DIGITAL IMAGE PROCESSING-1

Unit 1: Lecture 10-11

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Unit 1: Introduction to DIP

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Last Session

- Digital Image Fundamentals
  - Image Sampling and Quantization
  - Representation of Digital Image

Today's Session

- Recap of Isopreference curve
- Digital Image Fundamentals
  - Zooming and Shrinking
- Basic relationship between pixels

Varying N and k Simultaneously: Isopreference Curve

- Varying N: Sampling, spatial resolution
- Varying k : quantization, gray level resolution

Varying N and k Simultaneously

- Huang [1965] attempted to quantify experimentally the effects on image quality produced by varying N and k simultaneously
- Three sets of images : With little, intermediate and large amount of detail
  - Sets of these three types of images were generated by varying N (number of samples) and k (number of levels)
  - Observers were then asked to rank them according to their subjective quality.

Varying N and k Simultaneously

Images used in the experiment

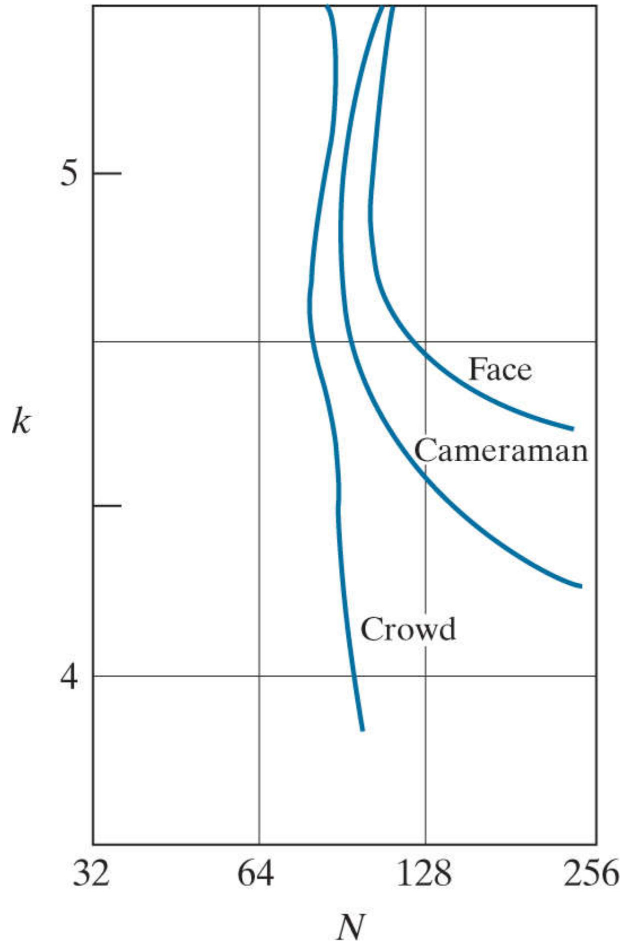
a. Image with a low level of detail.
b. Image with a medium level of detail.
c. Image with a relatively large amount of detail.

Varying N and k Simultaneously: Isopreference Curve

- Each point in the Nk-plane represents an image having values of N and k equal to the coordinates of that point

- Points lying on an isopreference curve correspond to images of equal subjective quality

- It was found that the *isopreference curves tended to shift right and upward, but their shapes in each of* the three image categories were *similar*



