Computer Vision

CSC-455

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Today's Lecture

- Image Size
- Image Resolution (Spatial & Gray Level)
- Image Resizing
- Connected Components & Binary Operations

GRAY LEVEL

- WE CALL THE INTENSITY OF A MONOCHROME IMAGE f AT COORDINATE (x, y) THE GRAY LEVEL (L) OF THE IMAGE AT THAT POINT.
- Thus, l lies in the range

$$L_{\min} \leq \ell \leq L_{\max}$$

- L_{min} is positive and L_{max} is finite.
- Gray scale = [L_{min}, L_{max}]
- Common practice, shift the interval to [0,L] : 0 = black, L-1 = white

Image Size

- Number of bits required to store an image

$$\boxed{b = M \times N \times k}$$

- Image having 2^k intensity levels
  - k – bit image
  - 256 intensity levels – 8 bit image

Image Size

TABLE 2.1
Number of storage bits for various values of N and k.

N/k	1 (L = 2)	2 (L = 4)	3 (L = 8)	4 (L = 16)	5 (L = 32)	6 (L = 64)	7 (L = 128)	8 (L = 256)
32	1,024	2,048	3,072	4,096	5,120	6,144	7,168	8,192
64	4,096	8,192	12,288	16,384	20,480	24,576	28,672	32,768
128	16,384	32,768	49,152	65,536	81,920	98,304	114,688	131,072
256	65,536	131,072	196,608	262,144	327,680	393,216	458,752	524,288
512	262,144	524,288	786,432	1,048,576	1,310,720	1,572,864	1,835,008	2,097,152
1024	1,048,576	2,097,152	3,145,728	4,194,304	5,242,880	6,291,456	7,340,032	8,388,608
2048	4,194,304	8,388,608	12,582,912	16,777,216	20,971,520	25,165,824	29,369,128	33,554,432
4096	16,777,216	33,554,432	50,331,648	67,108,864	83,886,080	100,663,296	117,440,512	134,217,728
8192	67,108,864	134,217,728	201,326,592	268,435,456	335,544,320	402,653,184	469,762,048	536,870,912

Image Formats

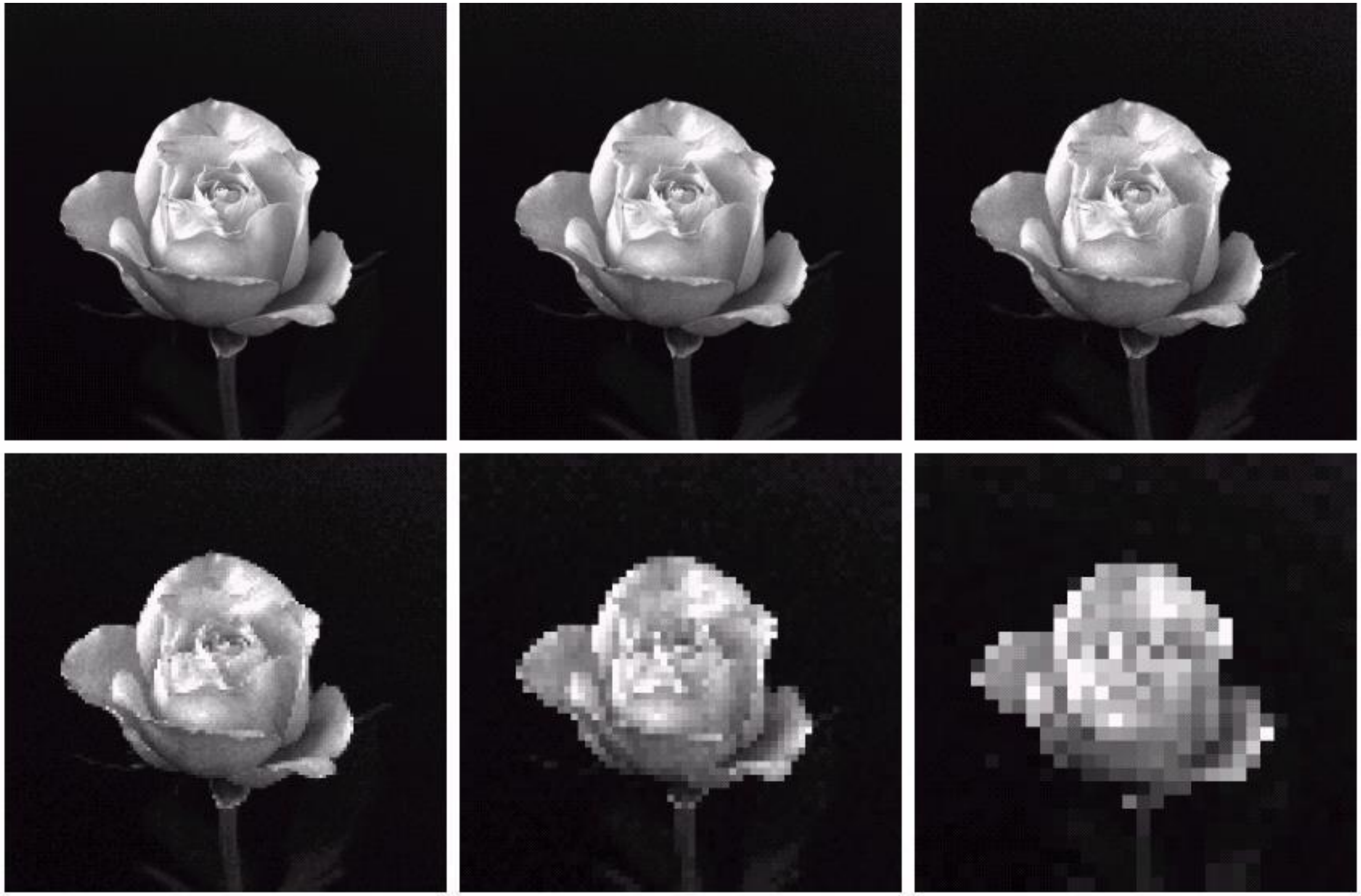
- Common image formats include:
  - 1 sample per point (B&W or Grayscale)
  - 3 samples per point (Red, Green, and Blue)

