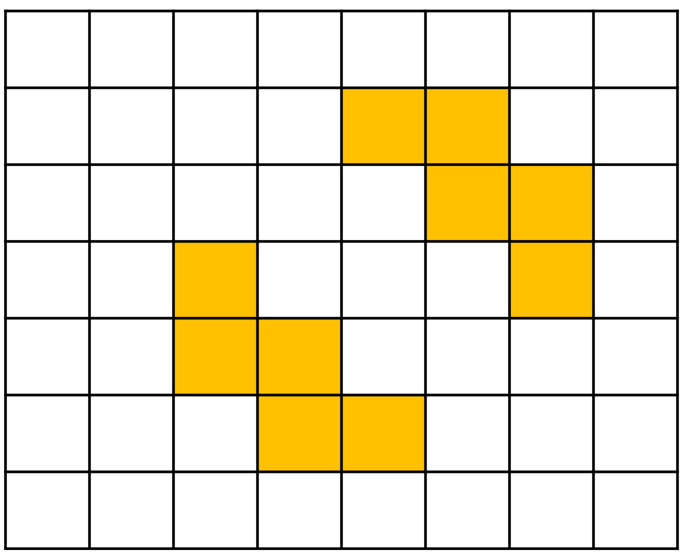
- Let S ⊆ I and p,q є S
- Then p is connected to q in S if there is a path from p to q consisting entirely of pixels in S
- For any p є S, the set of pixel in S that are connected to p is call a connected component of S



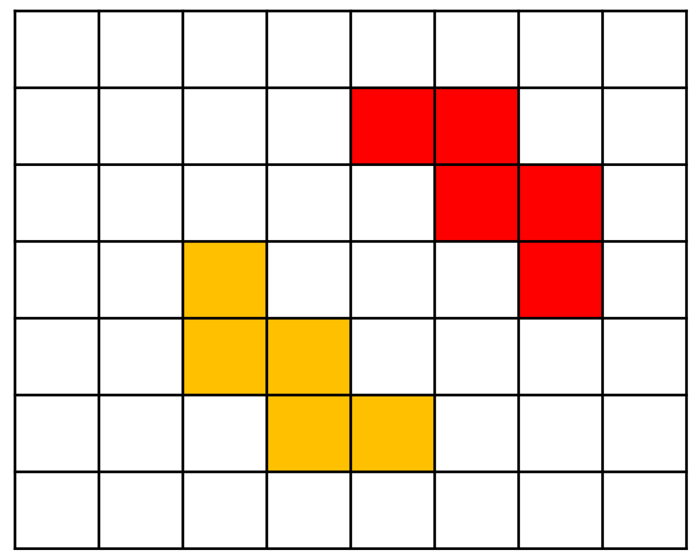
Point p is connected to point q and r but not connected with point k

Connected Component Labeling

- Ability to assign different label to the various disjoint connected components of an image
- Connected component labeling is fundamental step in automated image analysis



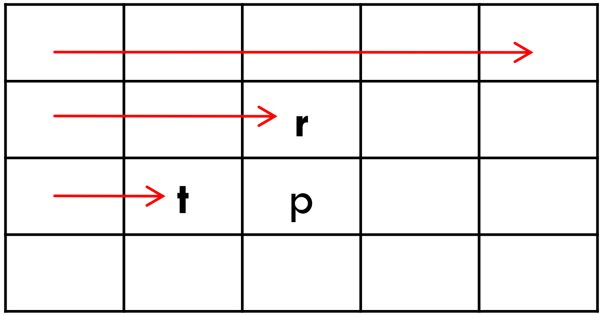
Two disjoint connected component



connected component labeling

Algorithm (Group identification)

- Scan image from Left to Right and Top to Bottom
- Assume 4 connectivity
- P be a pixel at any step in the scanning process



- Before p point r and t are scanned i.e before p its neighbours are scanned
- The purpose of this algorithm is to assign identification no.

Algorithm Steps

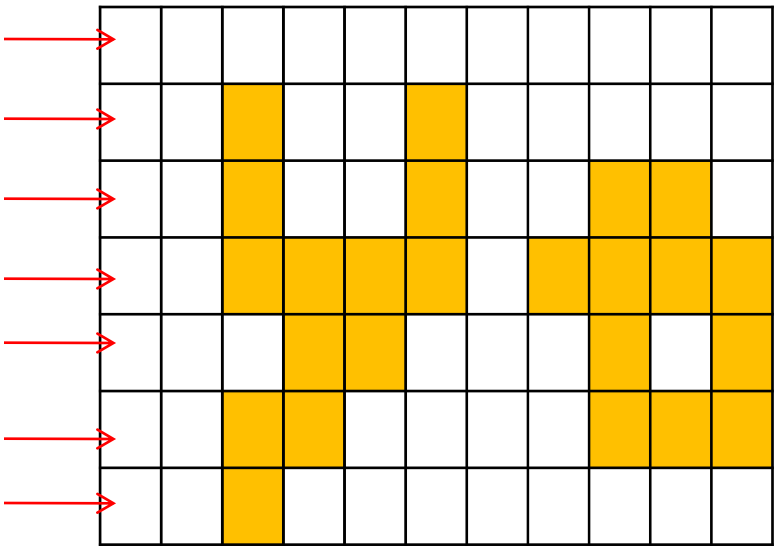
- $I(p)$: pixel at position p
- $L(p)$: label assigned to pixel location p
- If $I(p) = 0$, move to next scanning position
- If $I(p) = 1$, and $I(r) = I(t) = 0$
  - Then assign a new label to position p
- If $I(p) = 1$ and only one of two neighbour is 1
  - Then assign its label to p
- If $I(p) = 1$ and both r and t are 1
  - Then
    - If $L(r) = L(t)$ then $L(p) = L(r)$
    - If $L(r) \neq L(t)$ then assign one of the label to p

