Digital Image Processing

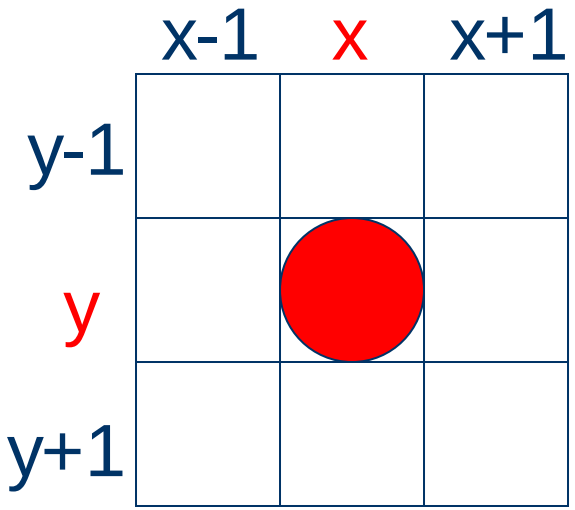
Lecture # 2D: Fundamentals

Contents

- Neighborhood & Connectivity
- Connected Component Labeling
- Distance Metrics
- Arithmetic & Logical Operators

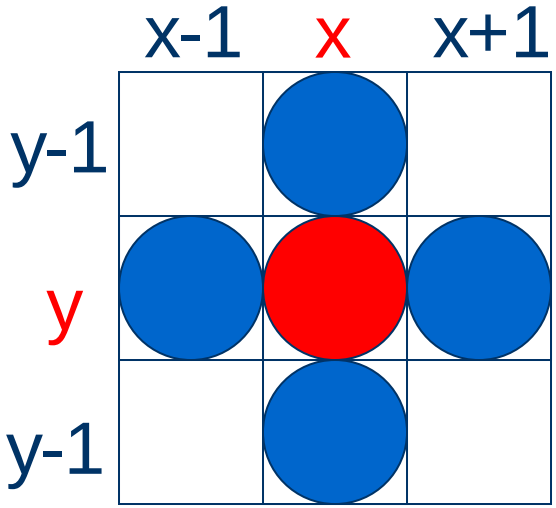
Relationships between pixels

- Neighbors of pixel are the pixels that are adjacent pixels of an identified pixel



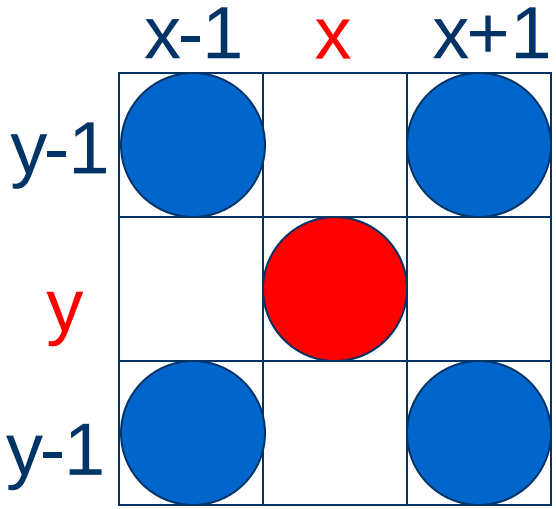
4- Neighbors of a Pixel –$N_4(p)$

What are the coordinates of each of the blue pixels



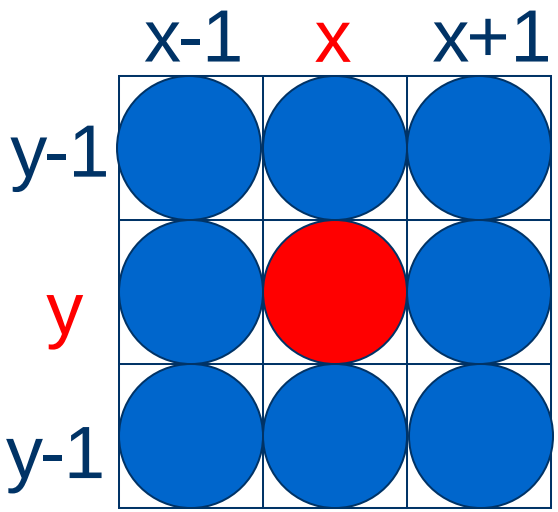
(x-1,y), (x+1,y), (x, y-1), (x, y+1)