- For most of this course we will focus on gray-scale images

Spatial & Gray Level Resolution

Spatial Resolution

Spatial Resolution



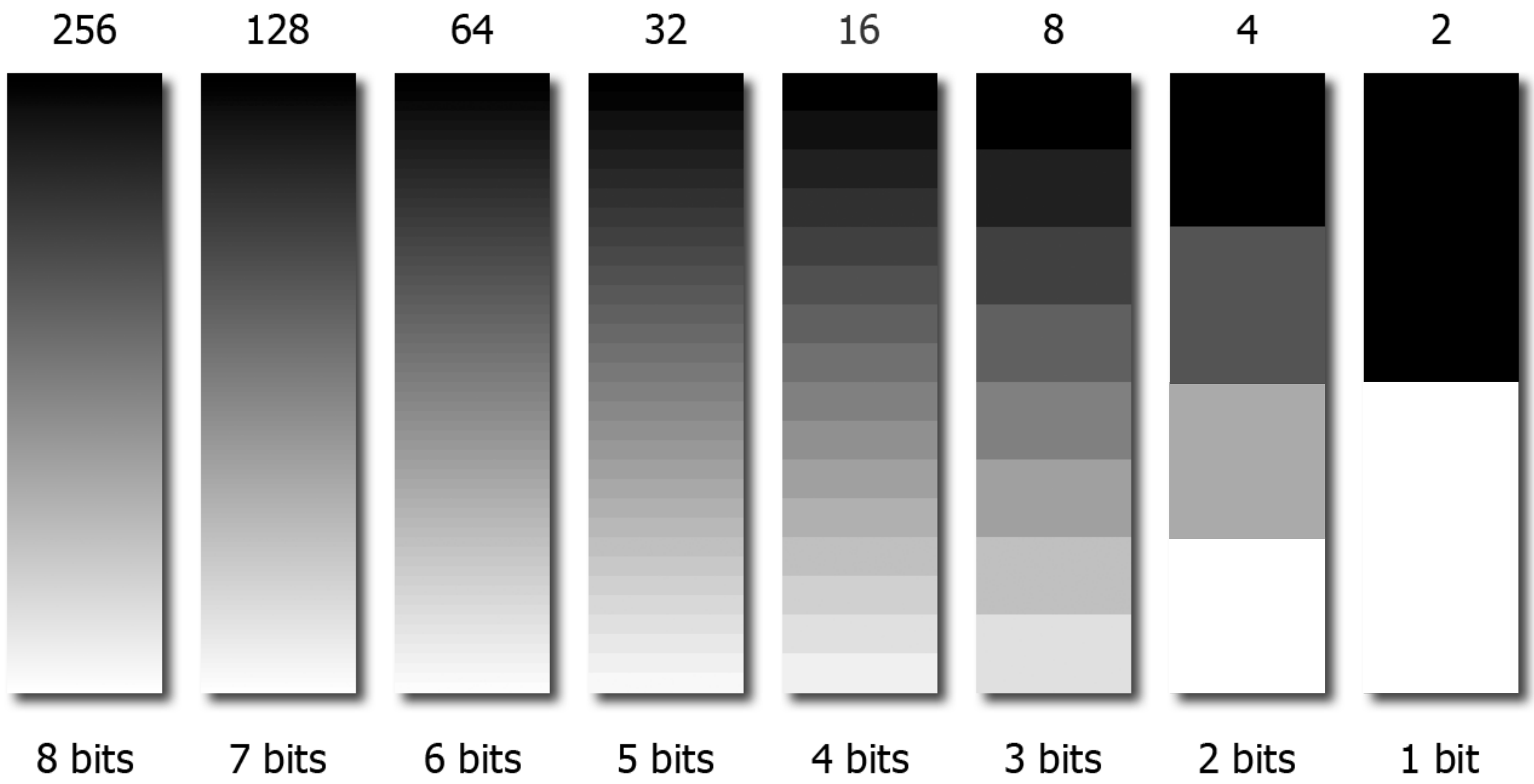
Intensity Level Resolution

- *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

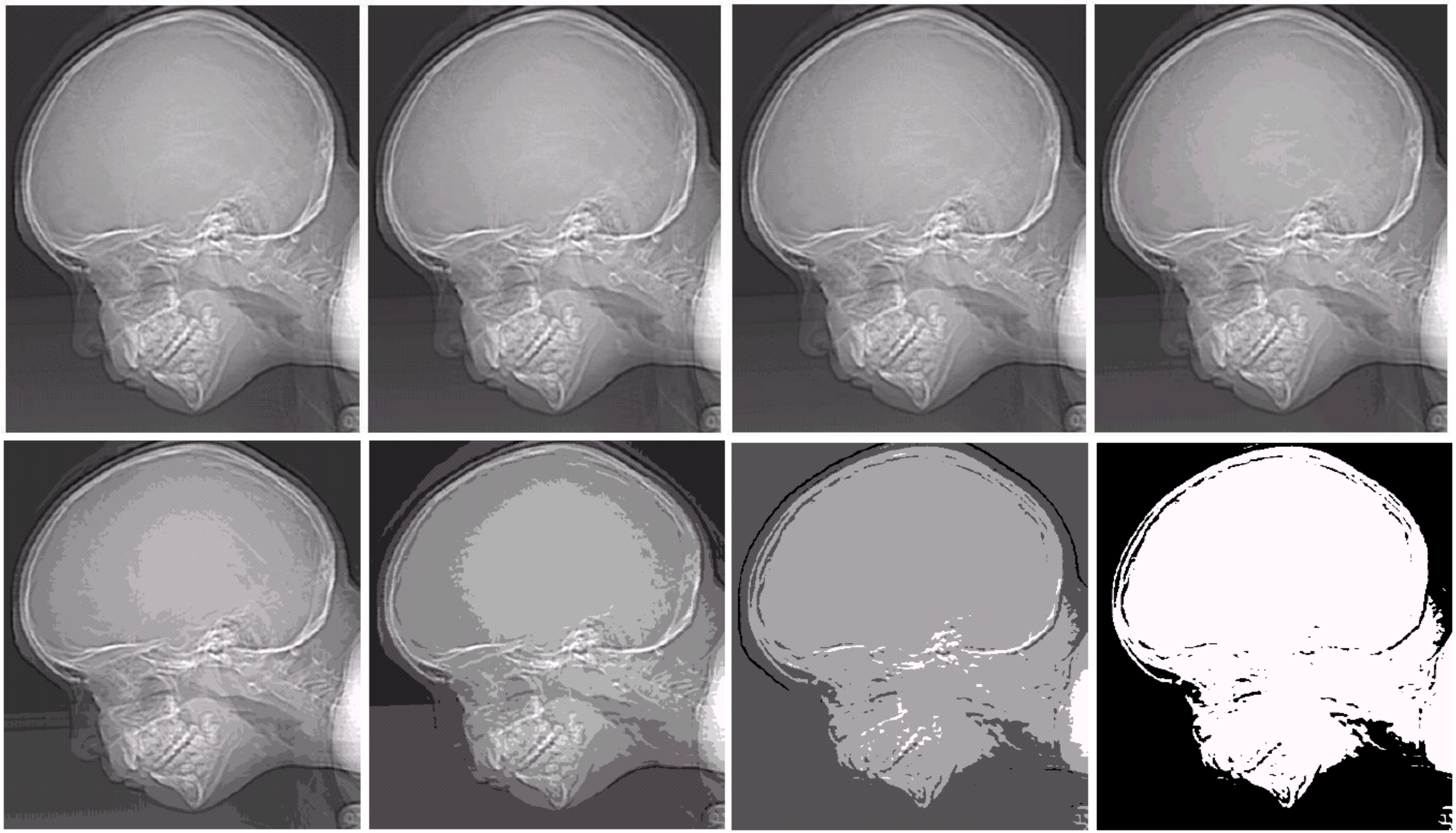
Number of Bits	Number of Intensity Levels	Examples
1	2	0, 1
2	4	00, 01, 10, 11
4	16	0000, 0101, 1111
8	256	00110011, 01010101
16	65,536	1010101010101010

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

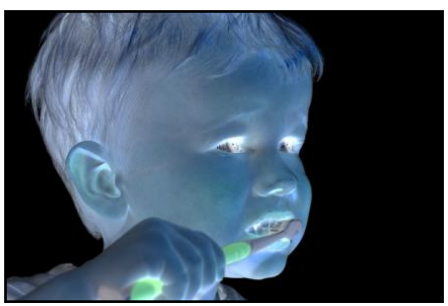
What types of image transformations can we do?

