DIGITAL IMAGE PROCESSING

Digital Image Fundamentals : Session 2

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Today’s Lecture

- **Image sampling and quantization – image interpolation**
- **Relationship between pixels**

Image Interpolation

- **Interpolation:** Process of using known data to estimate unknown values
  e.g., zooming, shrinking, rotating, and geometric correction

- **Interpolation** (or ***resampling***)**:** an imaging method to increase (or decrease) the number of pixels in a digital image.

Note: Some digital cameras use interpolation to produce a larger image than the sensor captured or to create digital zoom

Image Interpolation

Nearest Neighbor Interpolation

$f_1(x_2,y_2) =$
$f(\text{round}(x_2), \text{round}(y_2))$
$=f(x_1,y_1)$

$f(x_1,y_1)$

$f_1(x_3,y_3) =$
$f(\text{round}(x_3), \text{round}(y_3))$
$=f(x_1,y_1)$

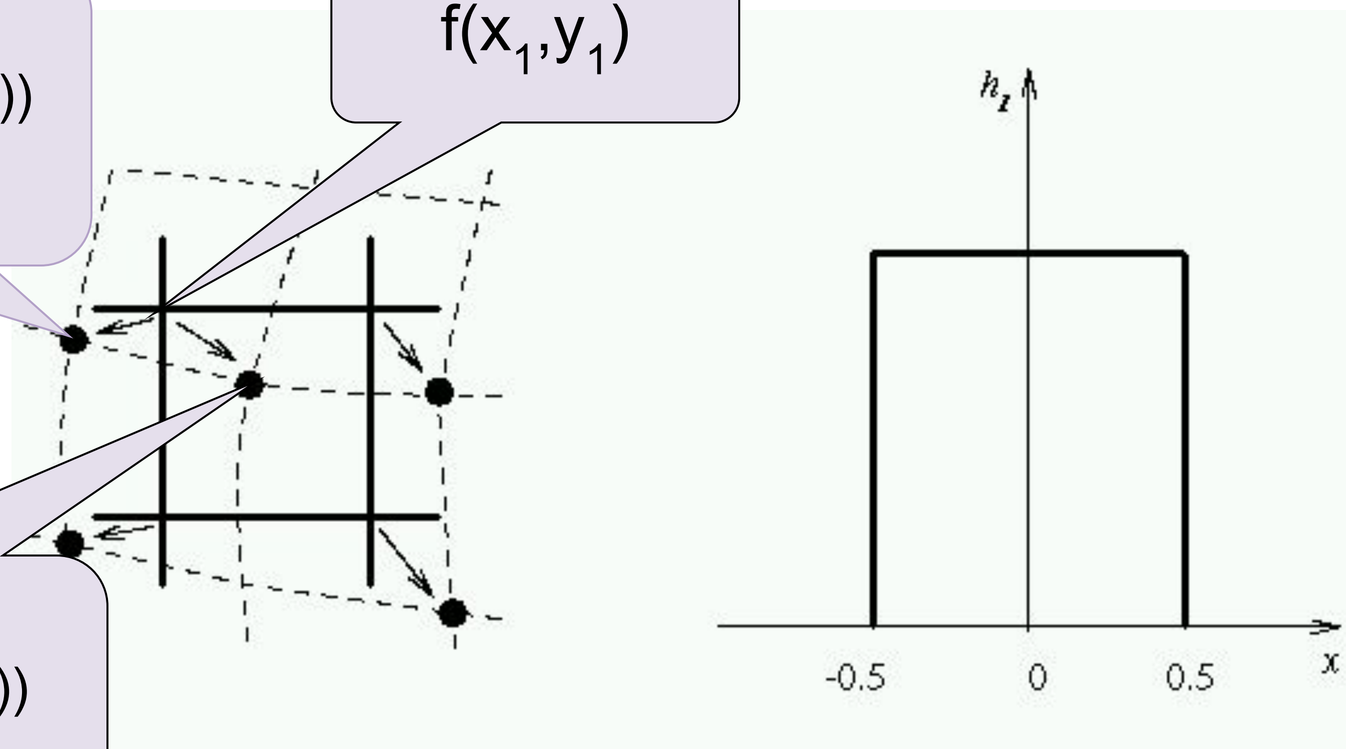
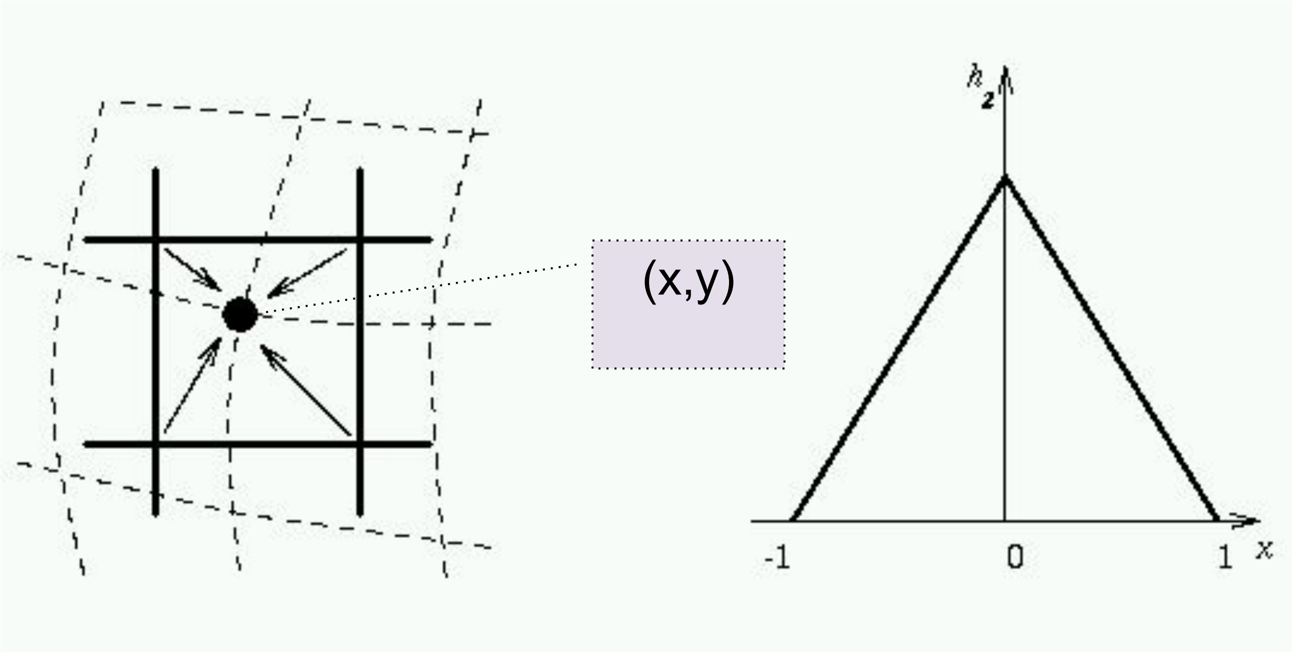


