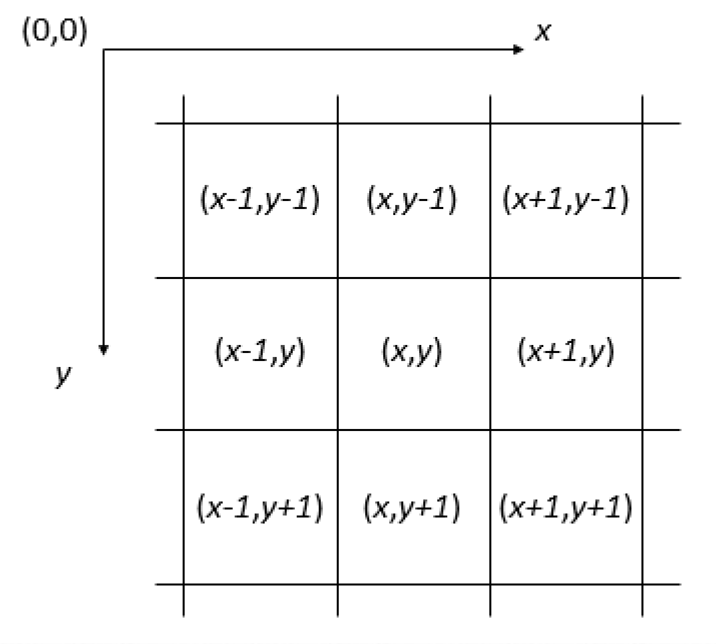
Basic Relationships Between Pixels

- Neighborhood
- Adjacency
- Connectivity
- Paths
- Regions and boundaries



Conventional indexing method

Neighbors of a Pixel

- Any pixel p*(x, y)* has two vertical and two horizontal neighbors, given by

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

- This set of pixels are called the 4-neighbors of
- P, and is denoted by N4(P).
- Each of them are at a unit distance from P.

	$(x,y-1)$	
$(x-1,y)$	**p**	**$(x+1,y)$**
	$(x,y+1)$	

4-neighborhood relation considers only vertical and horizontal neighbors.

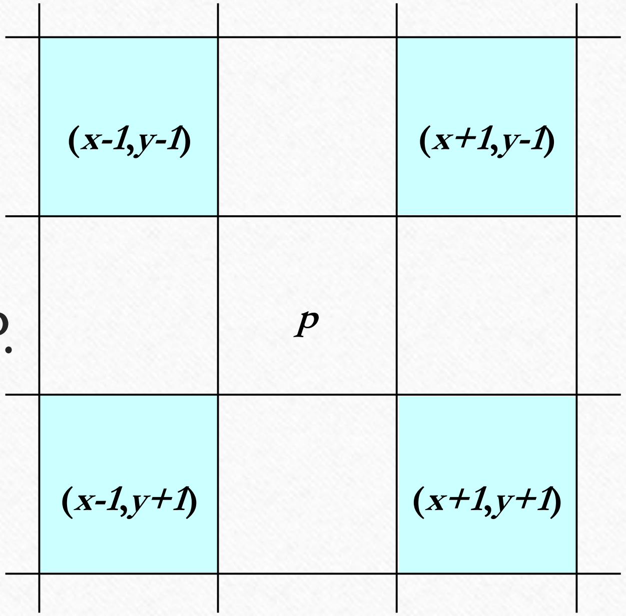
Note: $q \in N_4(p)$ implies $p \in N_4(q)$

Neighbors of a Pixel (Contd..)

- The four diagonal neighbors of p(x,y) are given by,

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

  This set is denoted by N_D(P).
- Each of them are at Euclidean distance of 1.414 from P.



Adjacency

Let V be set of gray levels values used to define adjacency.

- **<u>4-adjacency:</u> Two pixels *p* and *q* with values from V are 4-adjacent if q is in the set N4(*p*).**
- **<u>8-adjacency:</u> Two pixels *p* and *q* with values from V are 8-adjacent if q is in the set N8(*p*).**
- **<u>m-adjacency:</u> Two pixels *p* and *q* with values from V are m-adjacent if,**
  - **q is in N4(P) or**
  - **q is in N_D(p) and the set $[N_4(p) \cap N_4(q)]$ is empty**

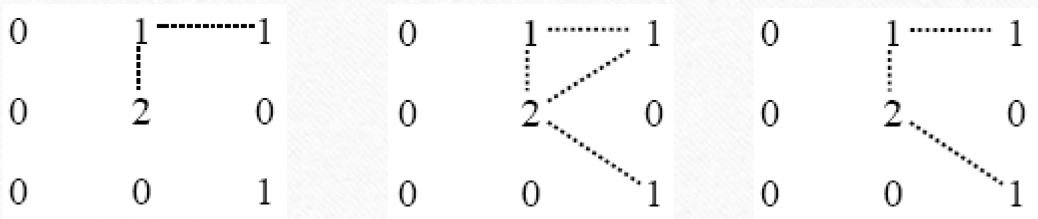
    (has no pixels whose values are from V).