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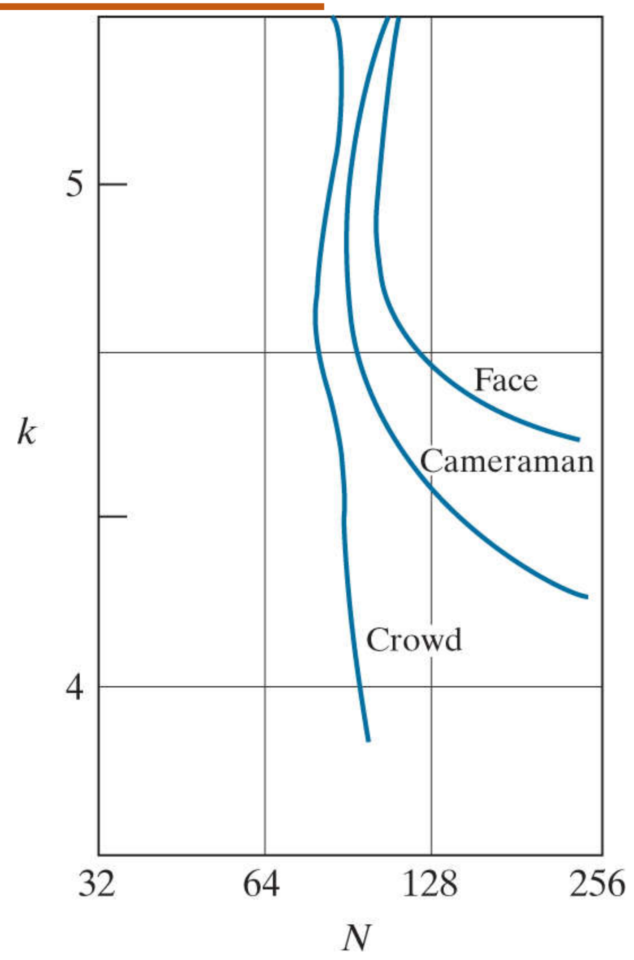
Analysis

- **A shift up and right in the curves simply means larger values for N and k, which implies *better picture quality.***
- **Curves tend to become more *vertical as the detail in the image increases.***
  - **For images with a large amount of detail only a few gray levels may be needed**
  - **This indicates that, for a fixed value of N, the perceived quality for this type of image is nearly independent of the number of gray levels used**
- **Perceived quality in the other two image categories remained the same in some intervals in which the spatial resolution was increased, but the number of gray levels actually decreased.**
  - **A decrease in k tends to increase the apparent contrast of an image, a visual effect that humans often perceive as improved quality in an image**



Representative isopreference curves for the three types of images

Zooming and Shrinking (digital images)

- Image Interpolation/Decimation is a basic tool used for zooming and Shrinking
- Zooming: Oversampling / Interpolation
  - Is the process of using known data to estimate values at unknown locations
- Shrinking: Undersampling / Decimation
  - Row column deletion

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Zooming and Shrinking Digital Images

- Zooming – oversampling
- Shrinking – undersampling
- Zooming and Shrinking – Digital Images

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Zooming of Digital Images

Zooming:

Creation of new pixel locations

↓

Assignment of gray levels to new locations

Steps for Zooming

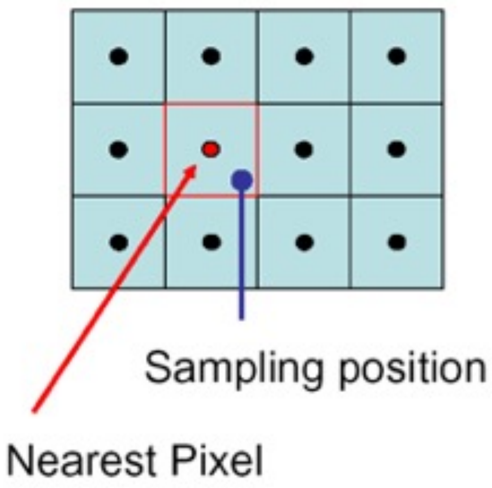
- In order to perform gray-level assignment to any point in the overlay (newly inserted pixels) we look for closest pixel in the original image and assign its gray level to the new pixel in the grid
  - Nearest Neighbor Interpolation (zoom 500 x 500 to 750 x 750 (enlarge 1.5 times)
    - Pixel replication
  - Bilinear Interpolation (use 4 nearest neighbors of a point (x, y))
    - If (x, y) – coordinates of a point in zoomed image and
    - If $v(x, y)$ – gray level assigned to it
    - Then assigned gray level is given by $v(x, y) = ax + by + cxy + d$
  - Bicubic interpolation
    - the output pixel value is a weighted average of pixels in the nearest 4-by-4 neighborhood (16 pixels).