Image Interpolation

Bilinear Interpolation



$$f_2(x,y) = (1-a)(1-b)f(l,k) + a(1-b)f(l+1,k)$$
$$+(1-a)bf(l,k+1) + abf(l+1,k+1)$$
$$l = floor(x), k = floor(y), a = x - l, b = y - k$$

Image Interpolation

Bicubic Interpolation

- The intensity value assigned to point (x, y) is obtained by the following equation

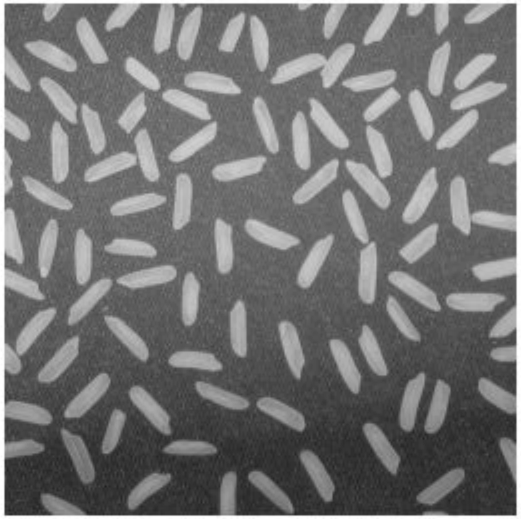
$$f_3(x, y) = \sum_{i=0}^{3} \sum_{j=0}^{3} a_{ij} x^i y^j$$

- The sixteen coefficients are determined by using the sixteen nearest neighbors.