Connectivity

- **To determine whether the pixels are adjacent.**
- **Let V be the set of gray-level values used to define connectivity; then Two pixels p, q that have values from the set V are:**
  - 4-connected, **if q ∈N4(p)**
  - 8-connected, **if q ∈ N8(p)**
  - m-connected, **iff**
    - **q ∈ N4(p) or**
    - **q ∈ ND(p) and the set $[N_4(p) \cap N_4(q)]$ is empty**

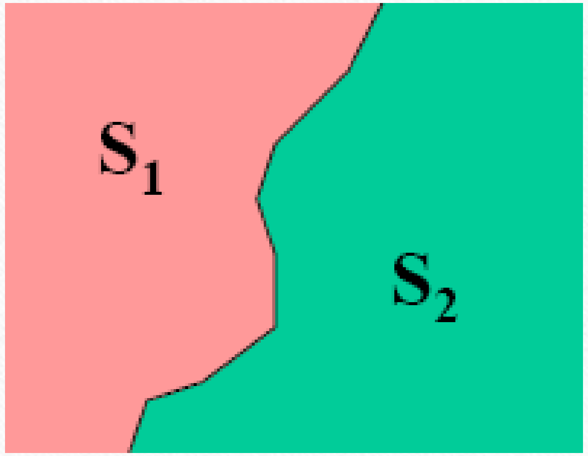
V = {1, 2}

a **b** **c**



Adjacency/Connectivity

- **Pixel p is *adjacent* to pixel q if they are connected.**
- **Two *image subsets* S1 and S2 are adjacent if some pixel in S1 is adjacent to some pixel in S2.**



Paths & Path lengths

- A *path* from pixel p with coordinates *(x, y)* to pixel *q* with coordinates *(s, t)* is a sequence of distinct pixels with coordinates:
- *(x0, y0), (x1, y1), (x2, y2) … (xn, yn)*,
- where *(x0, y0)=(x, y)* and *(xn, yn)=(s, t); (xi, yi)* is adjacent to *(xi-1, yi-1)* , $1 \le i \le n$
- Here *n* is the *length* of the path.
- We can define 4-, 8-, and m-paths based on type of adjacency used.

Distance Measure of Path

If distance depend on the path between two pixels such as *m-adjacency* then the D_m distance between two pixels is defined as the shortest *m-path* between the pixels.

$$
\begin{array}{cccc}
 & 0 & 0 & 1 \leftarrow q \\
 & 0 & 1 & 0 \\
p \rightarrow & 1 & 0 & 0
\end{array}
\qquad
\begin{array}{cccc}
 & 0 & 0 & 1 \leftarrow q \\
p & 1 & 1 & 0 \\
p \rightarrow & 1 & 0 & 0
\end{array}
\qquad
\begin{array}{cccc}
 & 0 & 1 & 1 \leftarrow q \\
 & 1 & 1 & 0 \\
p \rightarrow & 1 & 0 & 0
\end{array}
$$

$$D_m(p, q) = 2 \qquad D_m(p, q) = 3 \qquad D_m(p, q) = 4$$

Path Length

Find the shortest 4-, 8-, *m-path* between *p* and *q* for $V = \{0, 1\}$ and $V = \{1, 2\}$

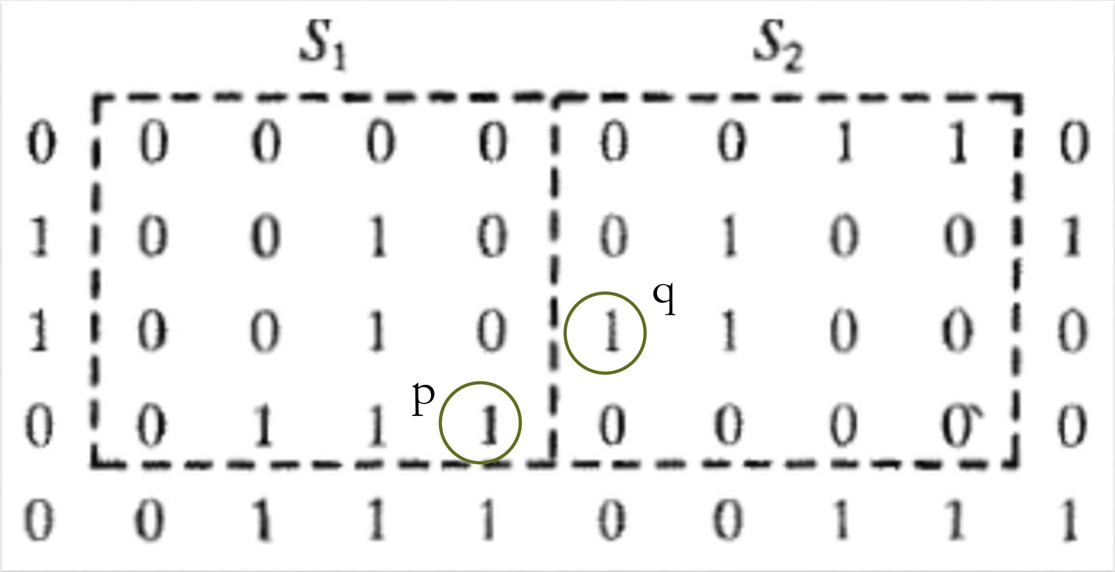
			(q)
3	1	2	1
2	2	0	2
1	2	1	1
1	0	1	2
(p)			