Diagonal Neighbors of a Pixel – $N_D(p)$



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

8- Neighbors of a Pixel –$N_8(p)$

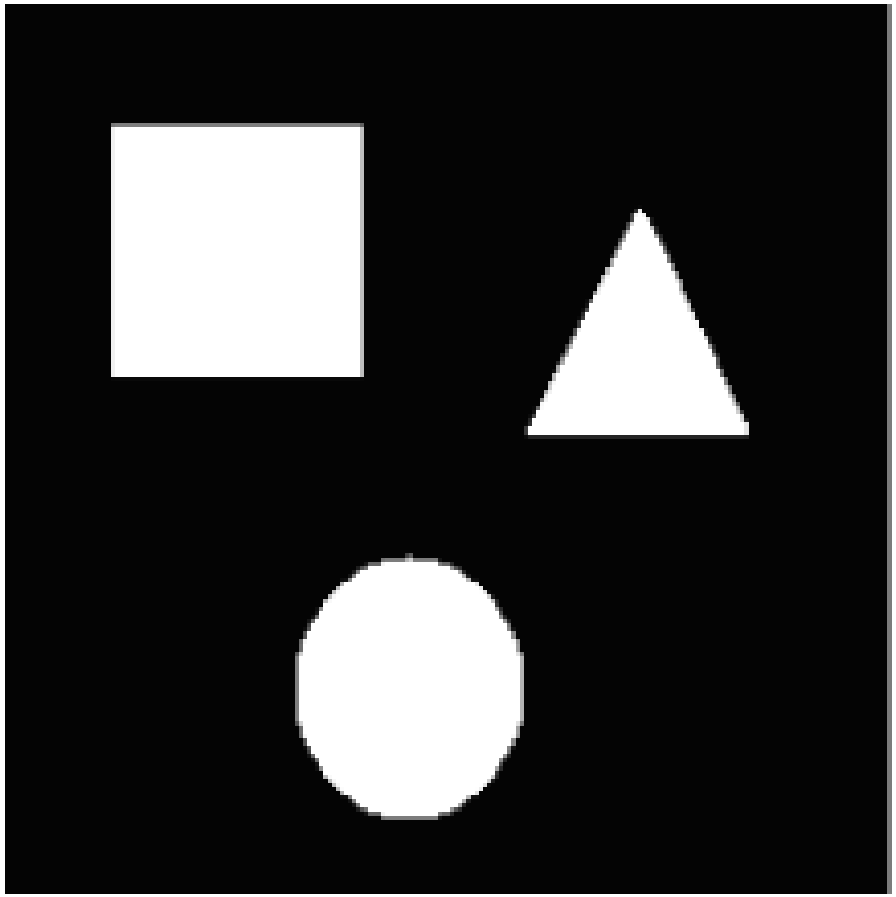


$$N_8(p) = N_4(p) + N_D(p)$$

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

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

Determine different regions in the image



Connectivity

- Establishing boundaries of objects and components of regions in an image
- Group the same region by assumption that the pixels being the same color or equal intensity
- Two pixels p & q are connected if
  - *They are adjacent in some sense*
  - *If their gray levels satisfy a specified criterion of similarity*

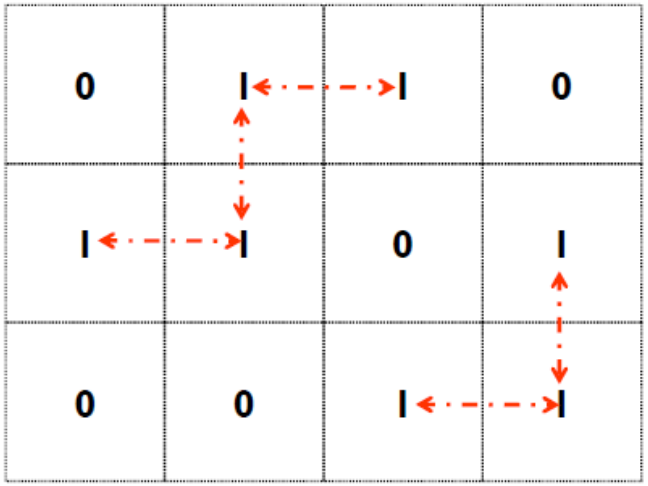
Connectivity

V: Set of gray levels used to define the criterion of similarity

4-connectivity

If gray level [illegible]

Set of gray levels V = {1}



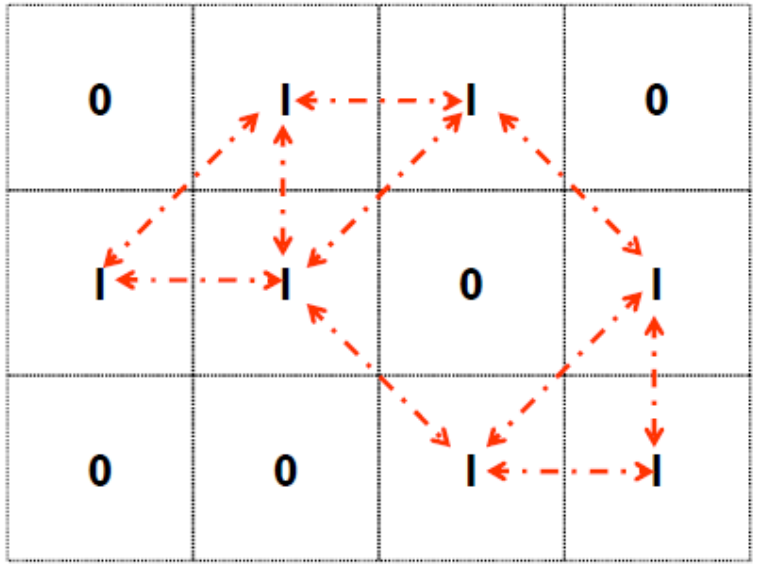
Connectivity

V: Set of gray levels used to define the criterion of similarity

8-connectivity

If gray level $(p,q) \in V$ and $p \in N_8(q)$

Set of gray levels V = {1}



Connectivity

V: Set of gray levels used to define the criterion of similarity

m-connectivity (Mixed Connectivity)

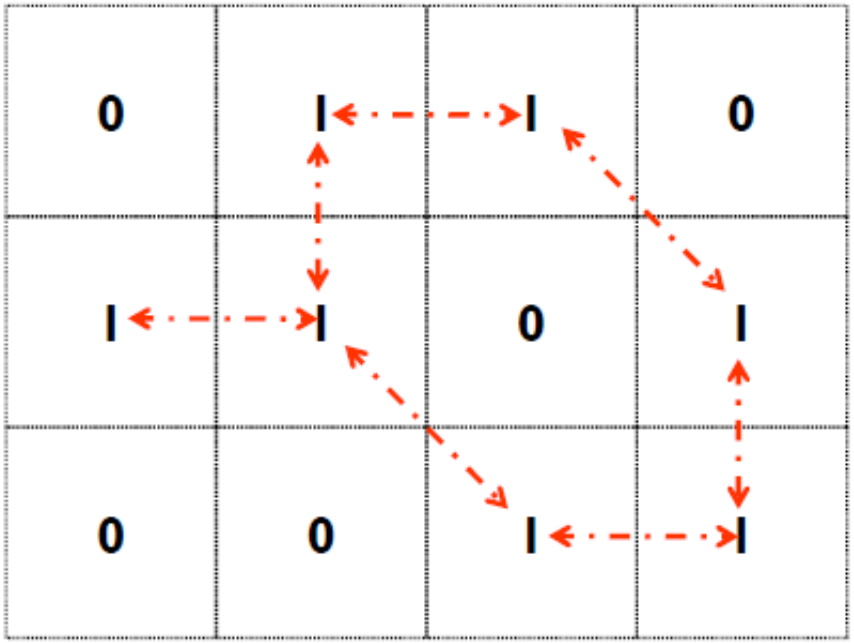
If gray level

a. $q \in N_4(p)$ or

b. 

