Digital Image Processing

Week-02

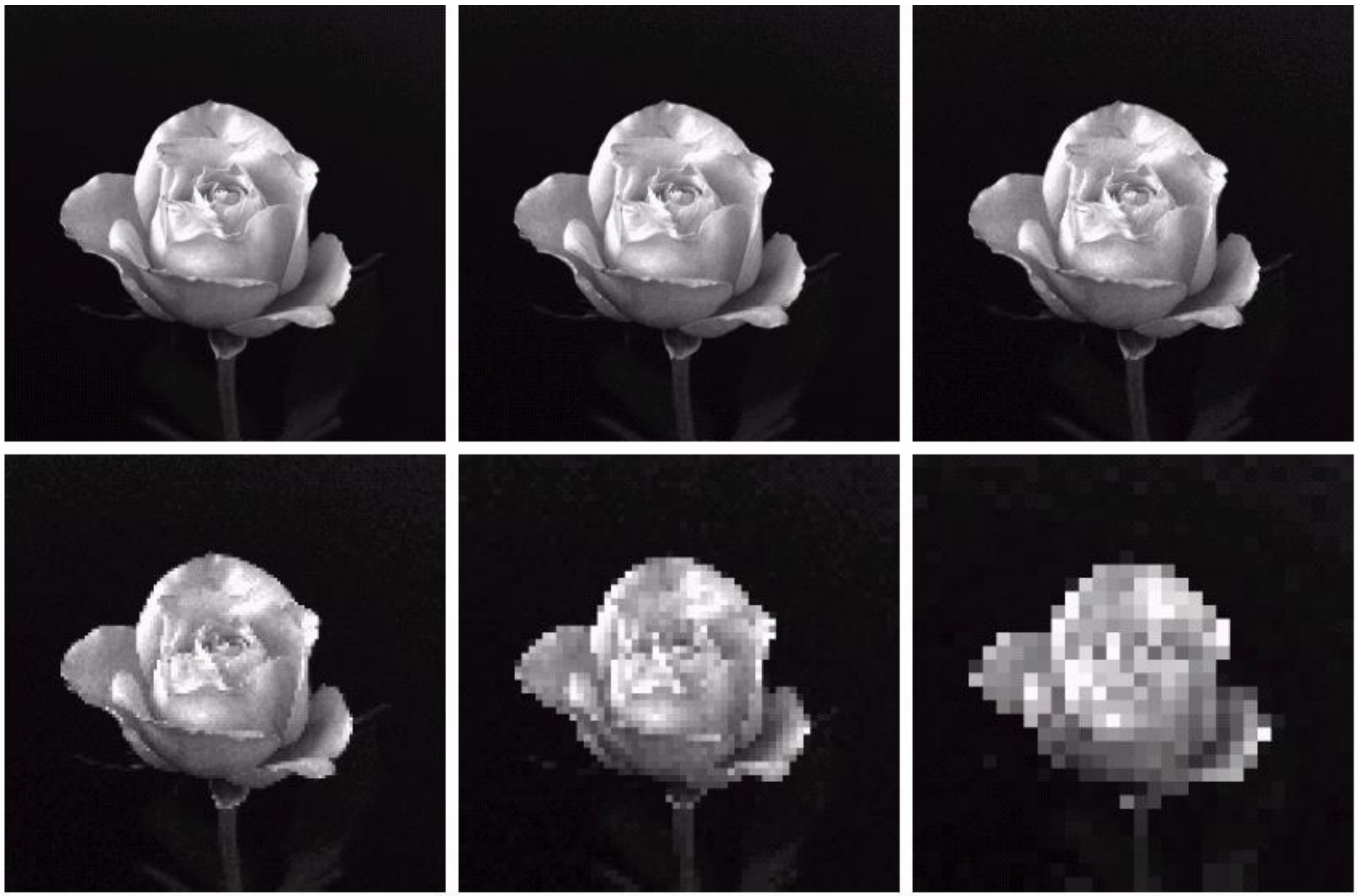
Contents

- Image Resolution
- Relationship between pixels
- Connectivity
- Connected Component Analysis