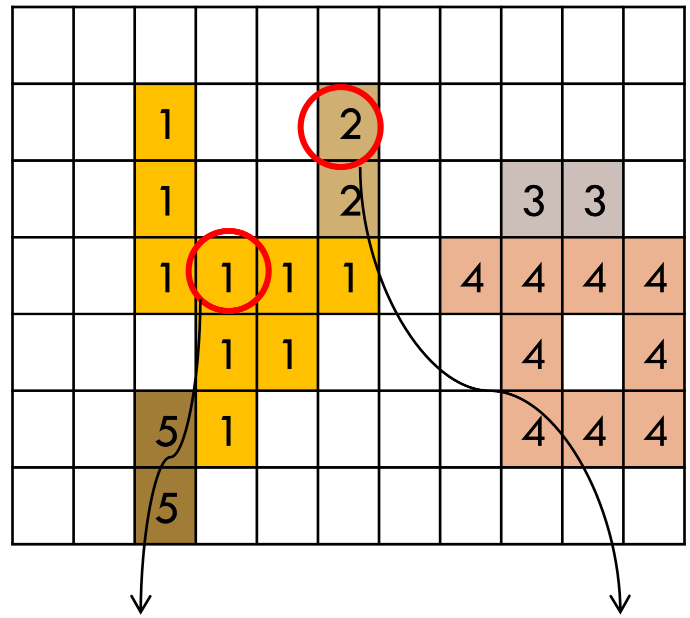
Algorithm Steps Cont..

- At the end of scan all pixel with value 1 are labeled
- Some label are equivalent
- Equivalent label make a pais
- During second pass process equivalent pairs to form equivalent classes
- Assign different label to each class
- In the second pass through the image replace each label by label assign to its equivalent class

Algorithm Demo

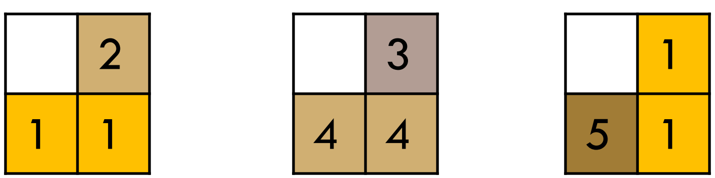
First Pass





Assign 1 because its left neighbour is 1

Assign new label (say 2) as I(r) = I(t) = 0



(1,2) , (4,3) and (5,1) are equivalent pair

Algorithm Demo

Second Pass : In the second pass through the image replace each label by label assign to its equivalent class

		1			1					
		1			1			3	3	
		1	1	1	1		3	3	3	3
			1	1				3		3
		1	1					3	3	3
		1								

Here two separate region/ group are identified **YELLOE** (1) region and **RED** (3) region

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Distance Measure

- Take three pixel
- $p \approx (x,y)$ $q \approx (s,t)$ $z \approx (u,v)$
- D is distance function if
  - $D(p,q) \geq 0$; $D(p,q) = 0$ iff $p = q$ (p & q is same pixel)
  - $D(p,q) = D(q,p)$ (distance from p to q & q to p is same)
  - $D(p, z) \leq D(p,q) + D(q,z)$

Distance Measure Technique

- **Euclidean Distance**
- **City Block Distance (Manhattan Distance)**
- **Chess Board Distance**
- Euclidean distance between two point p(x,y) & q(s,t) is defined as

$$D(p,q) = [|x-s|^2 + |y-t|^2]^{1/2}$$

Distance Measure Technique

- **City Block Distance**
- D_4 distance or City Block (Manhattan) distance is defined as

$$D_4\,(p,q) = |x\text{-}s| + |y\text{-}t|$$

- Point having city block distance from p less than or equal to r from diamond center

					3					
				3	2	3				
			3	2	1	2	3			
		3	2	1	p	1	2	3		
			3	2	1	2	3			
				3	2	3				
					3					

Distance Measure Technique

- **Chess Board Distance**
- D_8 distance or Chess Board Distance is defined as

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

- Point with $D_8 = 1$ are 8 neighbour of p

		3	3	3	3	3	3	3		
		3	2	2	2	2	2	3		
		3	2	1	1	1	2	3		
		3	2	1	P	1	2	3		
		3	2	1	1	1	2	3		
		3	2	2	2	2	2	3		
		3	3	3	3	3	3	3		