Example: m – Connectivity

- Set of gray levels V = {1}



Note: Mixed connectivity can eliminate the multiple path connections that often occurs in 8-connectivity

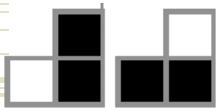
Paths and Regions

- Path: Let coordinates of pixel *p: (x, y)*, and of pixel *q: (s, t)*
- A *path* from p to q is a sequence of distinct pixels with coordinates: $(x_0, y_0), (x_1, y_1), \ldots\ldots, (x_n, y_n)$

  where $(x_0, y_0) = (x, y)$ & $(x_n, y_n) = (s, t)$, *and* (x_i, y_i) *is adjacent to* (x_{i-1}, y_{i-1}) $1 \leq i \leq n$

CC labeling – 4 Connectivity

- Process the image from left to right, top to bottom:



1.) If the next pixel to process is 1

i.) If only one of its neighbors (top or left) is 1, copy its label.

ii.) If both are 1 and have the same label, copy it.

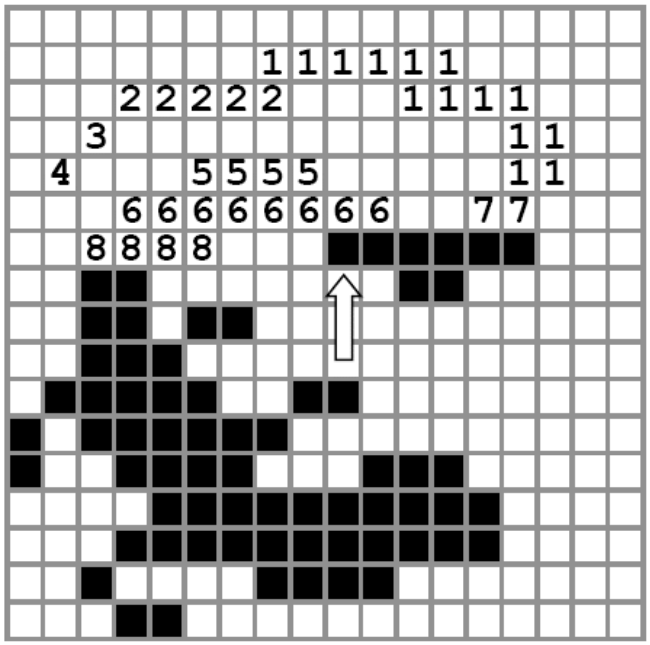
iii.) If they have different labels

– Copy the label from the left.

– Update the equivalence table.

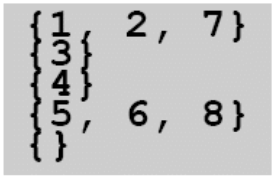
iv.) Otherwise, assign a new label.

Pass 1

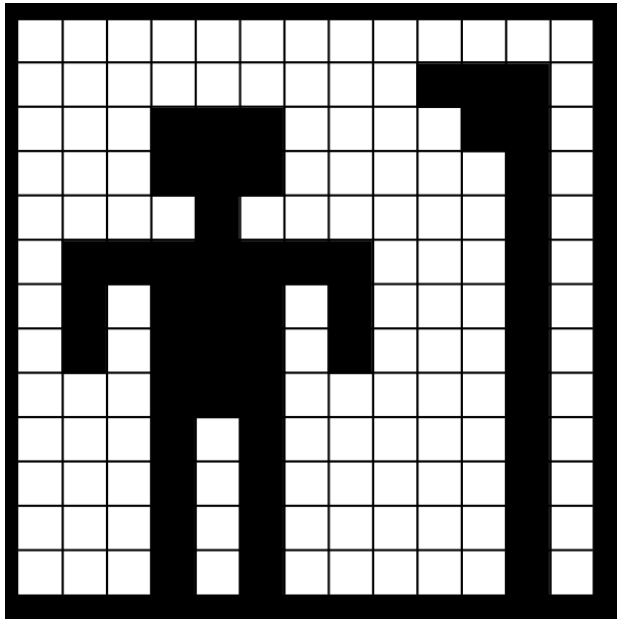


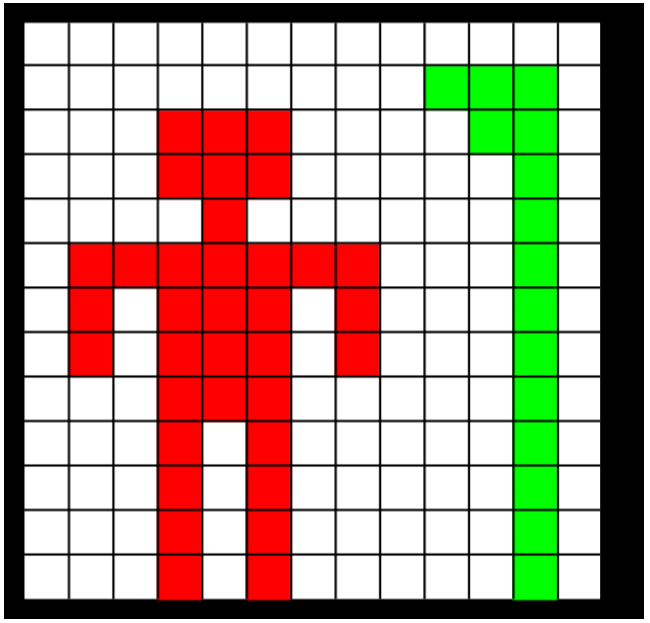
- Re-label with the smallest of equivalent labels