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

Methods for Zooming

1. Nearest Neighbor Interpolation:

- Lay an overlay (grid) of the desired increased size of the image
- create an imaginary 750 × 750 grid with the same pixel spacing as the original image,
- then shrink it so that it exactly overlays the original image
- Obviously, the pixel spacing in the shrunken 750 × 750 grid will be less than the pixel spacing in the original image.
- To assign an intensity value to any point in the overlay, we look for its closest pixel in the underlying original image and assign the intensity of that pixel to the new pixel in the 750 × 750 grid
- When intensities have been assigned to all the points in the overlay grid, we expand it back to the specified size to obtain the resized image



Methods for Zooming

1. Nearest Neighbor Interpolation

- Look for the closest pixel in the original image and assign its gray level to the new pixel in the grid
- Undesirable feature: *Checkerboard effect,* (particularly objectionable at high magnification)

Methods for Zooming

Pixel Replication:

- Special case of nearest neighbor interpolation

- Pixel replication is applicable when we want to increase the size of an image an integer number of times
- Duplication of rows and columns is done the required number of times to achieve the desired size
- The gray-level assignment of each pixel is predetermined by the fact that new locations are exact duplicates of old location

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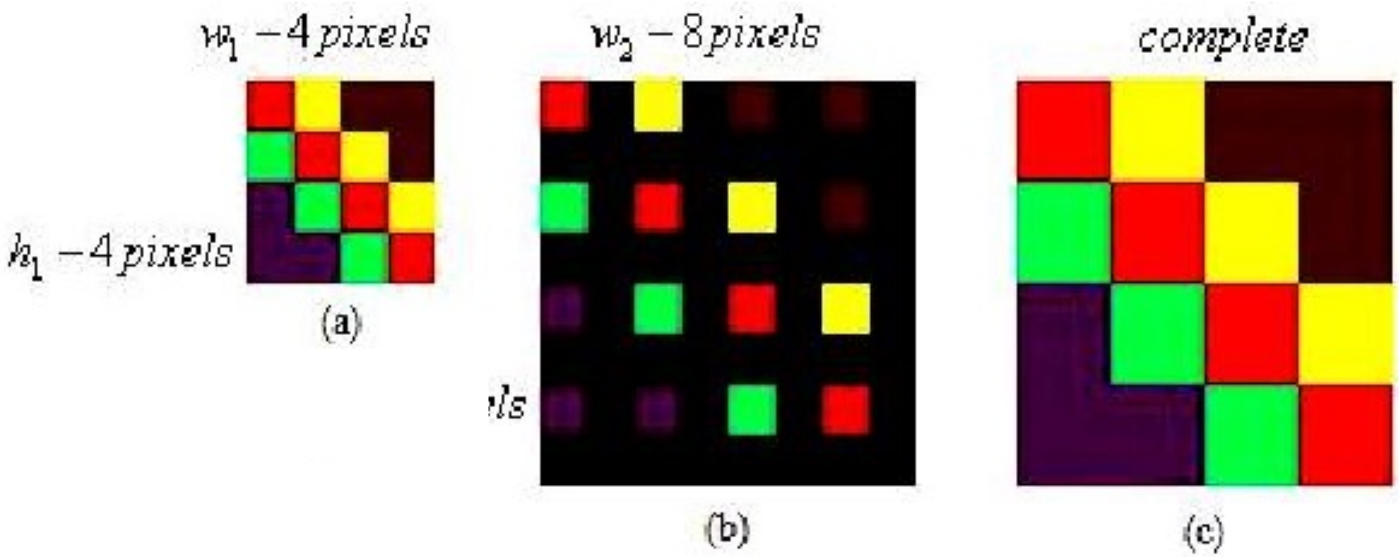
Zooming of Digital Images



- **Pixel replication (Nearest Neighbor Interpolation)**

Example: Pixel Replication

1. Consider an image $F = \begin{pmatrix} 2 & 1 \\ 1 & 3 \end{pmatrix}$. Perform zooming by using pixel replication

Step 1: Insert zeros in alternate locations

2	0	1	0
0	0	0	0
1	0	3	0
0	0	0	0

Step 2: Pixels are replicated as follows(single pixel selection):