Spatial & Gray Level Resolution

Spatial Resolution

Spatial Resolution



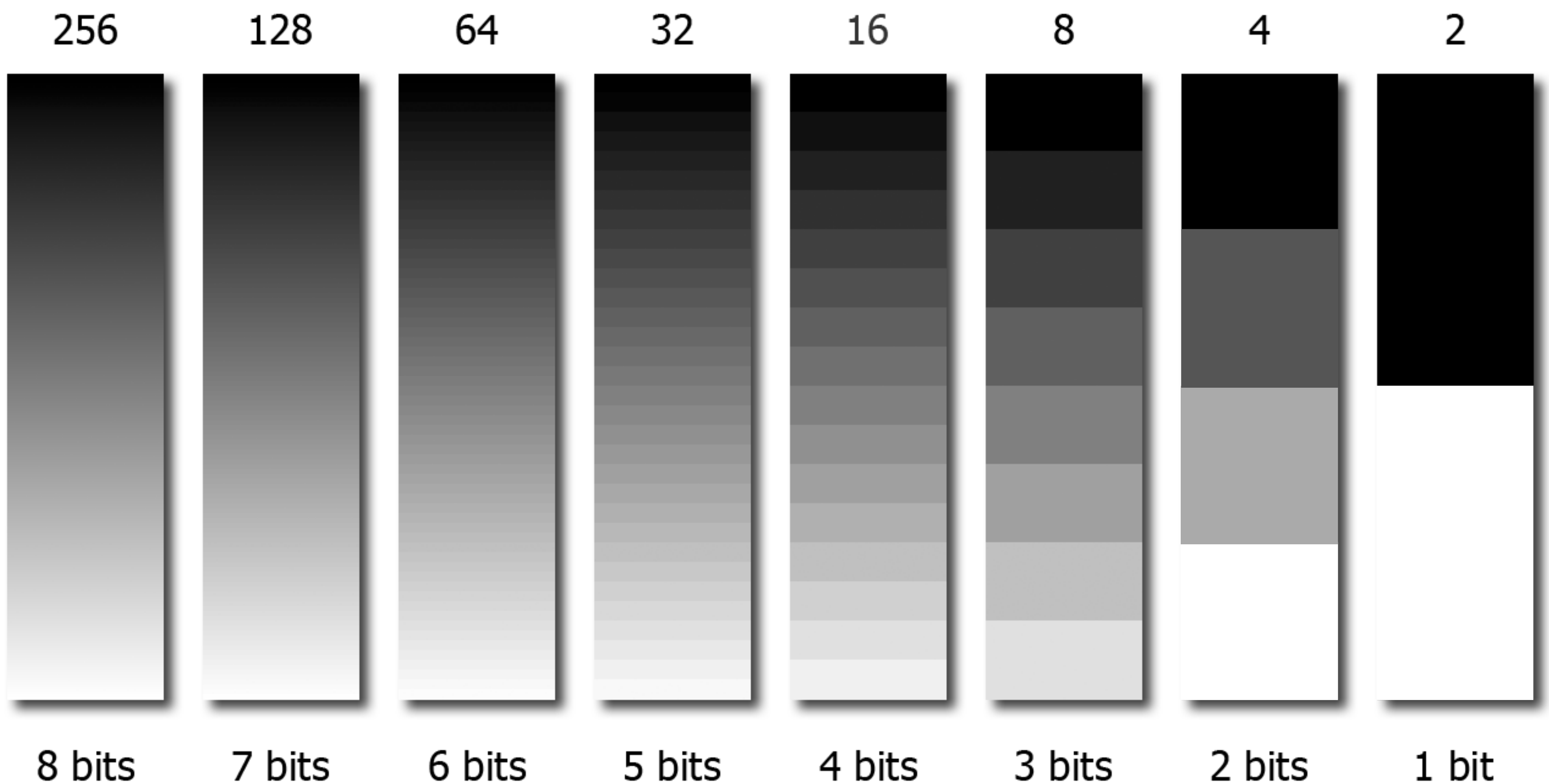
Intensity Level Resolution

- *Intensity level resolution* refers to the number of intensity levels used to represent the image
  - The more intensity levels used, the finer the level of detail in an image
  - Intensity level resolution is usually given in terms of the number of bits used to store each intensity level

Intensity Level Resolution

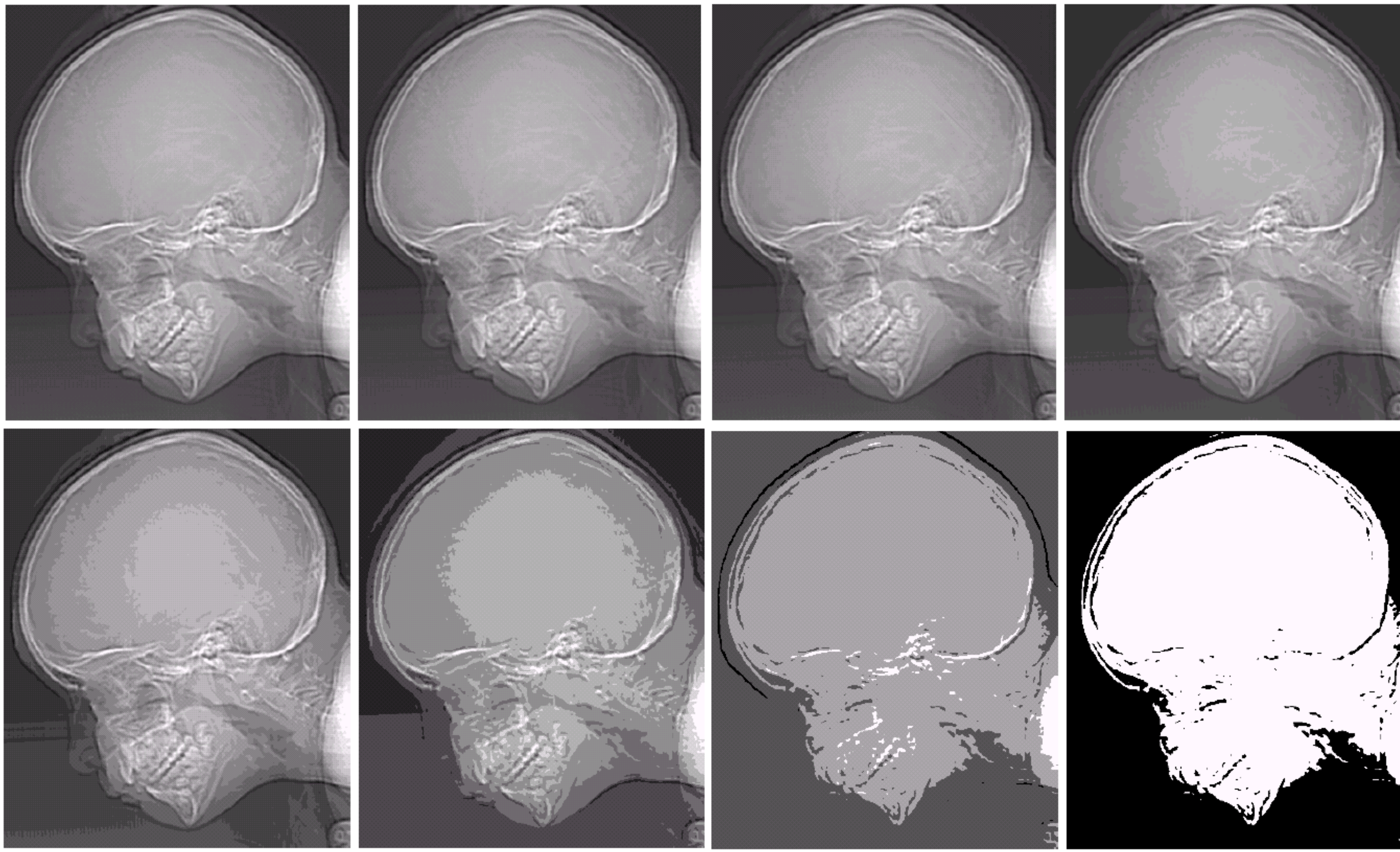
Number of Bits	Number of Intensity Levels	Examples
1	2	0, 1
2	4	00, 01, 10, 11
4	16	0000, 0101, 1111
8	256	00110011, 01010101
16	65,536	1010101010101010

Intensity Level Resolution



Intensity Level Resolution

256 grey levels (8 bits per pixel) | 128 grey levels (7 bpp) | 64 grey levels (6 bpp) | 32 grey levels (5 bpp)



16 grey levels (4 bpp) | 8 grey levels (3 bpp) | 4 grey levels (2 bpp) | 2 grey levels (1 bpp)

Resolution: How much is enough?

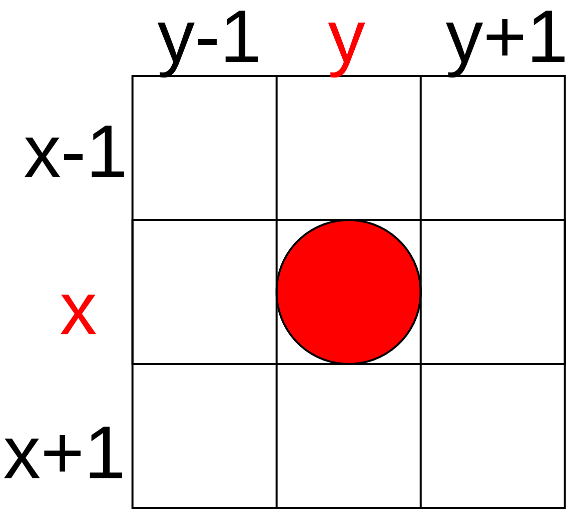
- How many samples and gray levels are required for a good approximation?
  - Quality of an image depends on number of pixels and gray-level number
  - The more these parameters are increased, the closer the digitized array approximates the original image
  - But: Storage & processing requirements increase rapidly as a function of N, M, and k

Resolution: How much is enough?