F

Filtering

$$G(\boldsymbol{x}) = h\{F(\boldsymbol{x})\}$$

G



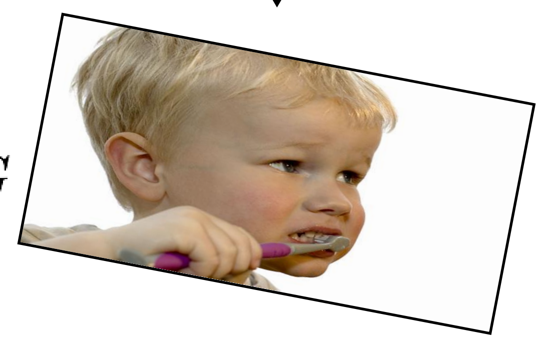
changes *range* of image function

F

Warping

$$G(\boldsymbol{x}) = F(h\{\boldsymbol{x}\})$$

G



changes *domain* of image function

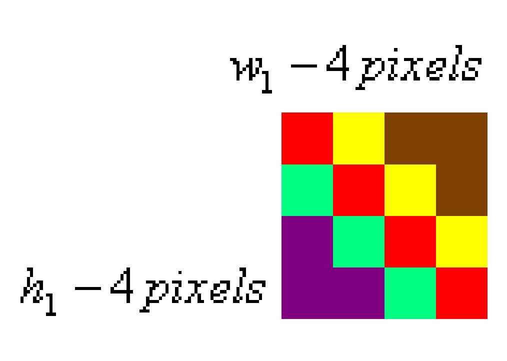
Image Resizing

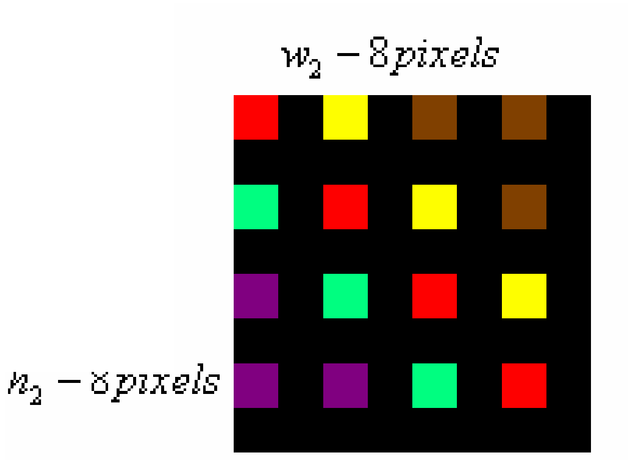
- Pixel replication

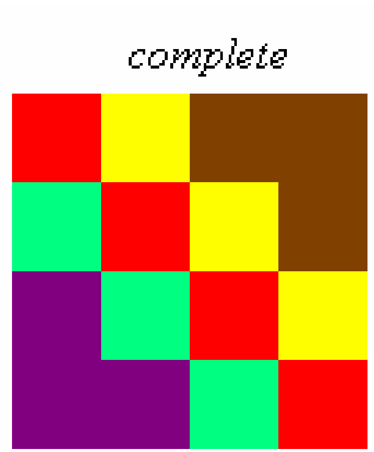
[1 2 3 4 5]

[1 1 2 2 3 3 4 4 5 5]   (One step)

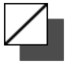
[1 1 1 2 2 2 3 3 3 4 4 4 5 5 5] (Two step)



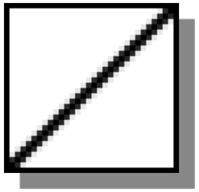




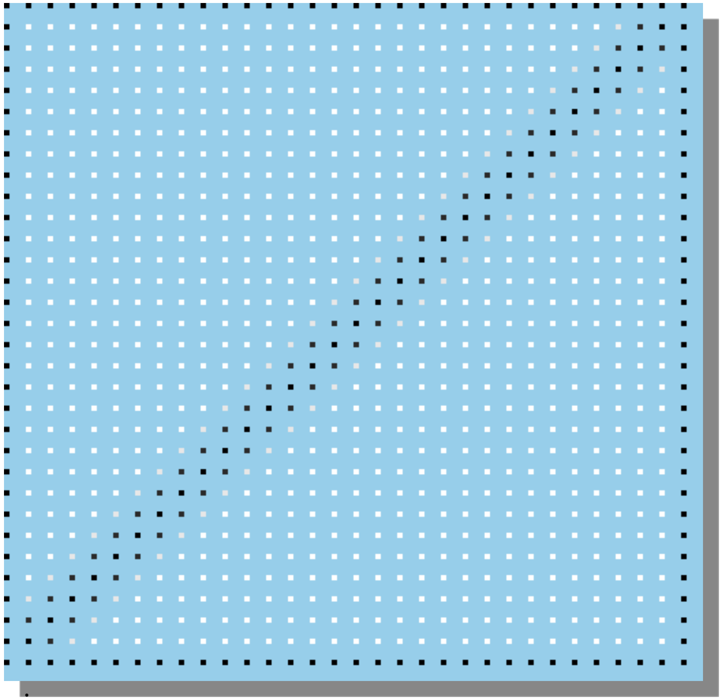
Enlarging an Image



Example: zoom this image 4x to get this image.