2	2	1	1
2	2	1	1
1	1	3	3
1	1	3	3

Example: Pixel Replication

2. Consider an image $F=\begin{pmatrix} 2 & 1 \\ 1 & 3 \end{pmatrix}$ perform zooming by using linear interpolation (taking average along row and column)

Step 1: Insert zeros in alternate locations

2	0	1	0
0	0	0	0
1	0	3	0
0	0	0	0

Step 2: Interpolate as follows (taking average of columns):

2	1.5	1	0.5
0	0	0	0
1	2	3	1.5
0	0	0	0

Example: Pixel Replication

Step 3: Interpolate as follows (taking average of rows):

2	1.5	1	0.5
0	0	0	0
1	2	3	1.5
0	0	0	0

Resultant image is as follows:

2	1.5	1	0.5
1.5	1.75	2	1
1	2	3	1.5
0.5	1	1.5	0.75

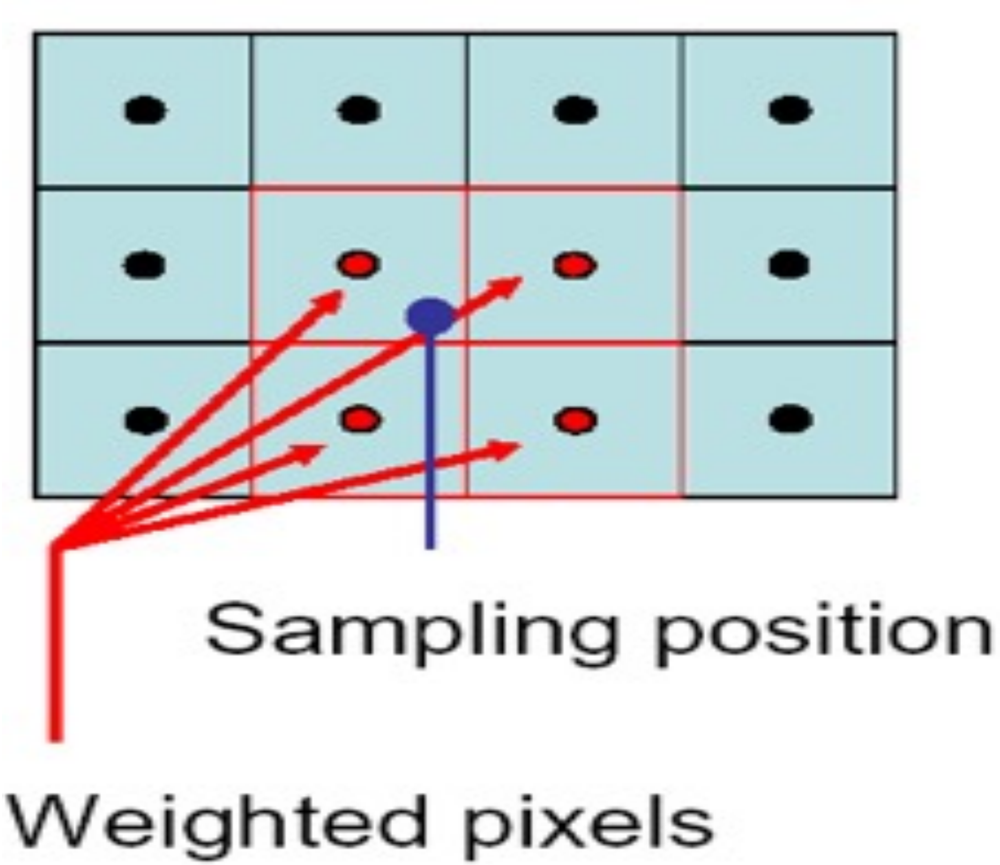
2. Bilinear Interpolation:

- Done using the four nearest neighbors of a point
- let (x,y) denote the coordinate of a point in the zoomed image and let v(x,y) denote the gray levels assigned to it .
- For bilinear interpolation the assigned gray level is given by

$$\mathbf{v(x,y) = ax+by+cxy+d}$$

where the four coefficients are determined from the four equations in four unknowns that can be written using the 4 nearest neighbor of point (x,y)