- Depends on what is in the image and what you would like to do with it

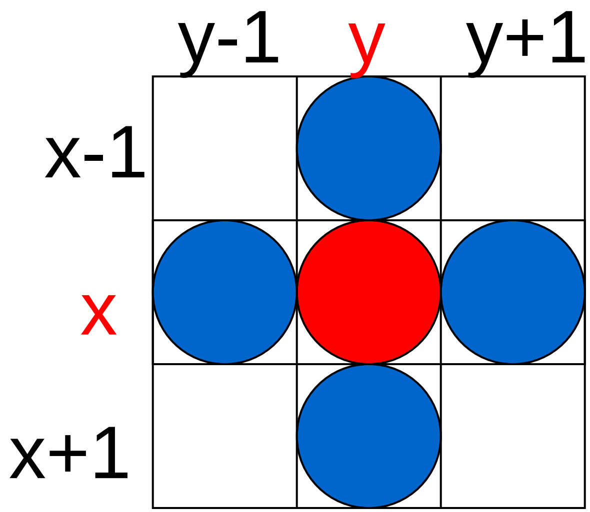
Relationships between pixels

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



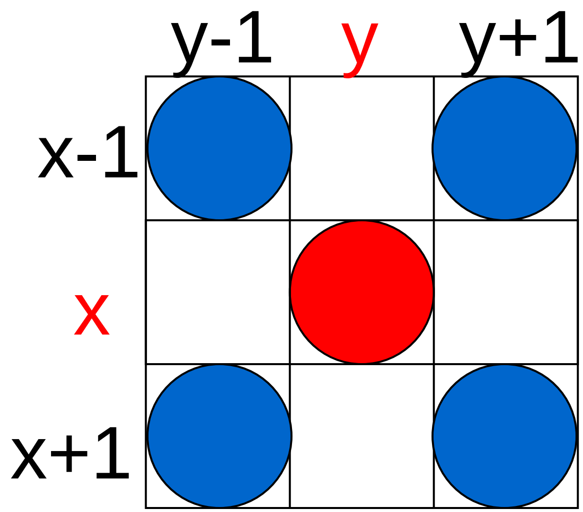
4- Neighbors of a Pixel –$N_4(p)$

What are the coordinates of each of the blue pixels



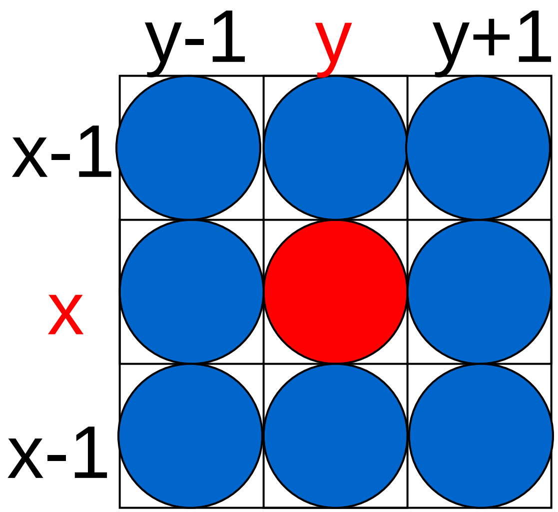
(x-1,y), (x+1,y), (x, y-1), (x, y+1)

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 –$N_8(p)$

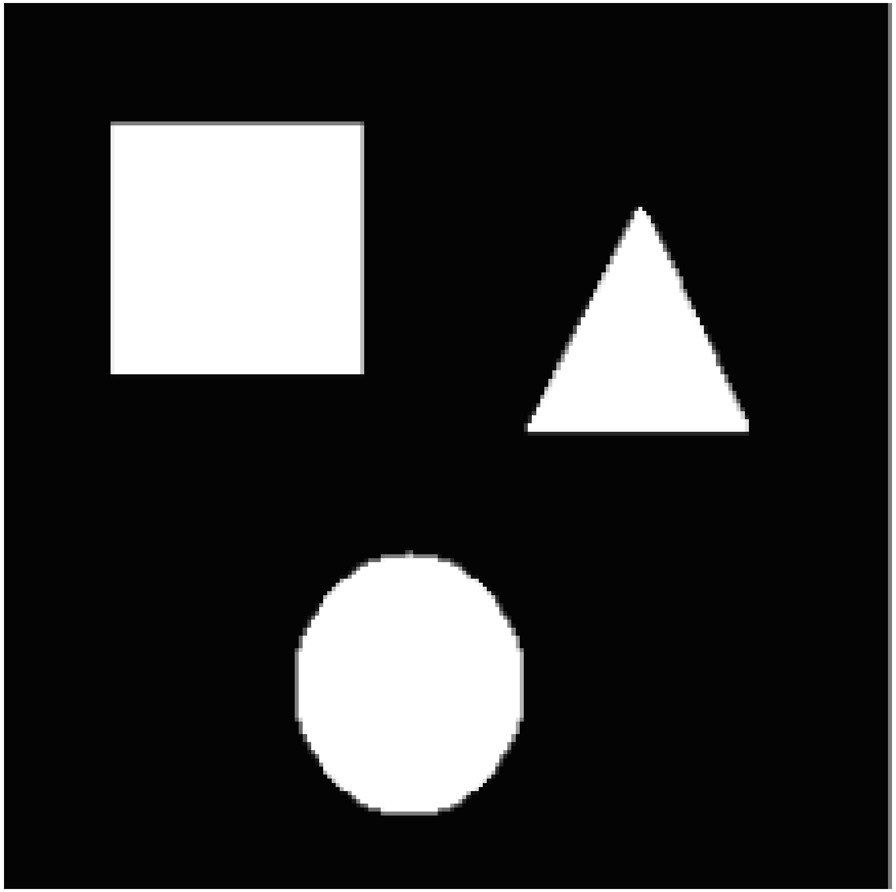


$$N_8(p) = N_4(p) \cup N_D(p)$$

(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 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 $$(p,q) \in V, and\ q \in N_4(p)$$