Pass 2

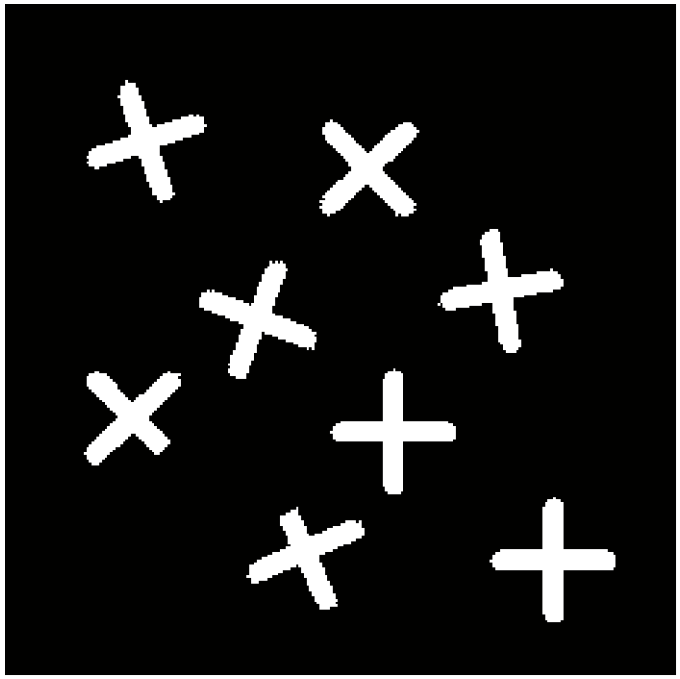


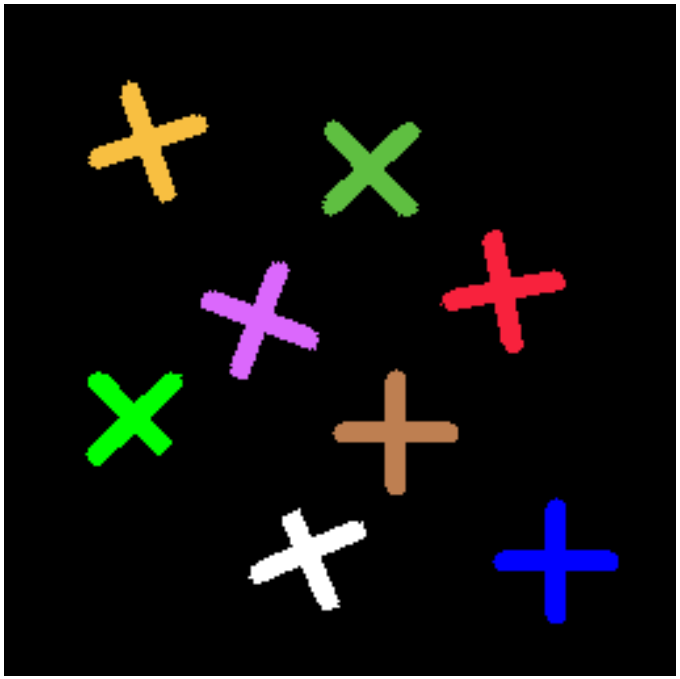
CC labeling – 4 Connectivity





CC labeling – 4 Connectivity

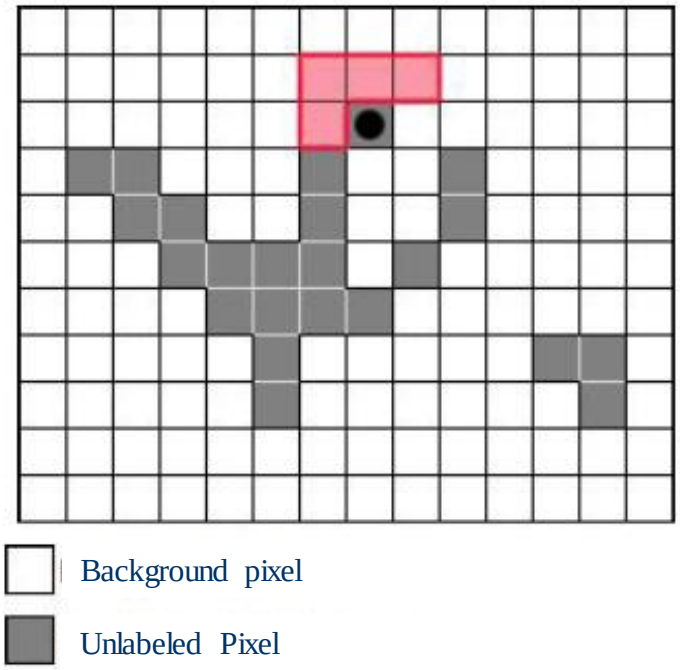


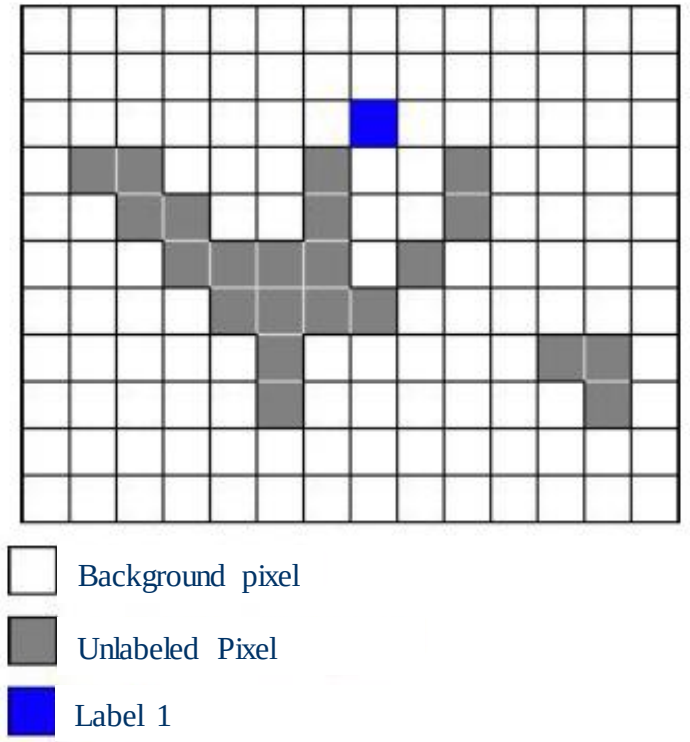


CC labeling – 8 Connectivity

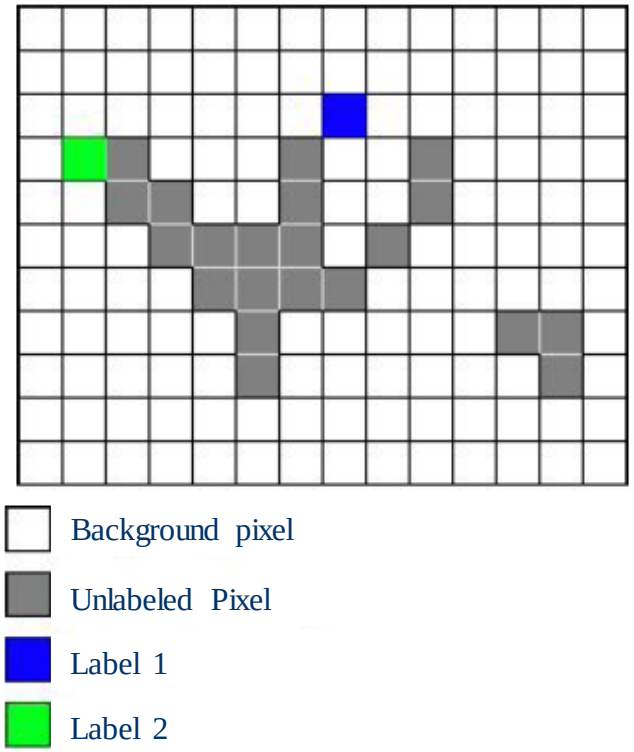
Same algorithm but examine also the upper diagonal neighbors of *p*