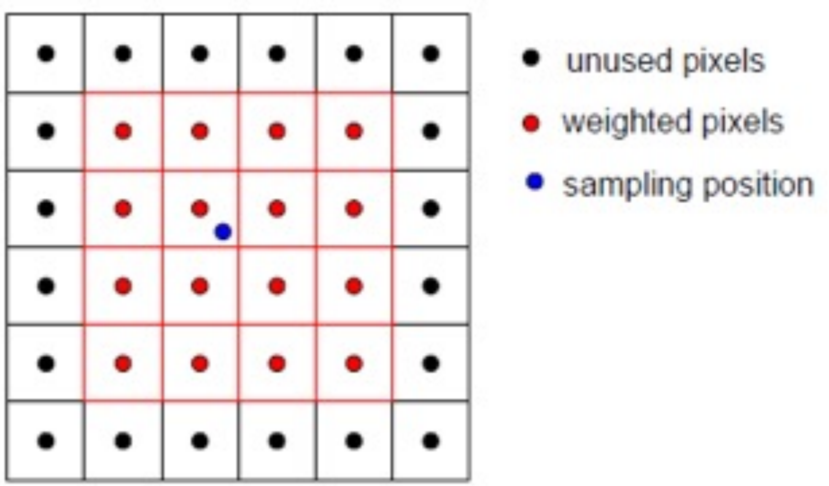
Methods for Zooming: Example (biiliear Inerpolation)



Methods for Zooming: Example (Bicubic Interpolation)

3. Bicubic interpolation

the output pixel value is a weighted average of pixels in the nearest 4-by-4 neighborhood (16 pixels).



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

Methods for Zooming: Example (Bicubic Interpolation)

123x150
Original
I=imread(‘lowres.jpg')

246x300
Nearest neighbour Interpolation
imresize(I,2,'nearest')

246x300
Bilinear Interpolation
imresize(I,2,‘bilinear’)

246x300
Bicubic Interpolation
imresize(I,2,‘bicubic')

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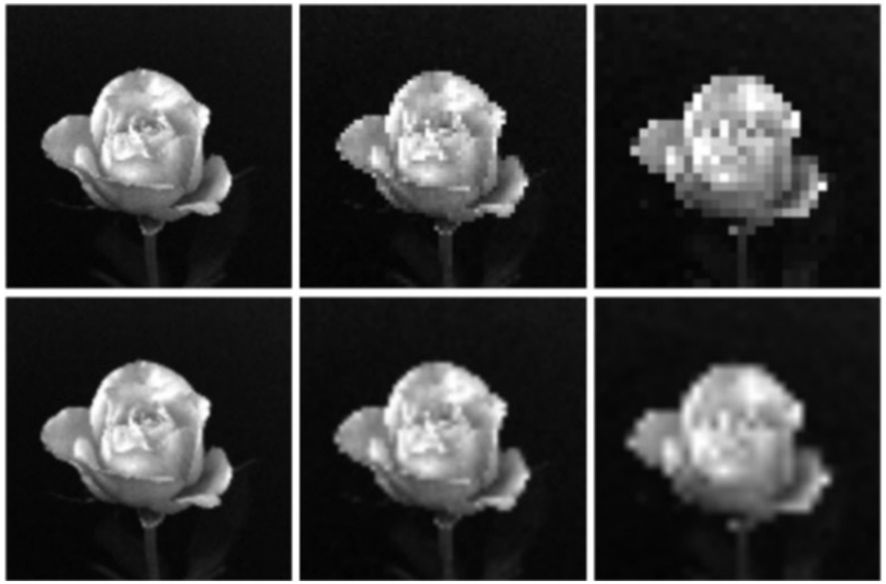
Zooming by nearest neighbor, Bilinear, Bicubic Methods

- The number of pixels considered affects the complexity of the computation
- Therefore the bilinear method takes longer than nearest-neighbor interpolation, and the bicubic method takes longer than bilinear
- However, greater the number of pixels considered, the more accurate the effect is, so there is a tradeoff between processing time and quality