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Arithmetic/Logical Operator

- If pixel p ϵ I_1 and q ϵ I_2 where I_1 and I_2 are two different images then
- **Arithmetic Operators are**
- p + q
- p – q
- p * q
- p % q
- **Logical Operator**
- p.q (Logical AND)
- p+q (Logical OR)
- p' (NOT)
- Logical operators are only applied to binary image

Logical Operator

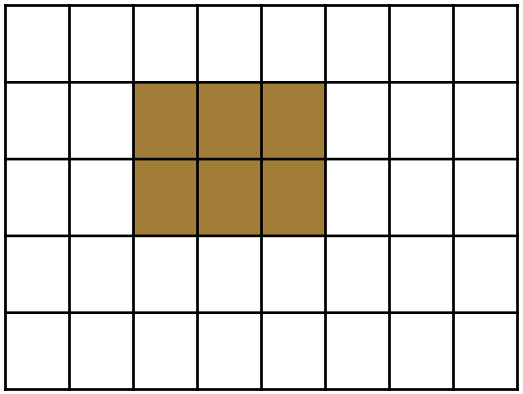
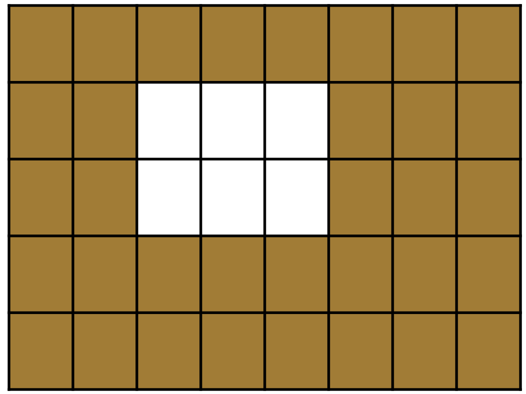
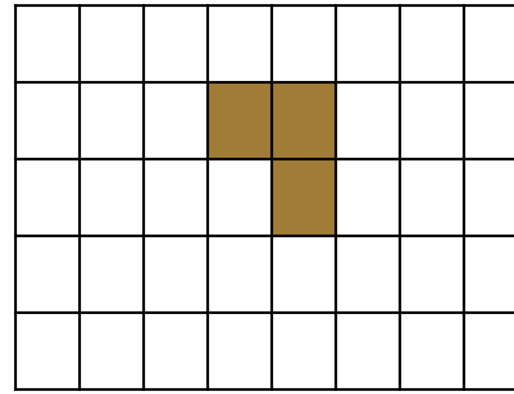


Image A



NOT (A)



(A) AND (B)

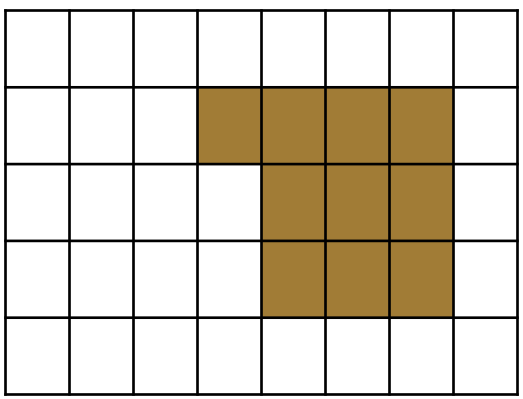
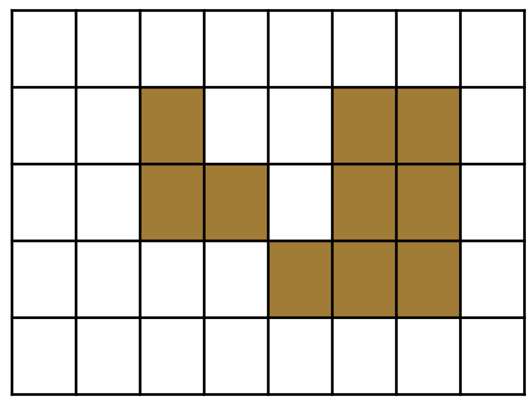


Image B



(A) XOR (B)

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Neighbourhood Operation

- The value assigned to a pixel is a function of its gray label and the gray label of its neighbours

Z_1	Z_2	Z_3
Z_4	Z_5	Z_6
Z_7	Z_8	Z_9

- Averaging

$$Z = 1/9\ (Z_1 + Z_2 + \ldots\ldots\ldots + Z_9)$$

Neighbourhood Operation

- More general form

Z_1	Z_2	Z_3
Z_4	Z_5	Z_6
Z_7	Z_8	Z_9

W_1	W_2	W_3
W_4	W_5	W_6
W_7	W_8	W_9

$$Z = W_1 Z_1 + W_2 Z_2 + \ldots\ldots + W_9 Z_9$$
$$= \sum W_i Z_i \quad \text{for } i = 1 \text{ to } 9$$

It is useful for

Noise filtering

Edge Detection

Various important operation can be implemented by proper selection of coefficient W_i

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