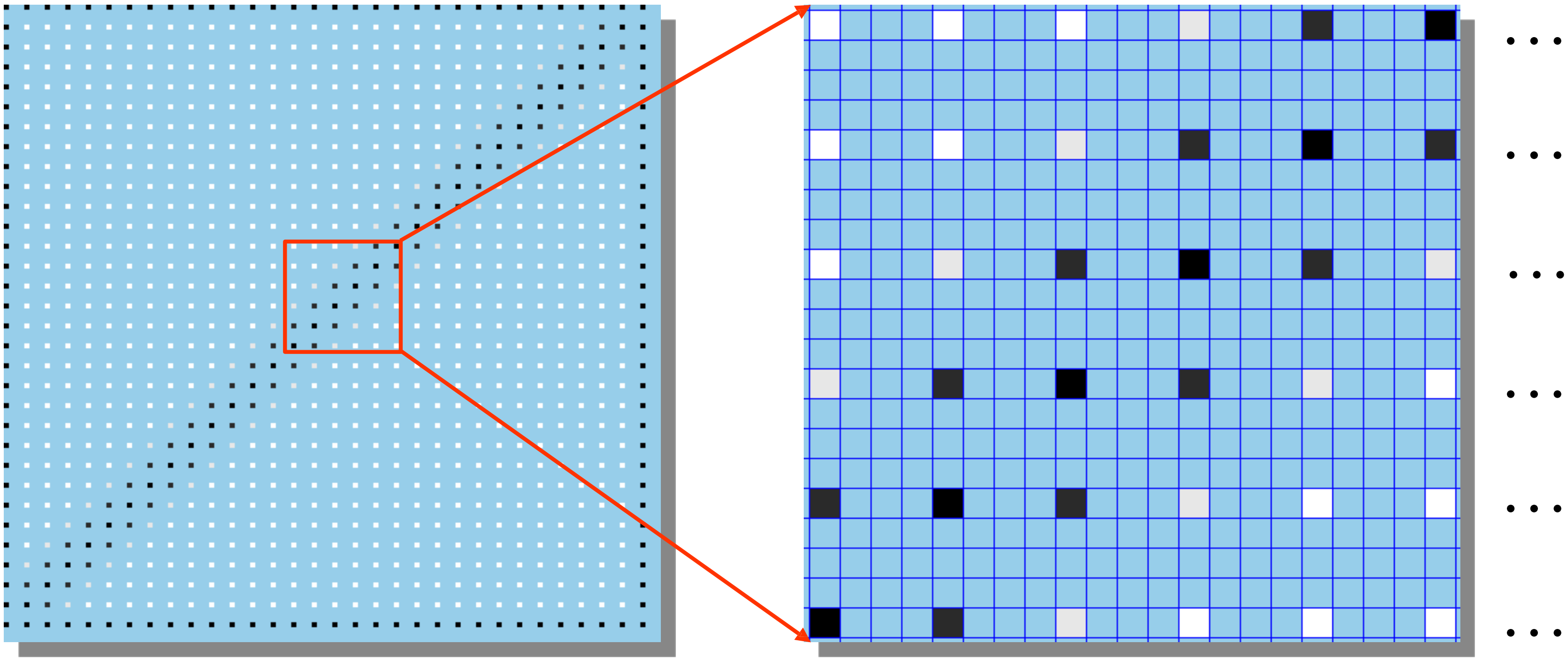


Start with a blank image 4 times the linear dimensions of the original.



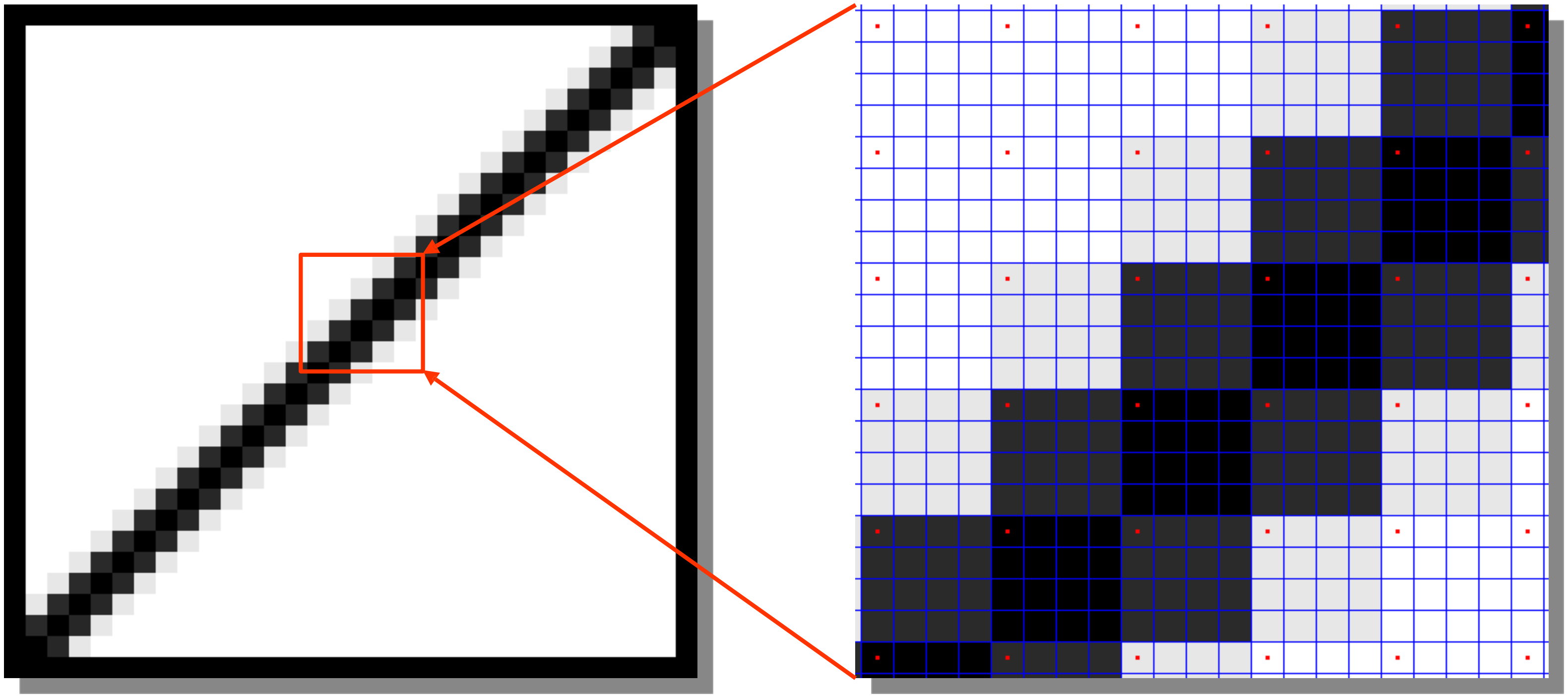
Fill in every 4th pixel in every 4th row with the original pixel values.

Enlarging an Image



Detail showing every 4th pixel in every 4th row with the original pixel values.