Set of gray levels V = {1}

0	1	1	0
1	1	0	1
0	0	1	1

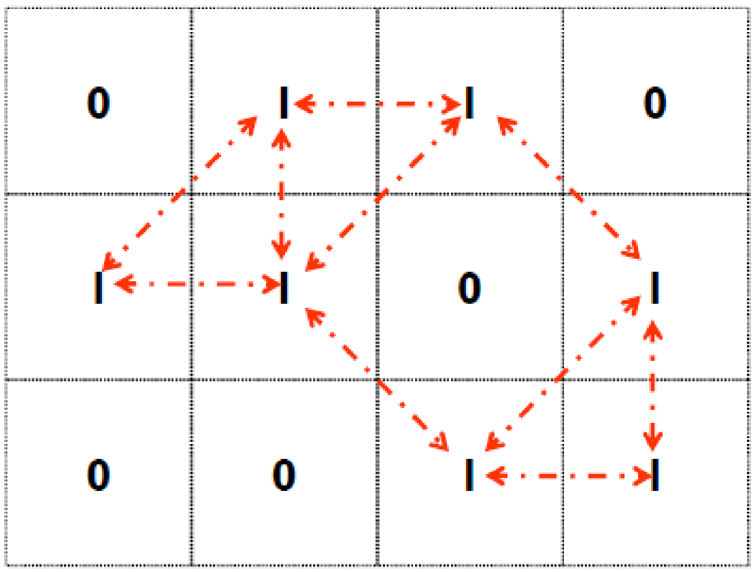
Connectivity

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

8-connectivity

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

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

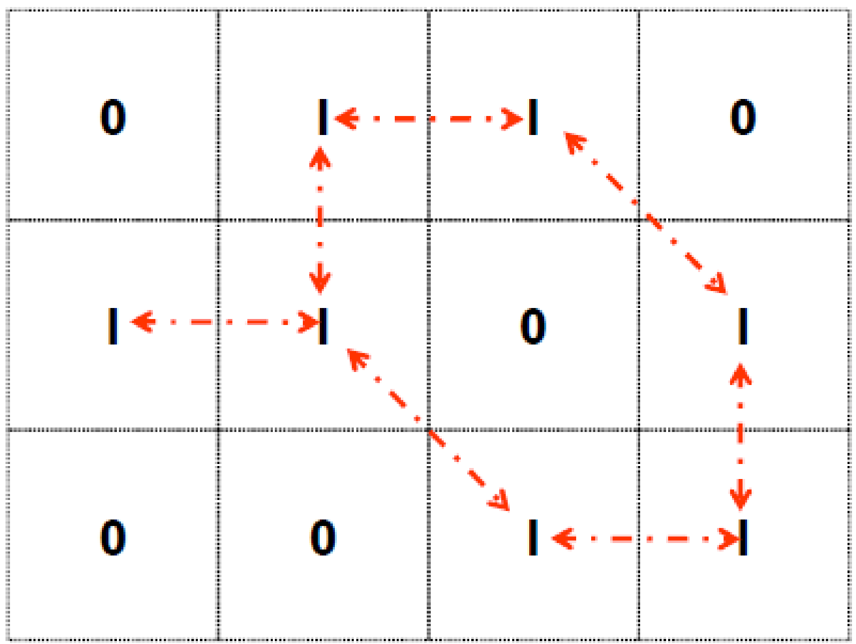
$(p, q) \in V, and\ q$ satisfies one of the following:

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

b. $q \in N_D(p)\ And\ N_4(p) \cap N_4(q)$ has no pixels whose values are from V

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

- 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}) $1 \le i \le n$

Test Yourself

Consider the image segment shown.

(a) Let $V = \{0, 1\}$ and compute the lengths of the shortest 4-, 8-, and m-path between p and q. If a particular path does not exist between these two points, explain why.

(b) Repeat for $V = \{1, 2\}$.

$$\begin{array}{ccccc} & 3 & 1 & 2 & 1\,(q) \\ & 2 & 2 & 0 & 2 \\ & 1 & 2 & 1 & 1 \\ (p) & 1 & 0 & 1 & 2 \end{array}$$

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)

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

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

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

Chessboard distance (D_8 distance)