Image Interpolation

Example

original image



nearest

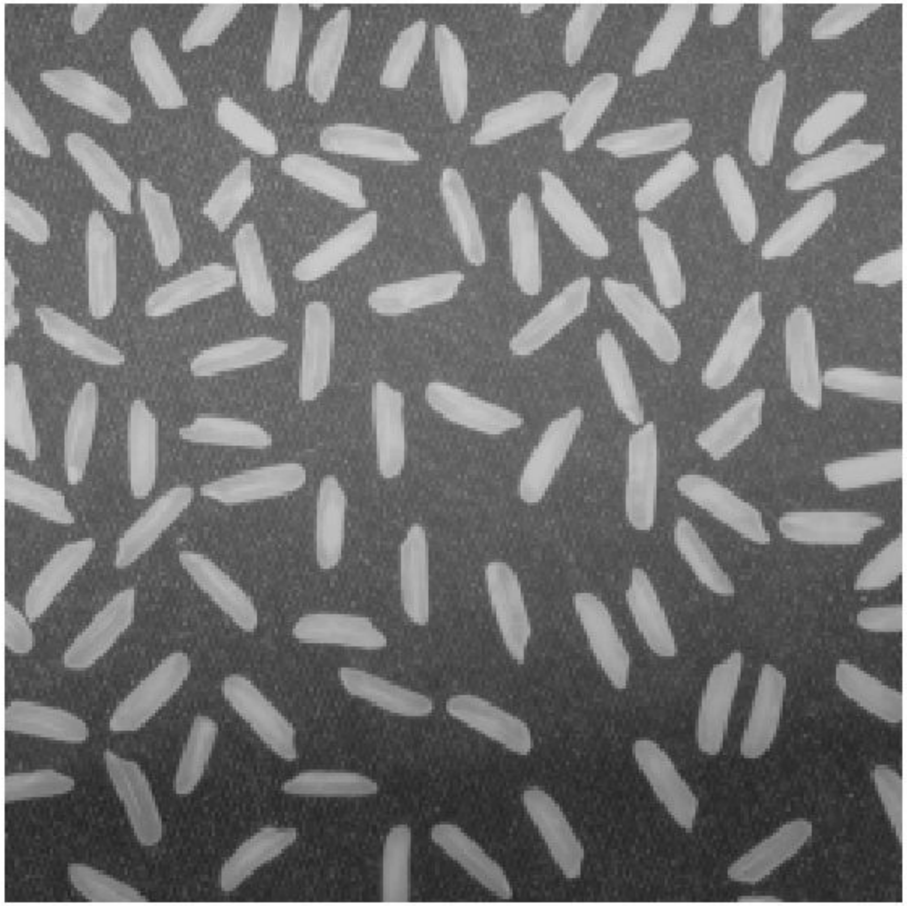
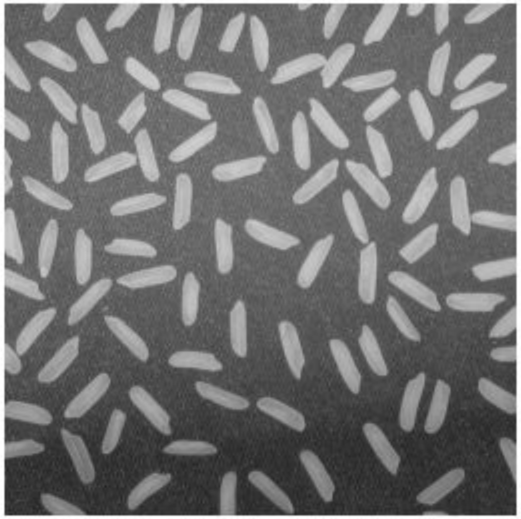