Enlarging an Image



Replicate the values

Enlarging an Image

- Nearest neighbour interpolation
  - Simple but produces undesired artefacts
- Bilinear Interpolation
  - Contribution from 4 neighbors
- Bicubic Interpolation
  - Contribution from 16 neighbors

Interpolation: Comparison

We'll enlarge this image by a factor of 4 …

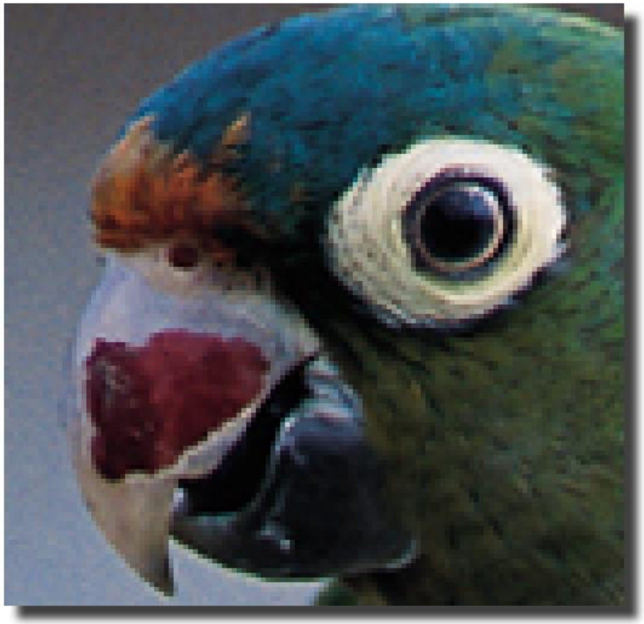
… via bilinear interpolation and compare it to a nearest neighbor enlargement.

Interpolation: Comparison

Original Image

To better see what happens, we'll look at the parrot's eye.