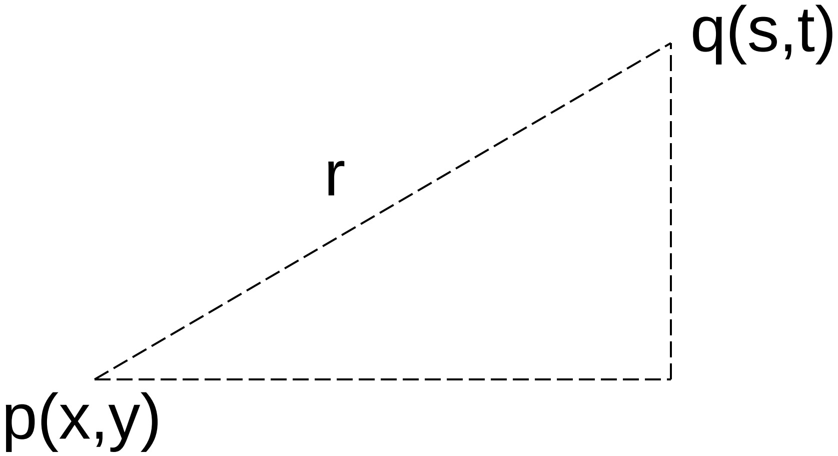
$$D_8(p,q) = \max(|x-s|, |y-t|)$$

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

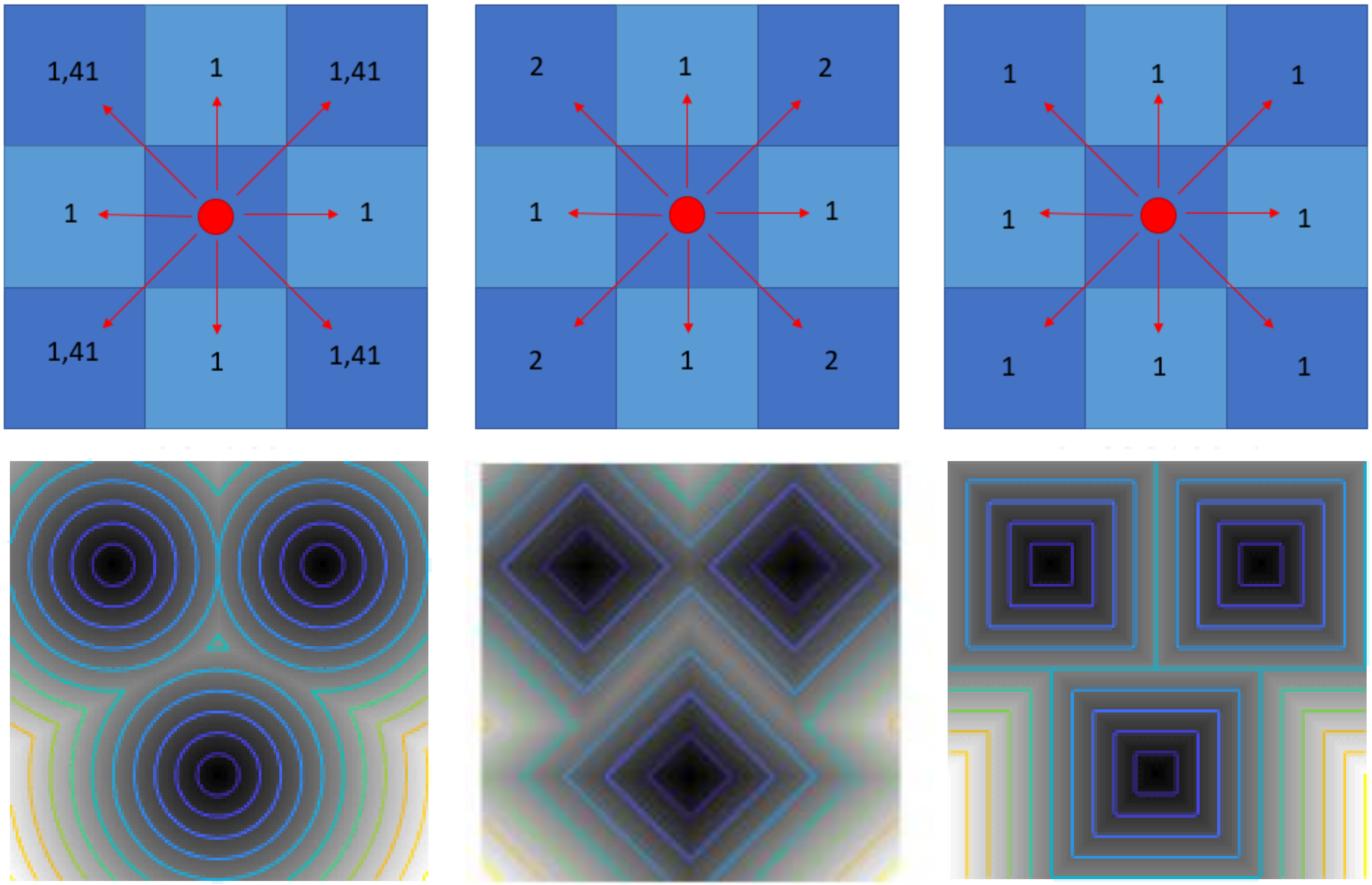
$$D_e(p,q)=\sqrt{(x-s)^2+(y-t)^2}$$



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

Distance Maps

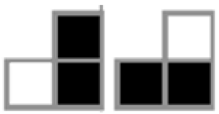
EUCLIDEAN (STRAIGHT LINE) | **L1 (CITY BLOCK)** | **CHEBYSHEV (CHESSBOARD)**



Connected Component Analysis

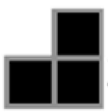
CC labeling – 4 Connectivity

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

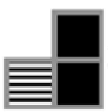


1.) If the next pixel to process is 1

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



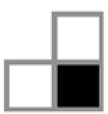
ii.) If both are 1 and have the same label, copy it.



iii.) If they have different labels

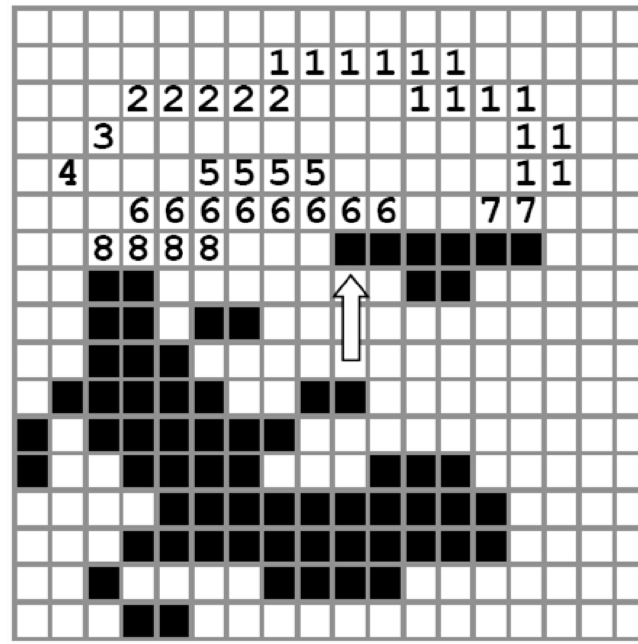
– Copy the label from the left.

– Update the equivalence table.



iv.) Otherwise, assign a new label.

Pass 1

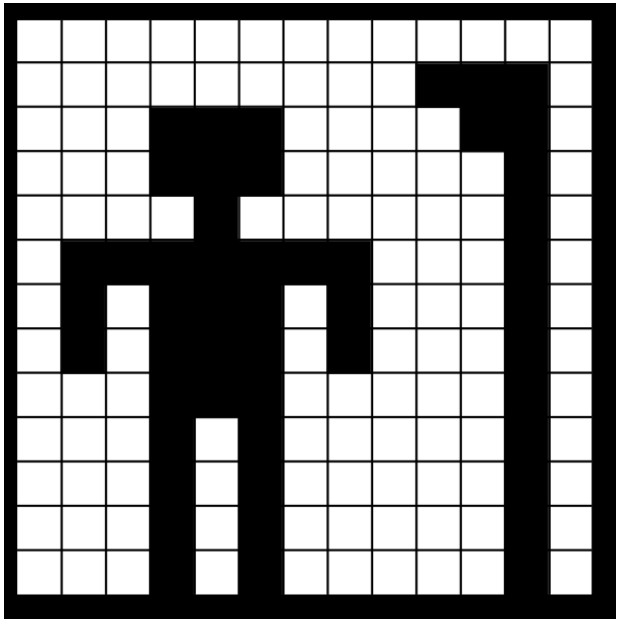


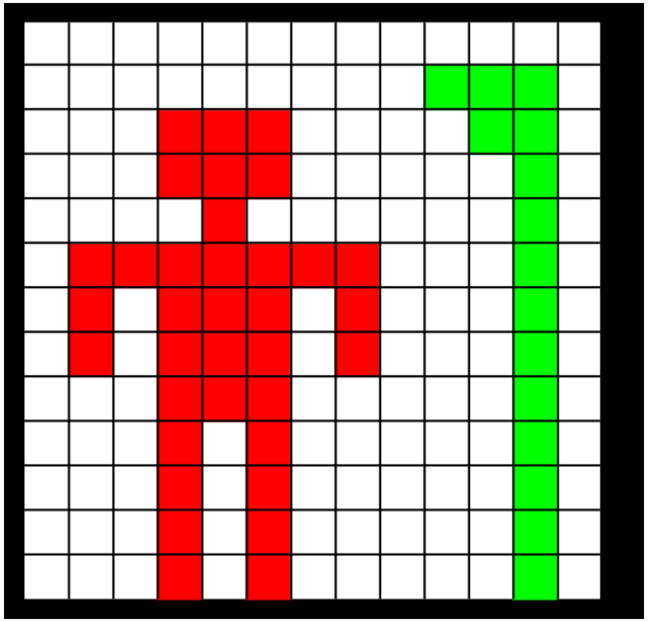
- Re-label with the smallest of equivalent labels