Image Interpolation

Example

original image



bilinear

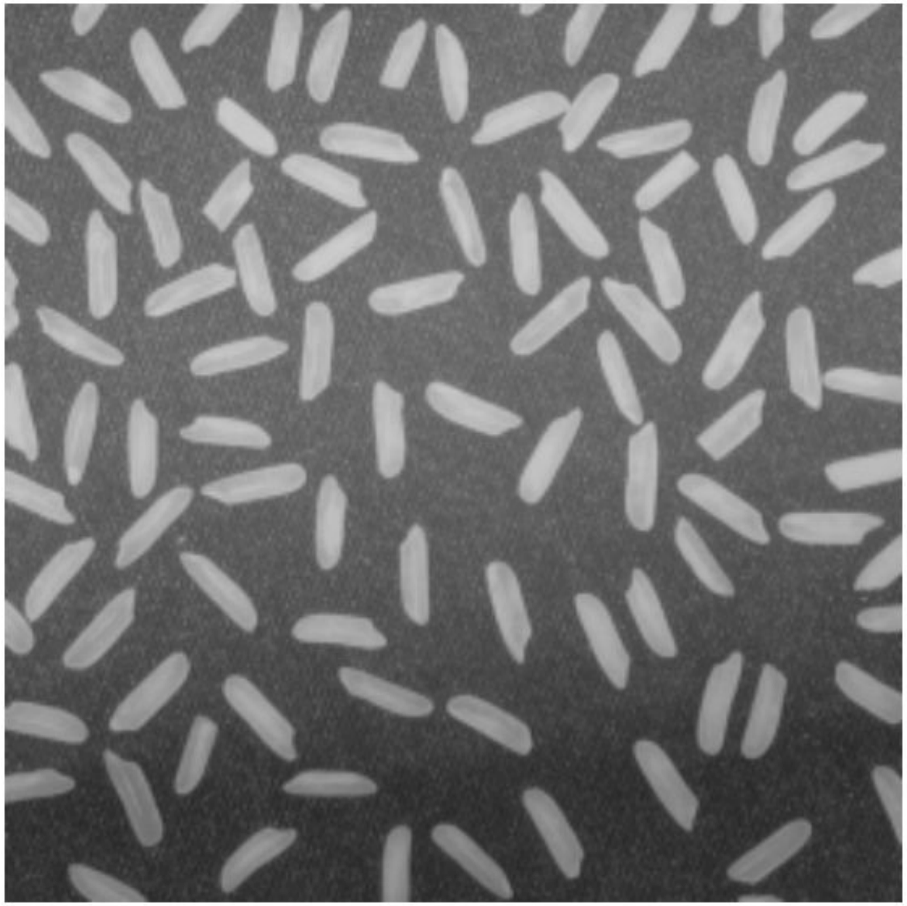
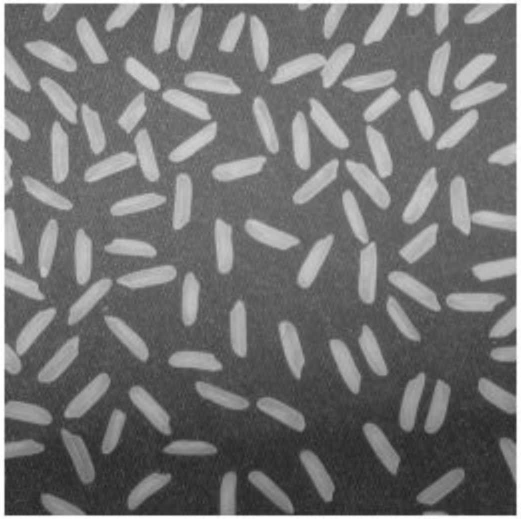