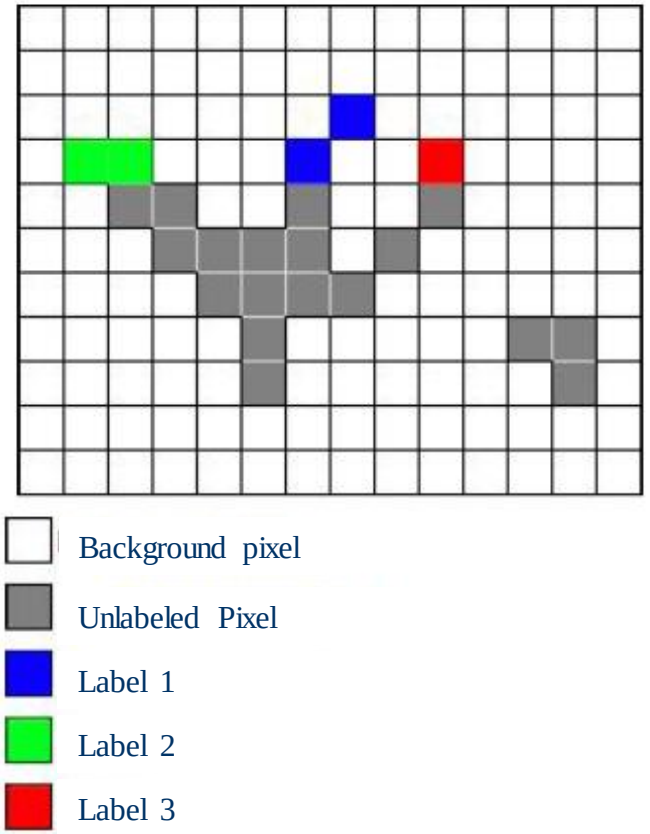
CC labeling – 8 Connectivity



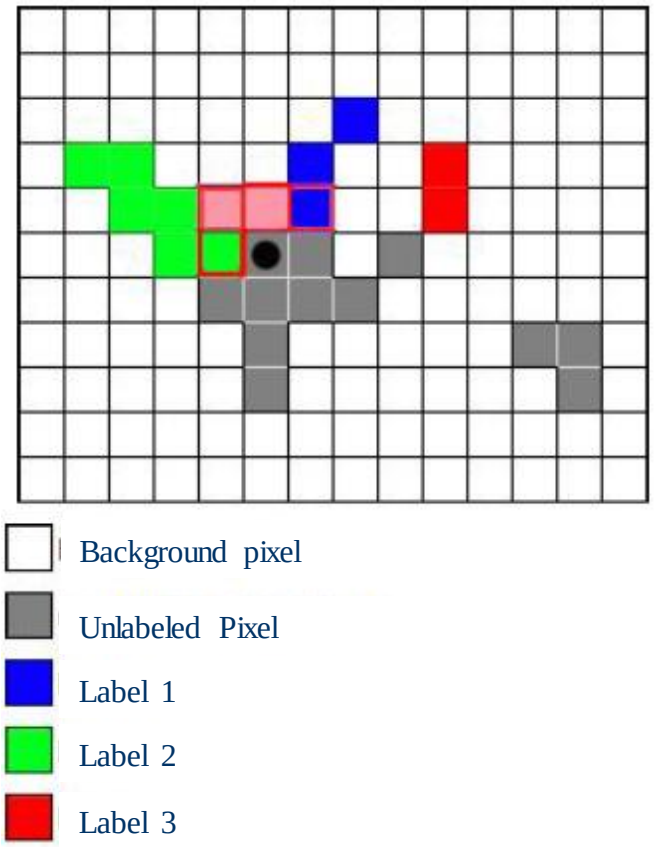


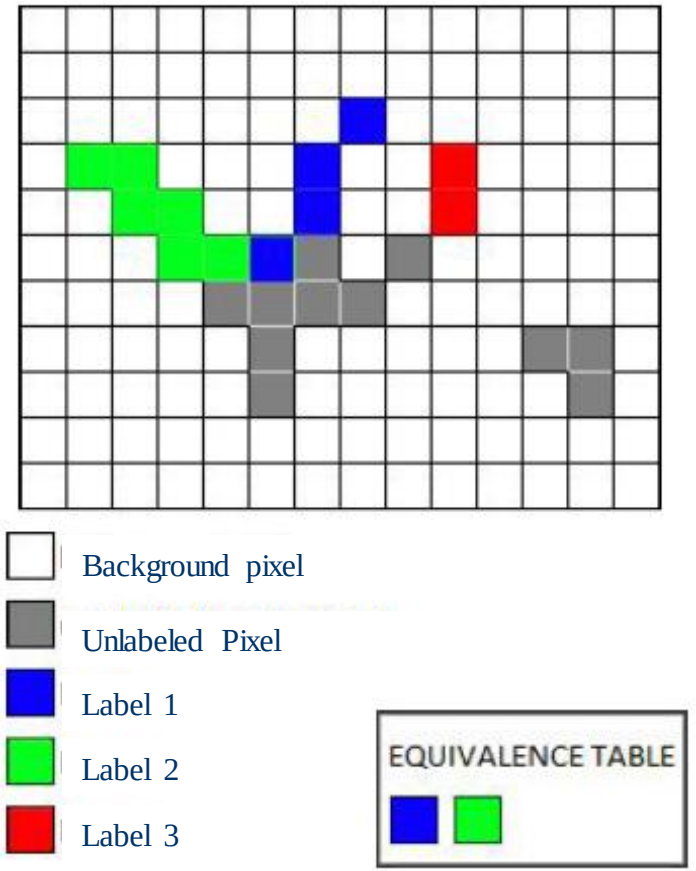
CC labeling – 8 Connectivity



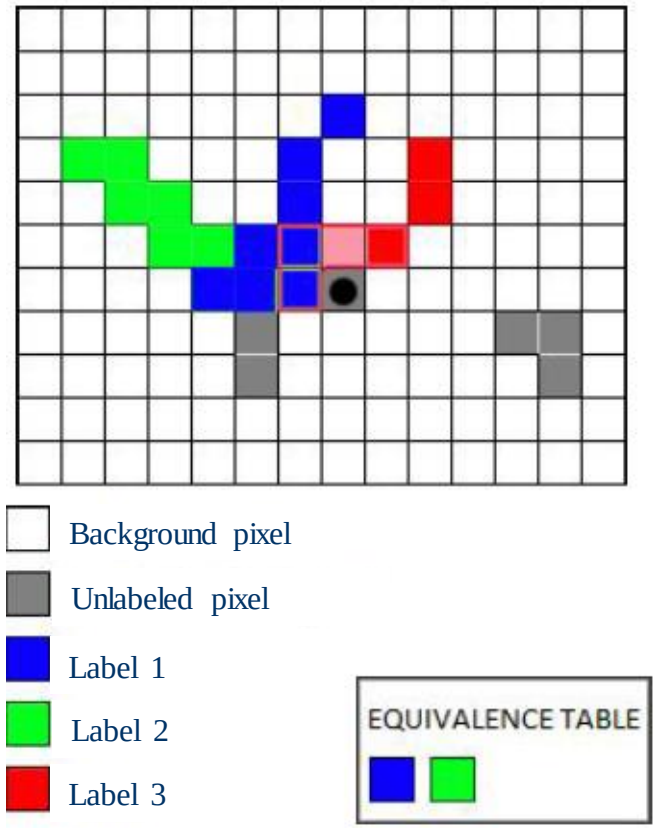


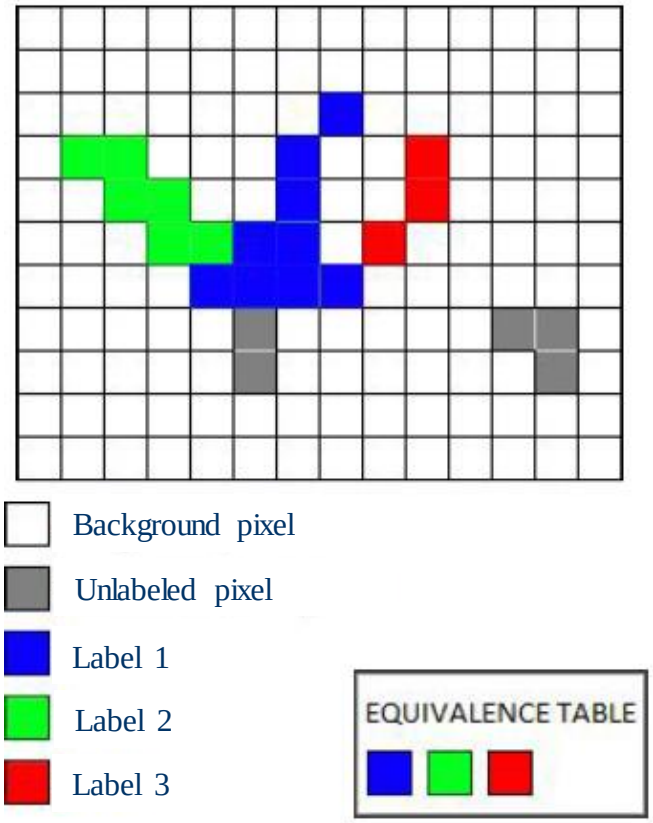
CC labeling – 8 Connectivity



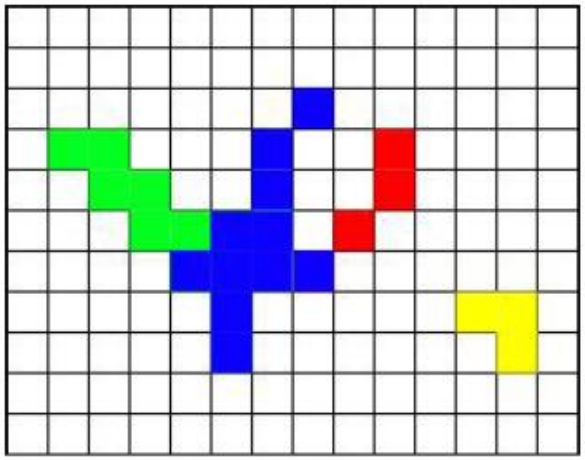


CC labeling – 8 Connectivity





CC labeling – 8 Connectivity



Background pixel

Unlabeled pixel

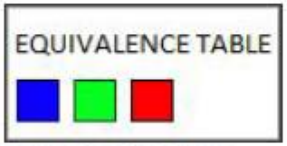
Label 1

Label 2

Label 3

Label 4

EQUIVALENCE TABLE



Background pixel

Unlabeled pixel

Label 1

Label 2