Zooming by nearest neighbor, Bilinear, Bicubic Methods

- Pixel replication is a special case of nearest neighbor interpolation.
- Applicable when size of an image is needed to be increased integer number of times.
- Duplication – required number of times to achieve the desired size.
- Disadvantage – Checkerboard effect

Zooming of Digital Images



a	b	c
d	e	f

Top row: images zoomed from 128 x 128, 64 x 64, 32 x 32 pixels to 1024 x 1024 pixels, using nearest neighbor gray-level interpolation

Bottom row: same sequence, but using bilinear interpolation

Shrinking Digital Images

- Image shrinking is done similar to zooming process
- Equivalent process of pixel replication is row-column deletion.

Steps Involved:

Step 1: Expand the grid to fit the original image

Step 2: Use gray-level nearest neighbor or bilinear interpolation

Step 3: Shrink the grid back to its original specified size

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Examples

1. An image is of 2400 pixels wide and 2400 pixels high. The image was scanned at 300dpi. What is the physical size of the image?
2. A scenic image whose physical dimension is 2.5 inch x 2 inch on paper is scanned at 150 dpi. How many pixels would be there in the scanned image?
3. Given a gray scale image on paper whose physical dimension is 2.5 inch x 2 inch scanned at the rate of 150 dpi. Calculate the following:

   (a) How many bits are required to represent the image?

   (b) How much time is required to transmit the image if the modem is 28 kbps?

   (c) Estimate these 2 values if it were a binary image.

Some Basic Relationship Between Pixels

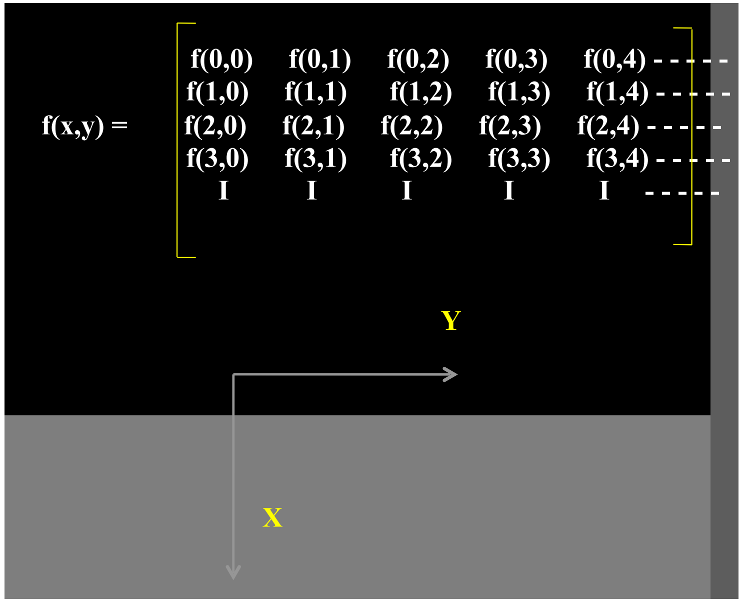
- An image is denoted by *f(x, y).*
- Lowercase letters such as p and q are used to represent particular pixels in an image.
- The structure of a digital image allows stating some basic relationships between pixels that can be useful in some practical cases.
- The pixels are organized in a regular structure and can have a limited number of values.

Some Basic Relationship Between Pixels

- Neighbor of a pixel
- Adjacency, connectivity, regions and boundaries
- Distance Measures

Some Basic Relationship Between Pixels

- Consider the representation of an image as



Neighbors of a Pixel

(x-1,y-1) (0,0)	(x-1,y) (0,1)	(x-1,y+1) (0,2)	- - - - - -
(x,y-1) (1,0)	(x,y) (1,1)	(x,y+1) (1,2)	- - - - - -
(x+1,y-1) (2,0)	(x+1,y) (2,1)	(x+1,y+1) (2,2)	- - - - - -
⋮	⋮	⋮	⋮

4 - Neighbors of a Pixel, $N_4(P)$

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

$N_4(P)$: 4-neighbors of p.

- 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 $N_4(P)$
- **Each pixel is unit distance from (x ,y)**

Neighbors of a Pixel

4 diagonal Neighbors of a Pixel: $N_D(p)$:
Diagonal-neighbors of p.