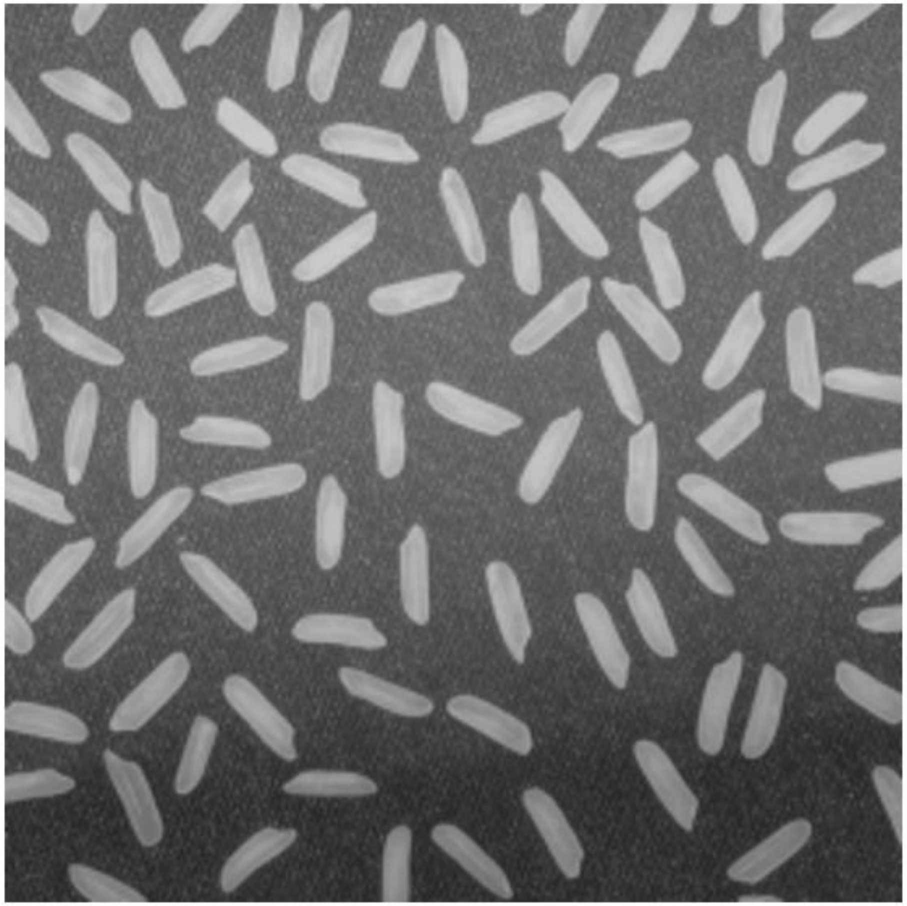
Image Interpolation

Example

original image



bicubic



Relationship between Pixels

- **Neighbourhood**
- **Adjacency**
- **Connectivity**
- **Paths**
- **Regions and**

Relationship between Pixels

A. Neighbors of a pixel p at coordinates (x, y)

a. **4-neighbors of p**, denoted by $\mathbf{N_4(p)}$:

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

a. **4 diagonal neighbors of p**, denoted by $\mathbf{N_D(p)}$:
$(x-1, y-1)$, $(x+1, y+1)$, $(x+1, y-1)$, and $(x-1, y+1)$

a. **8 neighbors of p**, denoted $\mathbf{N_8(p)}$:

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

Relationship between Pixels

A. Adjacency

Let V be the set of intensity values.

a. **4-adjacency**: Two pixels p and q with values from V are 4-adjacent if q is in the set $N_4(p)$.

b. **8-adjacency**: Two pixels p and q with values from V are 8-adjacent if q is in the set $N_8(p)$.

Relationship between Pixels

c. m-adjacency: Two pixels p and q with values from V are m-adjacent if

i. q is in the set $N_4(p)$, or

ii. q is in the set $N_D(p)$ and the set $N_4(p) \cap N_4(p)$ has no pixels whose values are from V.

Relationship between Pixels

A. Path

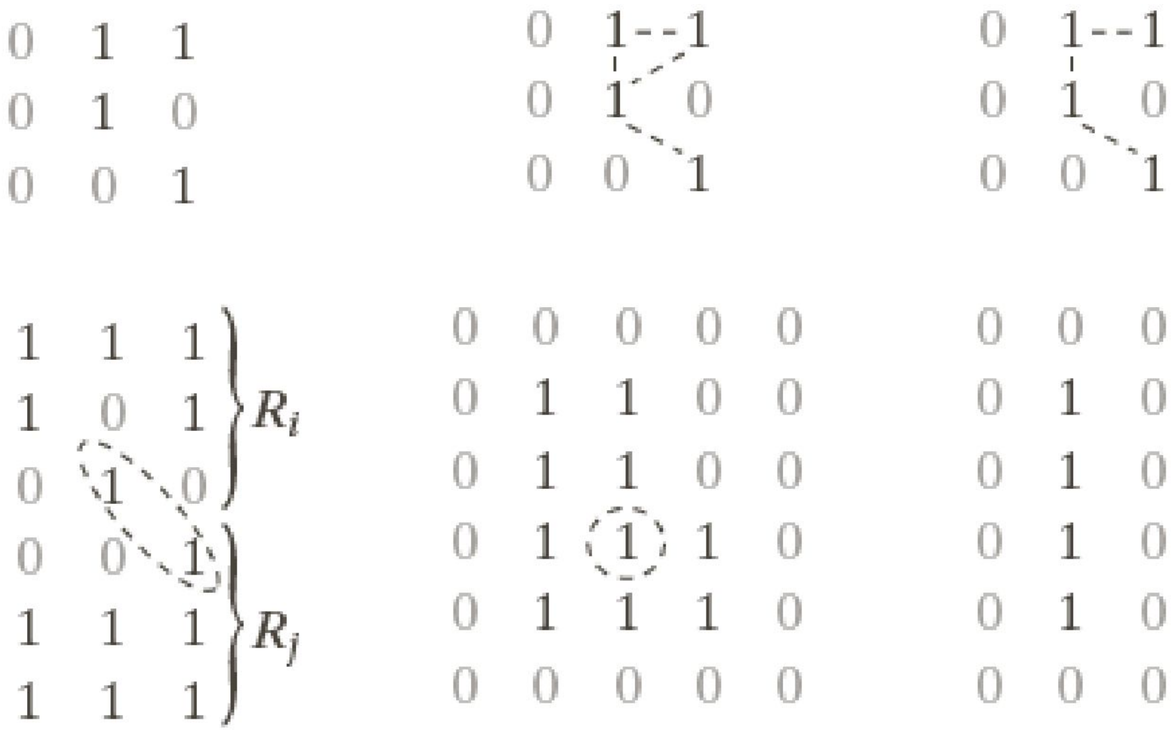
a. A (digital) ***path*** (or curve) from pixel p with coordinates (x_0, y_0) to pixel q with coordinates (x_n, y_n) is a sequence of distinct pixels with coordinates (x_0, y_0), (x_1, y_1),…, (x_n, y_n); where (x_i, y_i) and (x_{i-1}, y_{i-1}) are adjacent for $1 \leq i \leq n$.