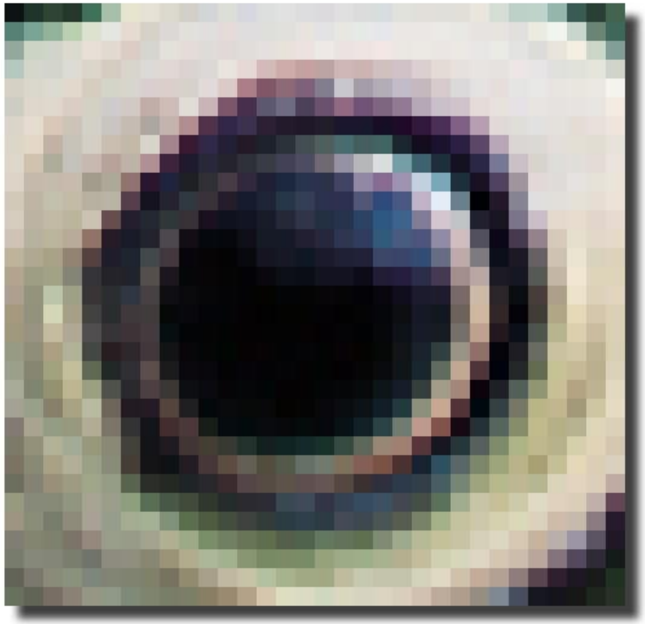
Interpolation: Comparison



Pixel replication

Bilinear interpolation

Interpolation: Comparison

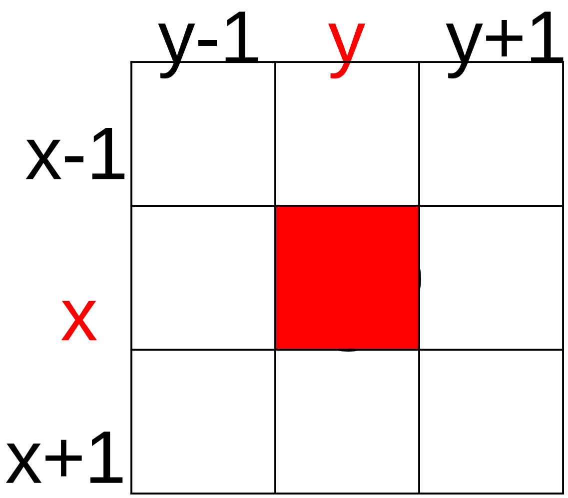


Pixel replication

Bilinear interpolation

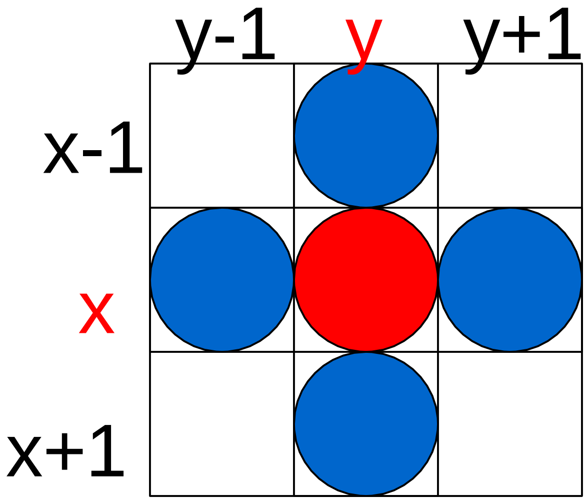
Relationships between pixels

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



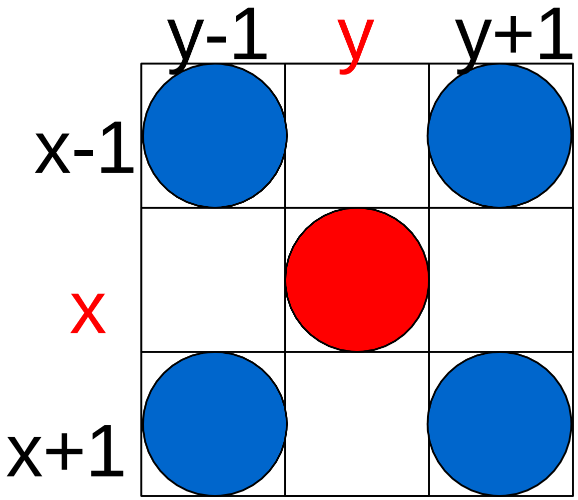
4- Neighbors of a Pixel –$N_4(p)$

What are the coordinates of each of the blue pixels



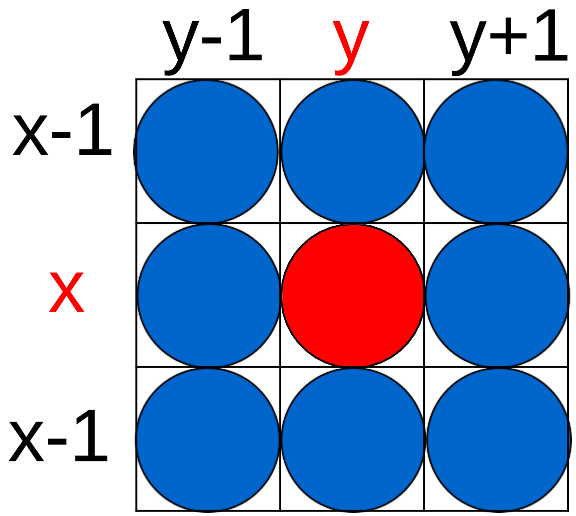
(x-1,y), (x+1,y), (x, y-1), (x, y+1)