Pass 2

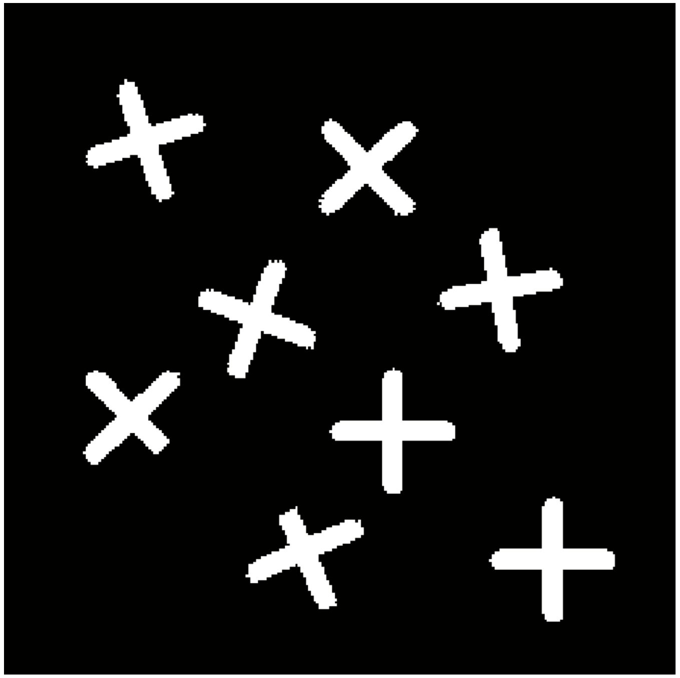
```
{1, 2, 7}
{3}
{4}
{5, 6, 8}
{}
```

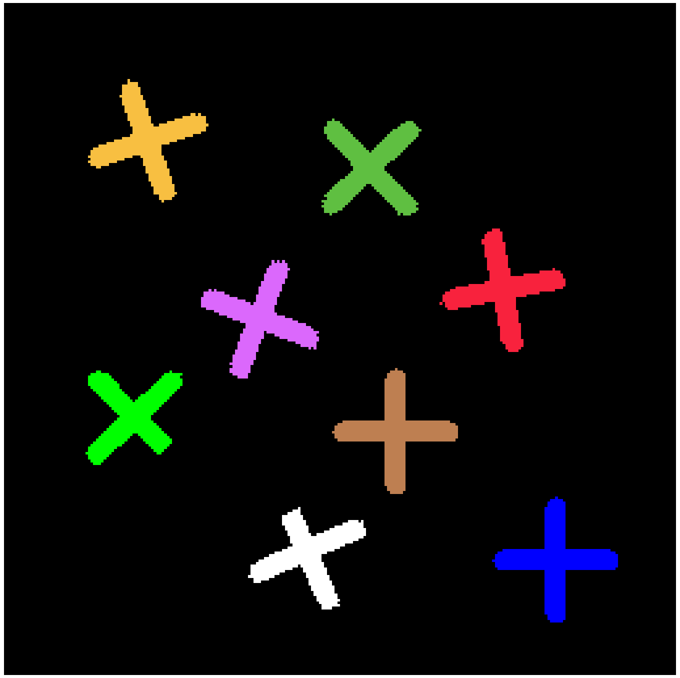
CC labeling – 4 Connectivity





CC labeling – 4 Connectivity

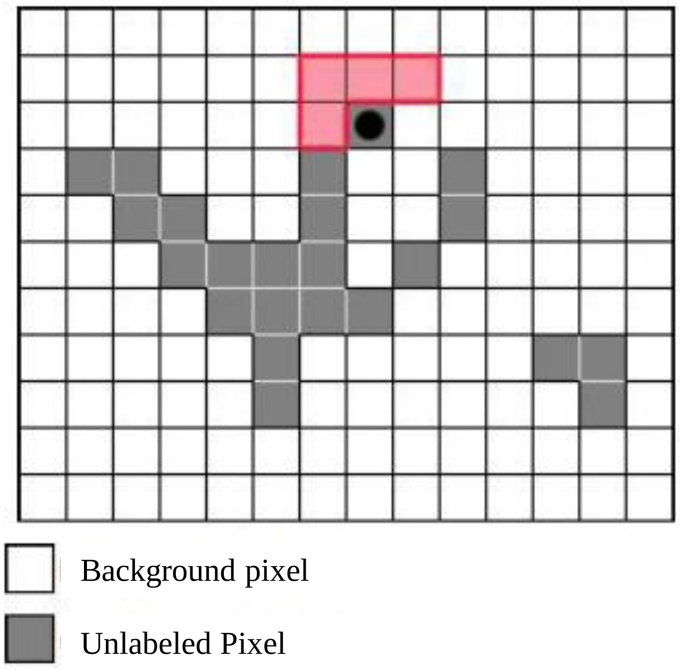


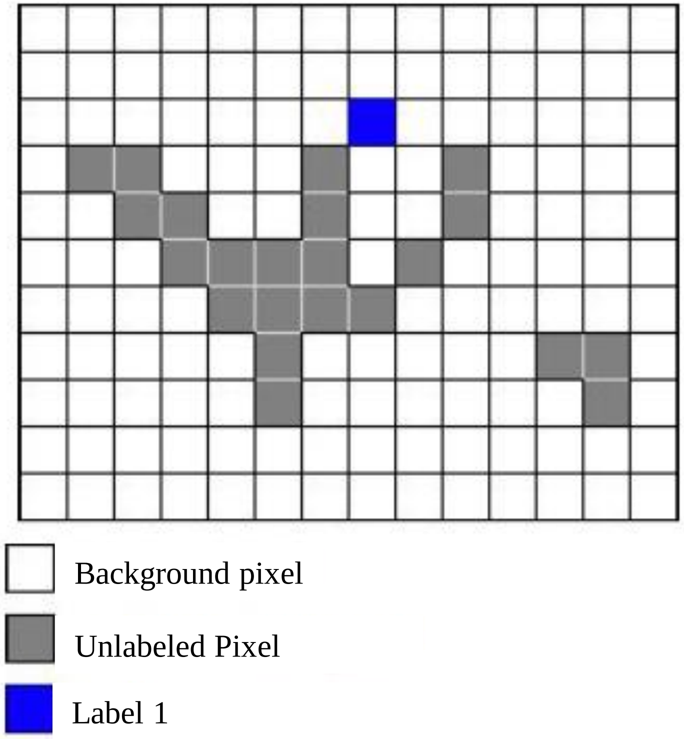


CC labeling – 8 Connectivity

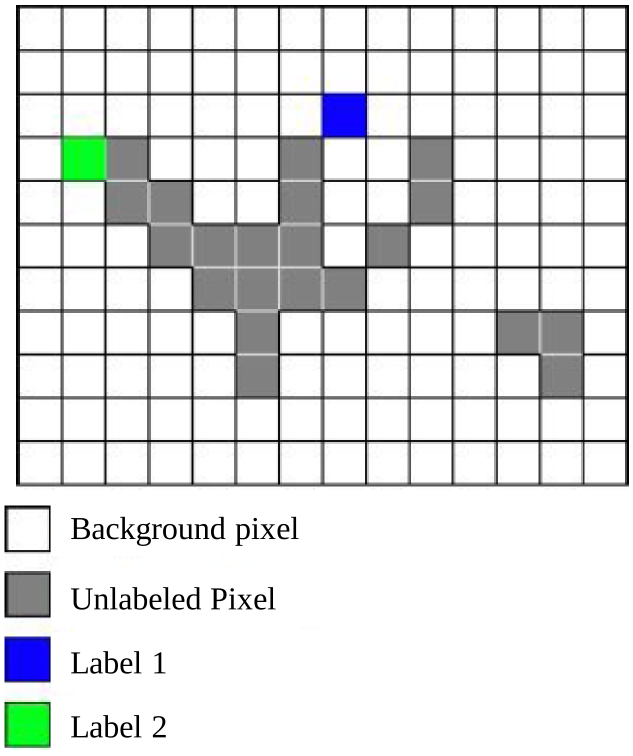
Same algorithm but examine also the upper diagonal neighbors of *p*