b. Here n is the ***length*** of the path.

c. If $(x_0, y_0) = (x_n, y_n)$, the path is ***closed*** path.

d. We can define 4-, 8-, and m-paths based on the type of adjacency used.

Relationship between Pixels



a	b	c
d	e	f

FIGURE 2.25 (a) An arrangement of pixels. (b) Pixels that are 8-adjacent (adjacency is shown by dashed lines; note the ambiguity). (c) m-adjacency. (d) Two regions that are adjacent if 8-adjecency is used. (e) The circled point is part of the boundary of the 1-valued pixels only if 8-adjacency between the region and background is used. (f) The inner boundary of the 1-valued region does not form a closed path, but its outer boundary does.

Relationship between Pixels

Connected in S

Let S represent a subset of pixels in an image. Two pixels p with coordinates (x_0, y_0) and q with coordinates (x_n, y_n) are said to be **connected in *S*** if there exists a path

$$(x_0, y_0), (x_1, y_1), \dots, (x_n, y_n),$$

where $\forall i, 0 \leq i \leq n, (x_i, y_i) \in S$

Relationship between Pixels

Let $\boldsymbol{S}$ represent a subset of pixels in an image

- For every pixel p in $\boldsymbol{S}$, the set of pixels in $\boldsymbol{S}$ that are connected to p is called a ***connected component*** of $\boldsymbol{S}$.
- If $\boldsymbol{S}$ has only one connected component, then $\boldsymbol{S}$ is called ***connected set*.**
- We call $\boldsymbol{R}$ a ***region*** of the image if $\boldsymbol{R}$ is a connected set.
- Two regions, $\boldsymbol{R_i}$ and $\boldsymbol{R_j}$ are said to be ***adjacent*** if their union forms a connected set.
- Regions that are not to be adjacent are said to be ***disjoint*.**

Relationship between Pixels

- ***Boundary (or border)***
  - The ***boundary*** of the region $\boldsymbol{R}$ is the set of pixels in the region that have one or more neighbors that are not in $\boldsymbol{R}$.
  - If $\boldsymbol{R}$ happens to be an entire image, then its boundary is defined as the set of pixels in the first and last rows and columns of the image.

- ***Foreground and background***
  - An image contains $\boldsymbol{K}$ disjoint regions, $\boldsymbol{R_k}, \boldsymbol{k} = \boldsymbol{1}, \boldsymbol{2}, \ldots, \boldsymbol{K}$. Let $\boldsymbol{R_u}$ denote the union of all the K regions, and let $(\boldsymbol{R_u})^c$ denote its complement.

    All the points in $\boldsymbol{R_u}$ is called ***foreground***;

    All the points in $(\boldsymbol{R_u})^c$ is called ***background***.

Relationship between Pixels

Distance Measure

- Given pixels *p, q* and *z* with coordinates (x, y), (s, t), (u, v) respectively, the distance function D has following properties:

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

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

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

Relationship between Pixels

Distance Measure

The following are the different Distance measures:

- Euclidean Distance :

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

- City Block Distance:

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

- Chess Board Distance:

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

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

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

Next Class

- **Digital Image Fundamentals**
  - Mathematical Operations in DIP

Thank you:
Question?