Label 3

Label 4

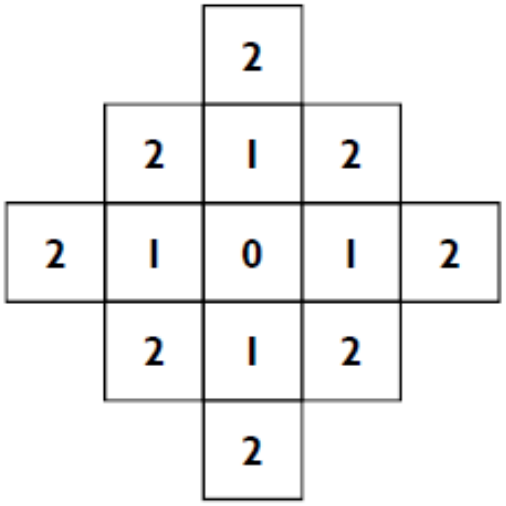
Distance Metrics

- Let pixels p, q and z have coordinates (x,y), (s,t) and (u,v) respectively.

- D is a distance function or metric if
  - $D(p,q) \geq 0$ *and*
  - $D(p,q) = 0$ *iff* $p = q$ *and*
  - $D(p,q) = D(q,p)$ *and*
  - $D(p,z) \leq D(p,q) + D(q,z)$

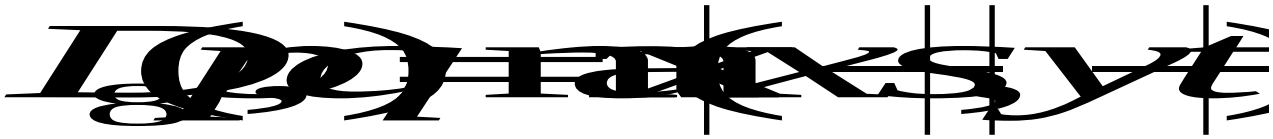
City block distance (D_4 distance)

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



- Diamond with center at *(x,y)*
- $D_4 = 1$ are the 4 neighbors of pixel *p(x,y)*

Chessboard distance (D_8 distance)

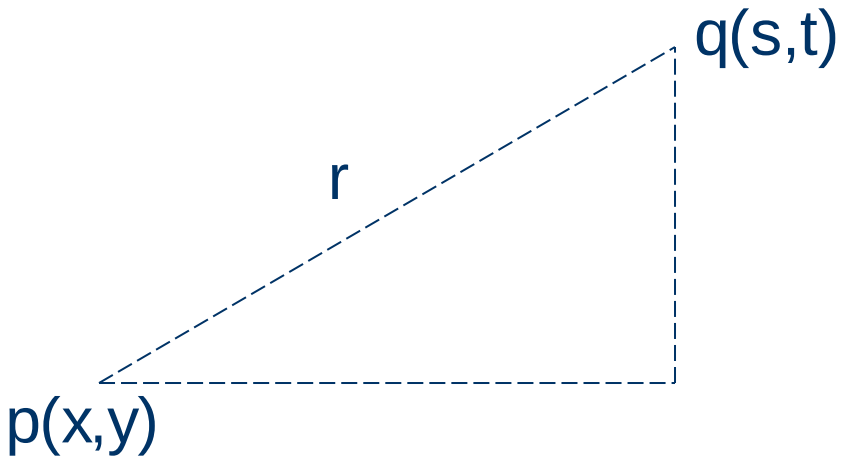


2	2	2	2	2
2	1	1	1	2
2	1	0	1	2
2	1	1	1	2
2	2	2	2	2

- Square centered at *p(x,y)*
- $D_8 = 1$ are the 8 neighbors of pixel *p(x,y)*

Euclidean Distance

$$D(p,q) = \sqrt{(x-s)^2 + (y-t)^2}$$



A circle with radius *r* centered at *(x,y)*

Arithmetic Operations

- Carried out between corresponding pixel pairs

$$s(x,y) = f(x,y) + g(x,y)$$

$$d(x,y) = f(x,y) - g(x,y)$$

$$p(x,y) = f(x,y) \times g(x,y)$$

$$v(x,y) = f(x,y) \div g(x,y)$$

Arithmetic Operations

- Conversion to range 0 – 255
- Difference of two 8-bit images: -255 to 255
- Sum of two 8-bit images: 0 to 510
- Solution?