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

- A Pixel p at coordinates (x, y) has 4 diagonal neighbors
- This set of pixels is called Diagonal-neighbors and denoted by $N_D(p)$
- $N_D(p)$: four diagonal neighbors of p have coordinates: (x+1,y+1), (x+1,y-1), (x-1,y+1), (x-1,y-1)
- Each of them are at Euclidean distance of 1.414 from P

Neighbors of a Pixel

8 neighbors of a Pixel: $N_8(p)$

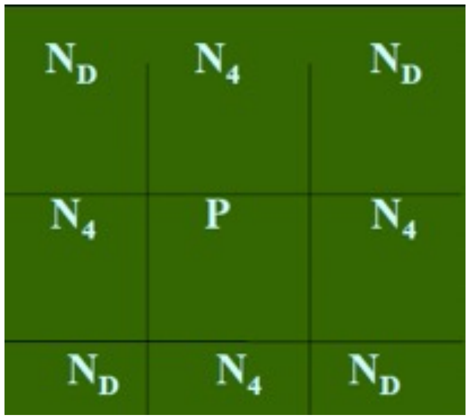
(x-1,y-1)	(x-1,y)	(x-1,y+1)
(x,y-1)	p(x,y)	(x,y+1)
(x+1,y-1)	(x+1,y)	(x+1,y+1)

N_8 (p) : 8-neighbors of p.

- N_4 (p) and N_D (p) together are called 8-neighbors of p, denoted by N_8 (p).
- diagonal neighbors + 4-neighbors = 8-neighbors of p.
- They are denoted by $N_8(p)$.
- So, $N_8(p) = N_4(p) + N_D(p)$
- $N_8 = N_4 \ U \ N_D$

Neighbors of a Pixel

- The points $N_D(P)$ and $N_4(P)$ are together known as 8-neighbors of the point P, denoted by $N_8(P)$.
- Some of the points in the N_4, N_D and N_8 may fall outside image when P lies on the border of image.



- N_4 - 4-neighbors
- N_D - diagonal neighbors
- N_8 - 8-neighbors (N_4 U N_D)

Some Basic Relationship Between Pixels

✓Neighbor of a pixel

- Adjacency, connectivity, regions and boundaries

- Distance Measures

Some Basic Relationship Between Pixels

Adjacency:

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

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

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

- m-adjacency(mixed adjacency): Two pixels *p and q with values from V are m-adjacent* if,
  - q is in $N_4(P)$ 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).

- ***4-adjacency:*** **Two pixels p and q with the values from set 'V' are 4-adjacent if q is in the set of $N_4(p)$.**
- **e.g. V = { 0, 1}**

1	1	0
1	1	0
1	0	1

- **p in RED color**
- **q can be any value in green color.**

- ***8-adjacency:*** **Two pixels p and q with the values from set ‘V’ are 8-adjacent if q is in the set of $N_8(p)$.**
- **e.g. V = { 1, 2}**

0	1	1
0	2	0
0	0	1

- **p in RED color**
- **q can be any value in green color**

- **m-adjacency:** **Two pixels *p and q with values from V are m-adjacent***
- **If,**
  - **q is in $N_4(P)$ 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).**

e.g. V = { 1 }

0 a	1 b	1 c
0 d	1 e	0 f
0 g	0 h	1 i

- ***m-adjacency example:*** **Two pixels p and q with the values from set ‘V’ are m-adjacent if**

  i) q is in N_4(p)

- **e.g. V = { 1 }**

0 a	1 b	1 c
0 d	1 e	0 f
0 g	0 h	1 I

- **b & c are m-adjacent.**

- ***m-adjacency example:*** **Two pixels p and q with the values from set 'V' are m-adjacent if**

  i) q is in $N_4(p)$

- **e.g. V = { 1 }**

0 a	1 b	1 c
0 d	1 e	0 f
0 g	0 h	1 I

- **b & e are m-adjacent.**

Next Session

- Relationship between pixels cont…
- Regions and boundaries
- Linear and non linear relations

THANK YOU

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