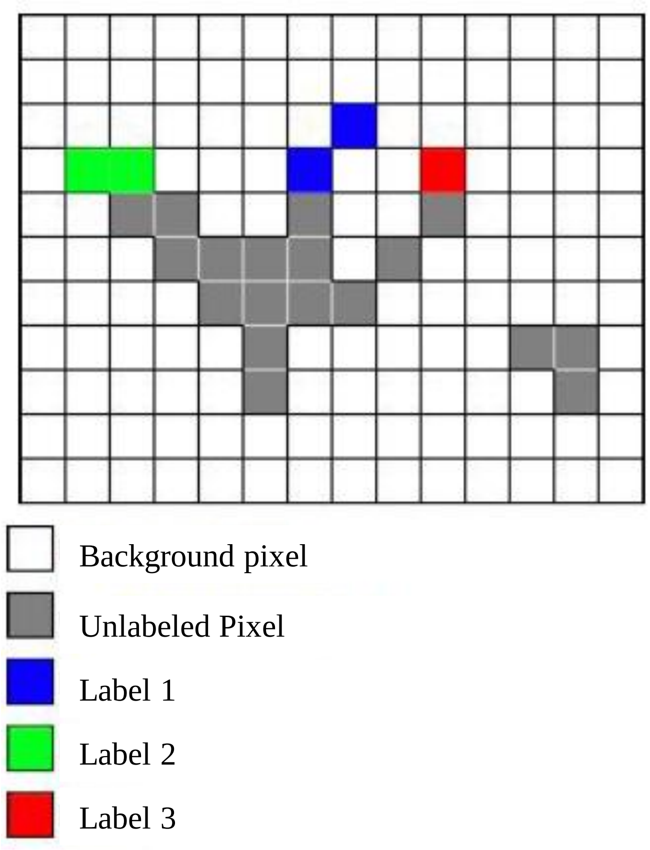
CC labeling – 8 Connectivity



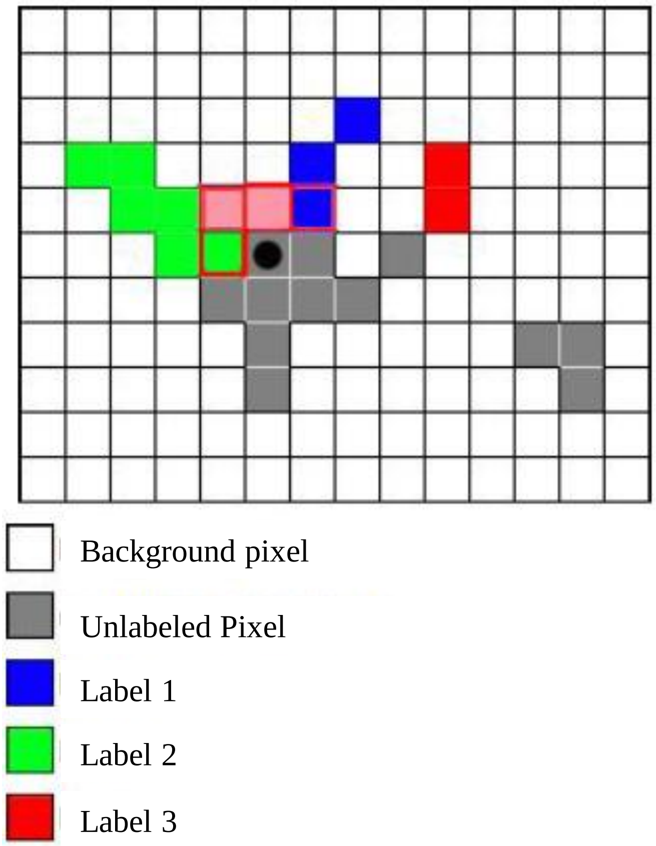


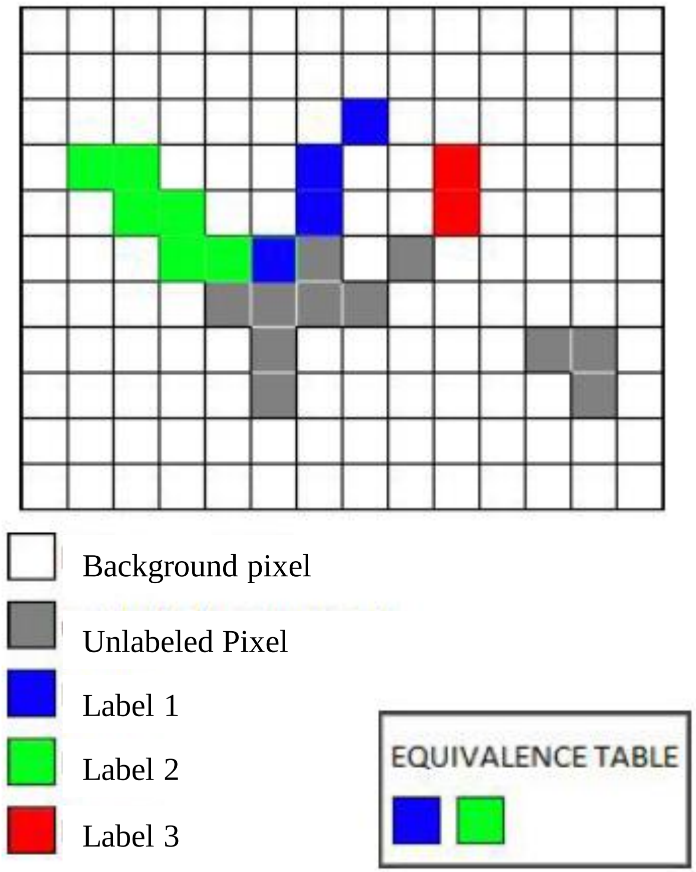
CC labeling – 8 Connectivity



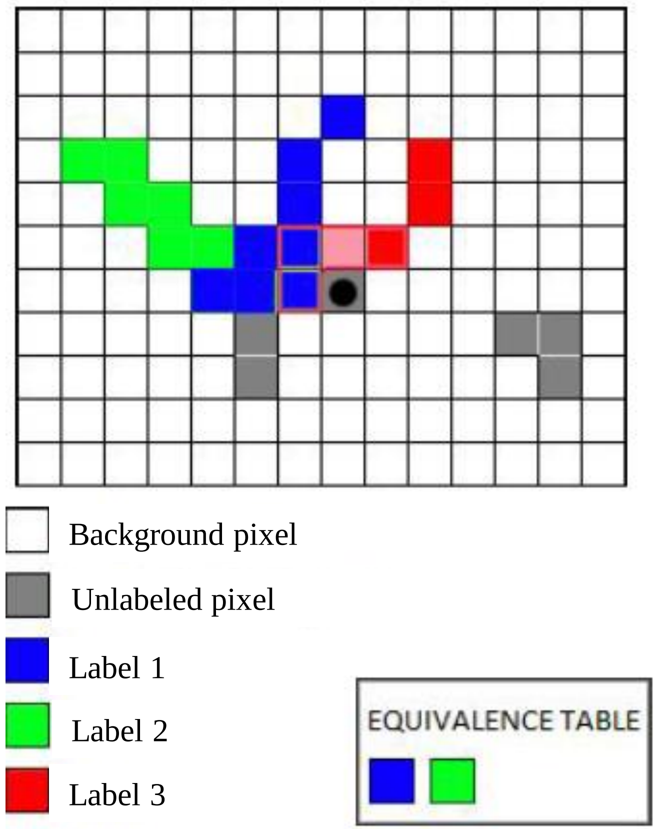


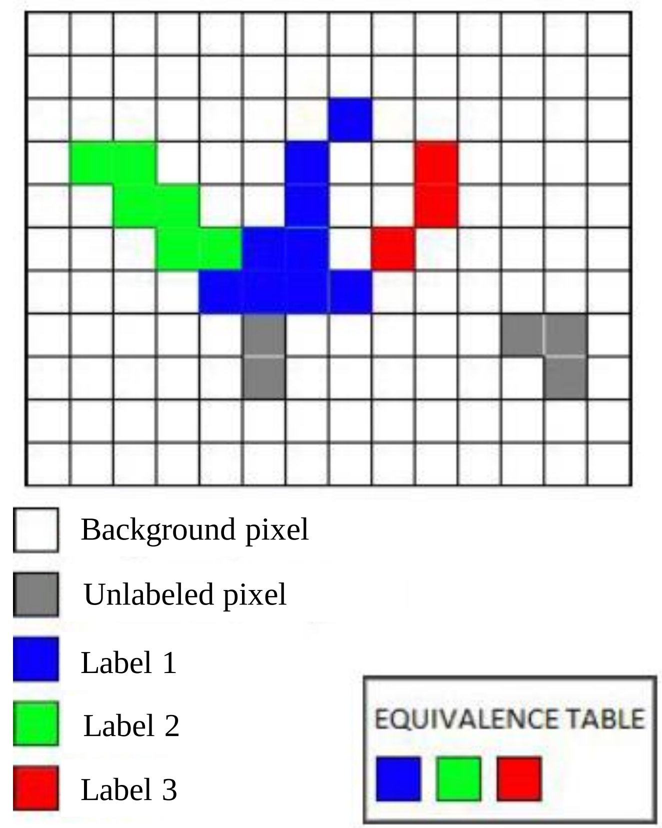
CC labeling – 8 Connectivity



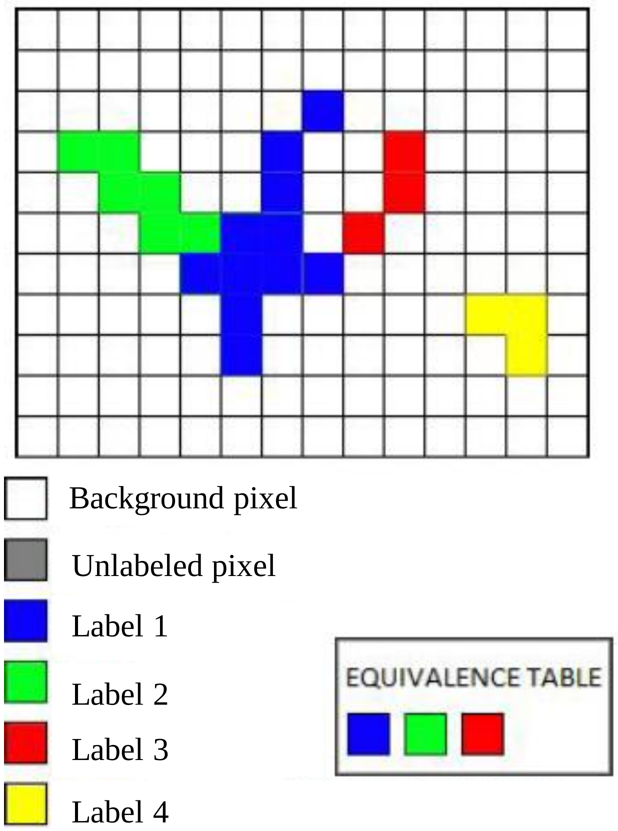


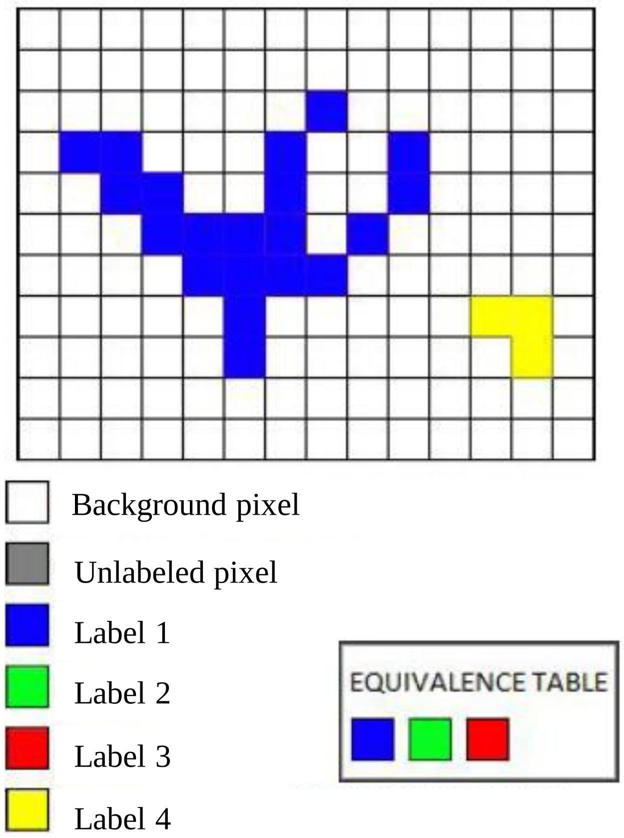
CC labeling – 8 Connectivity





CC labeling – 8 Connectivity





Today's Learning Outcomes

- Image resolution is purely dependent on the type of application and available resources
- Relationship between pixels is important
- Connected component analysis is one of the fundamental concept in image analysis

What's Next

- Image Enhancement
- Mathematical Transformation

Readings from Book (4^{th} Edn.)

- Chapter – 2

Acknowledgements

- Statistical Pattern Recognition: A Review – A.K Jain et al., PAMI (22) 2000
- Pattern Recognition and Analysis Course – A.K. Jain, MSU
- *Pattern Classification"* by Duda et al., John Wiley & Sons.
- Digital Image Processing", Rafael C. Gonzalez & Richard E. Woods, Addison-Wesley, 2018
- Machine Vision: Automated Visual Inspection and Robot Vision", David Vernon, Prentice Hall, 1991
- www.eu.aibo.com/
- Advances in Human Computer Interaction, Shane Pinder, InTech, Austria, October 2008

Material in these slides has been taken from, the following resources