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 – $N_8(p)$

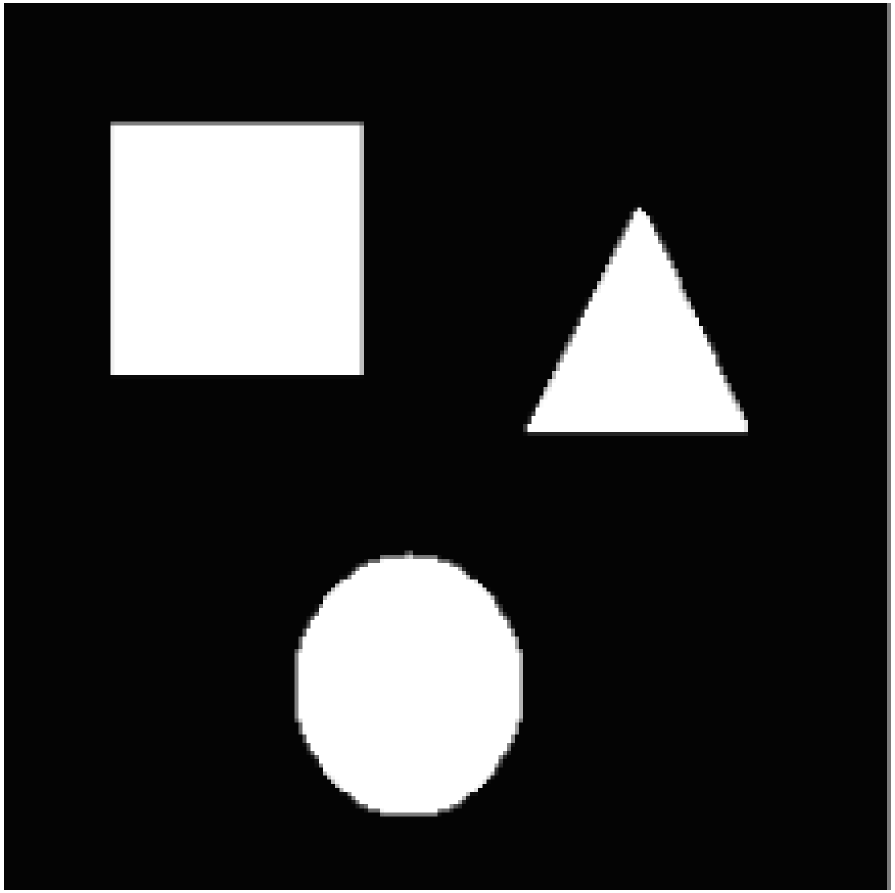


$$N_8(p) = N_4(p) \cup N_D(p)$$

(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*

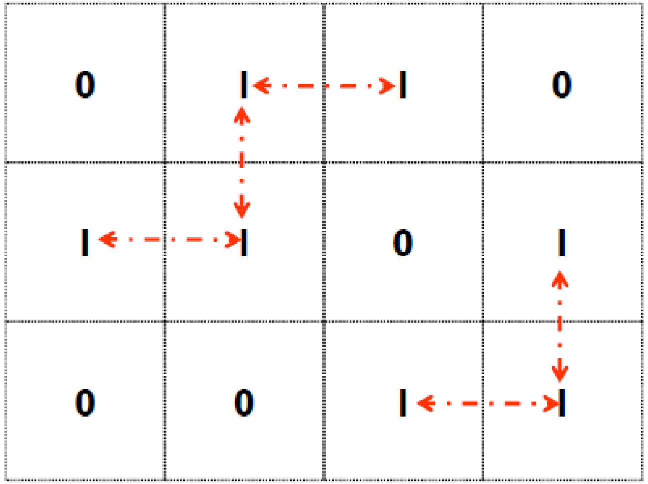
Connectivity

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}



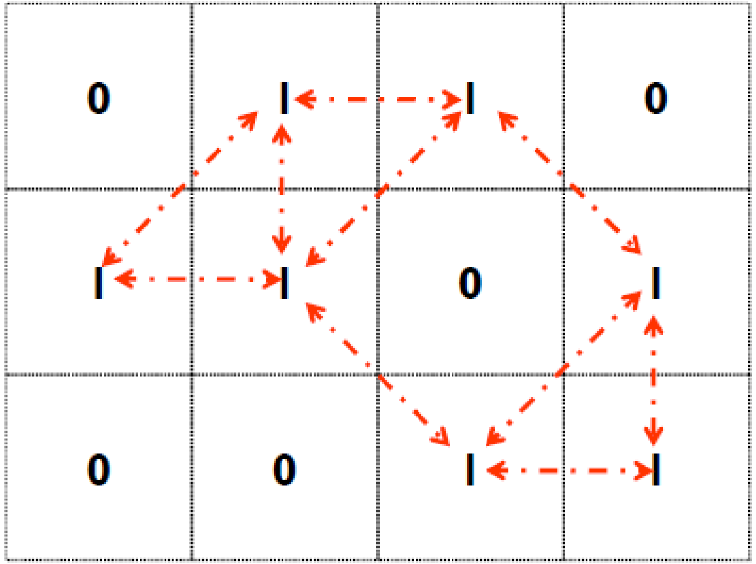
Connectivity