Set all values < 0 to 0

Set all values > 255 to 255

Full range of arithmetic operation not captured

Arithmetic Operations

- First perform the operation

$$f_m = f - \min(f)$$

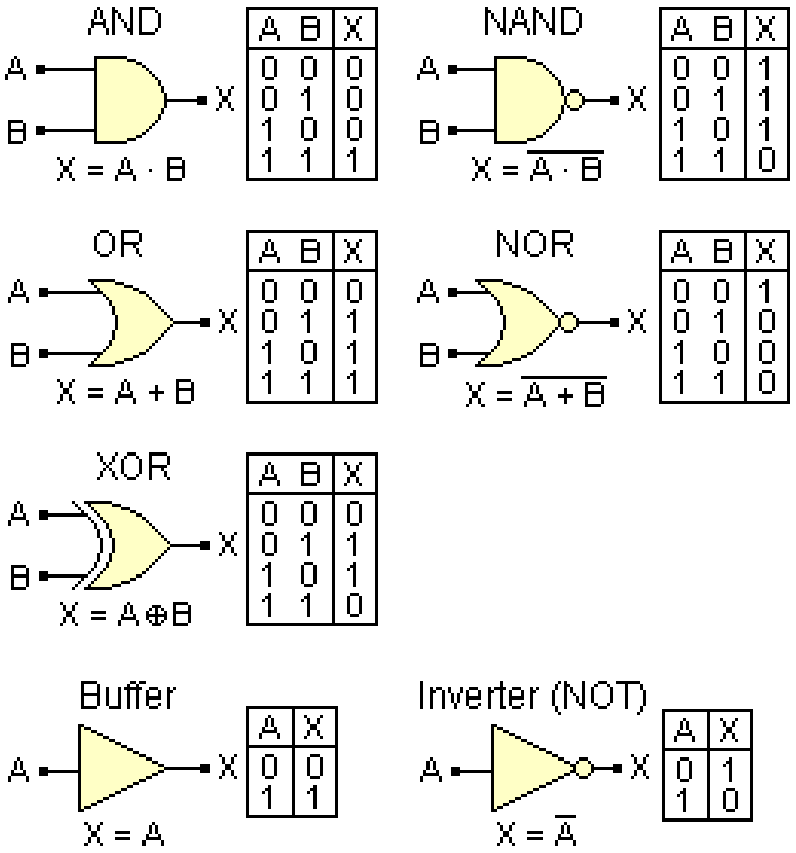
Creates an image whose minimum value is 0

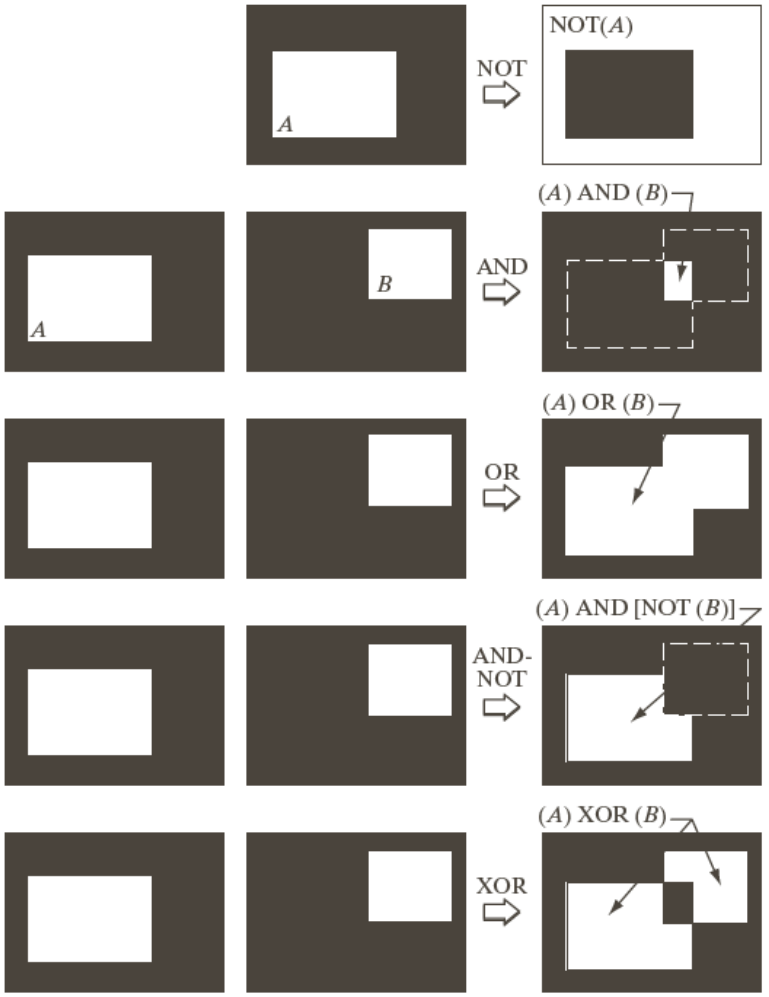
- Then perform

$$f_s = K[f_m / \max(f_m)]$$

Creates a scaled image f_s with values in the range [0 K]

Logical Operations (Binary Images)





Acknowledgements

- Digital Image Processing", Rafael C. Gonzalez & Richard E. Woods, Addison-Wesley, 2002
- Peters, Richard Alan, II, Lectures on Image Processing, Vanderbilt University, Nashville, TN, April 2008
- Brian Mac Namee, Digitial Image Processing, School of Computing, Dublin Institute of Technology
- Computer Vision & Computer Graphics, Mark Borg

Material in these slides has been taken from the following resources