Tasks done using neighbourhood processing

- Smoothing / averaging
- Noise removal / filtering
- Edge detection
- Contrast enhancement

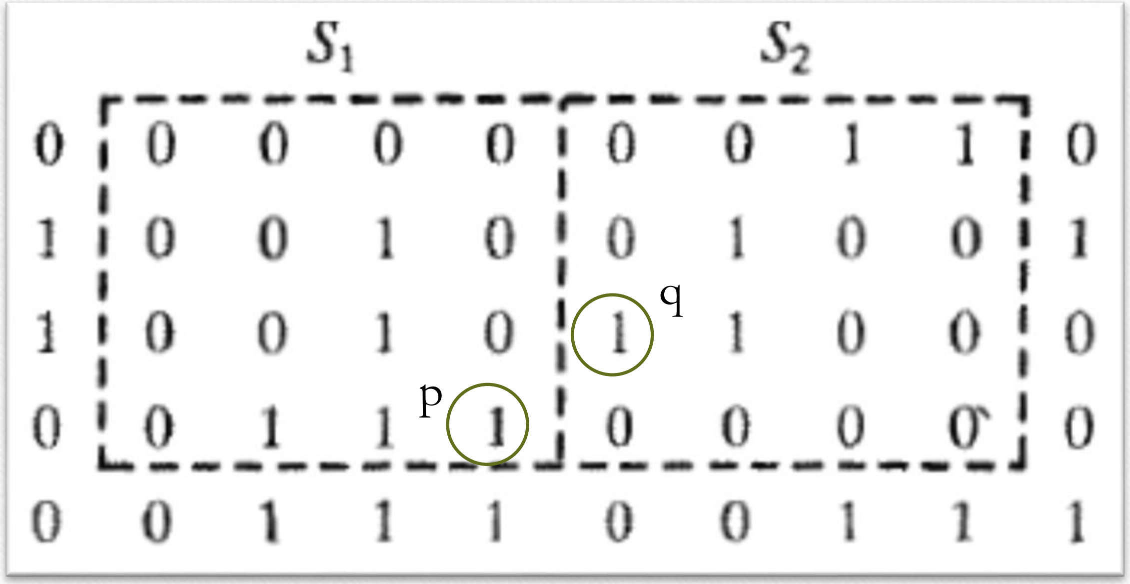
Problem-1

- Consider the two image subsets, S_1 and S_2, shown in the following figure. For V={1}, determine whether these two subsets are
  a) 4-adjacent
  b) 8-adjacent
  c) m-adjacent



Solution

1. S1 and S2 are not 4-connected because q is not in the set N_4(p)
2. S1 and S2 are 8-connected because q is in the set N_8(p)
3. S1 and S2 are *m*-connected because
   a) q is in N_4(p), (**or**)
   b) q is in N_D(p) (**and**)
   c) the set $N_4(p) \cap N_4(q)$ is empty.



Distance measures

- Given pixels *p, q* and *z* with coordinates

$$(x, y), (s, t), (u, v)$$

respectively, the distance function D has following properties:

a. $D(p, q) \geq 0$; [D(p, q) = 0, iff p = q]

b. $D(p, q) = D(q, p)$

c. $D(p, z) \leq D(p, q) + D(q, z)$

Distance measures

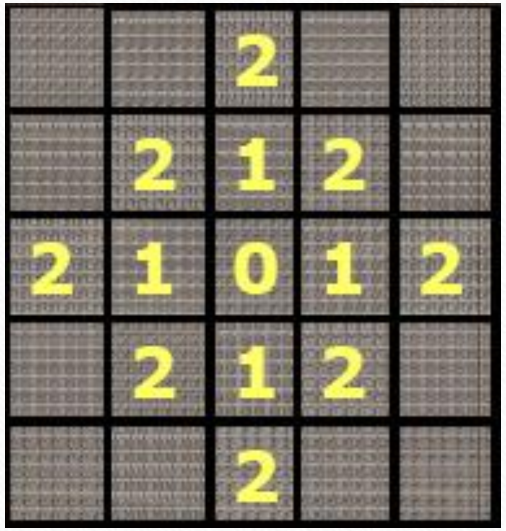
- The following are the different Distance measures:

Euclidean Distance : $D_e(p, q) = SQRT[(x - s)^2 + (y - t)^2]$

Distance measures

- **City Block Distance:**

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



Distance measures

- **Chess Board 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