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

8-connectivity

$$(p,q) \in V, and\ q \in N_8(p)$$

If gray level



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

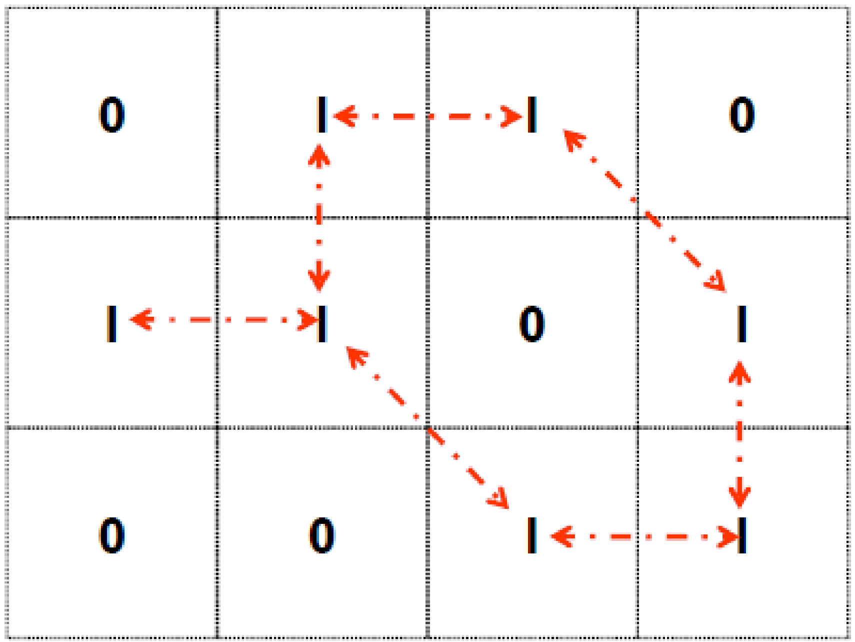
$(p,q) \in V, and\ q$ satisfies one of the following:

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

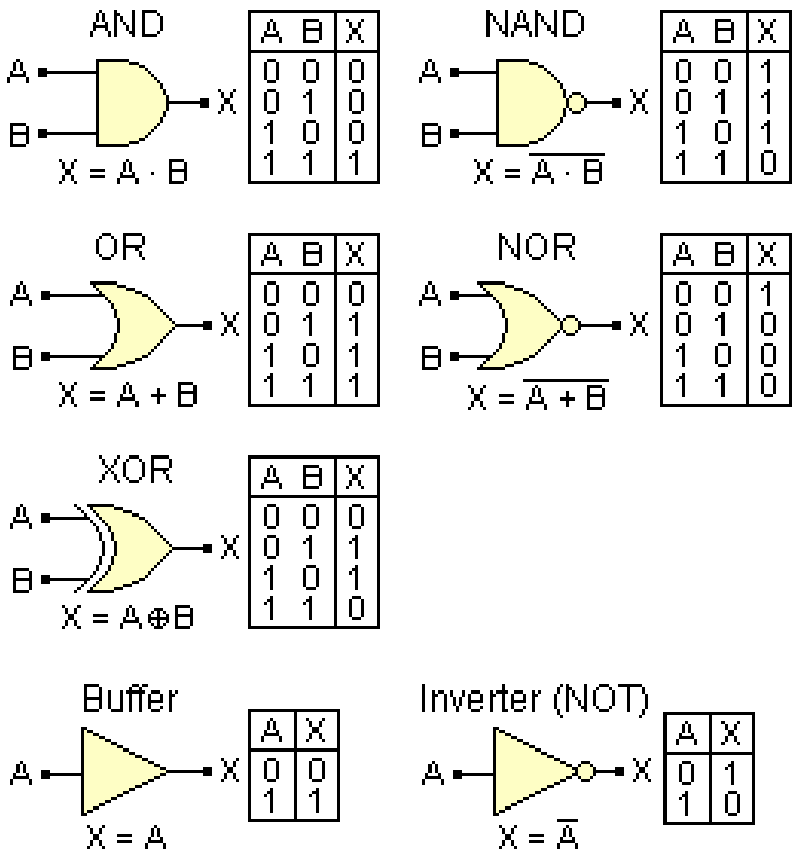
Example: m – Connectivity

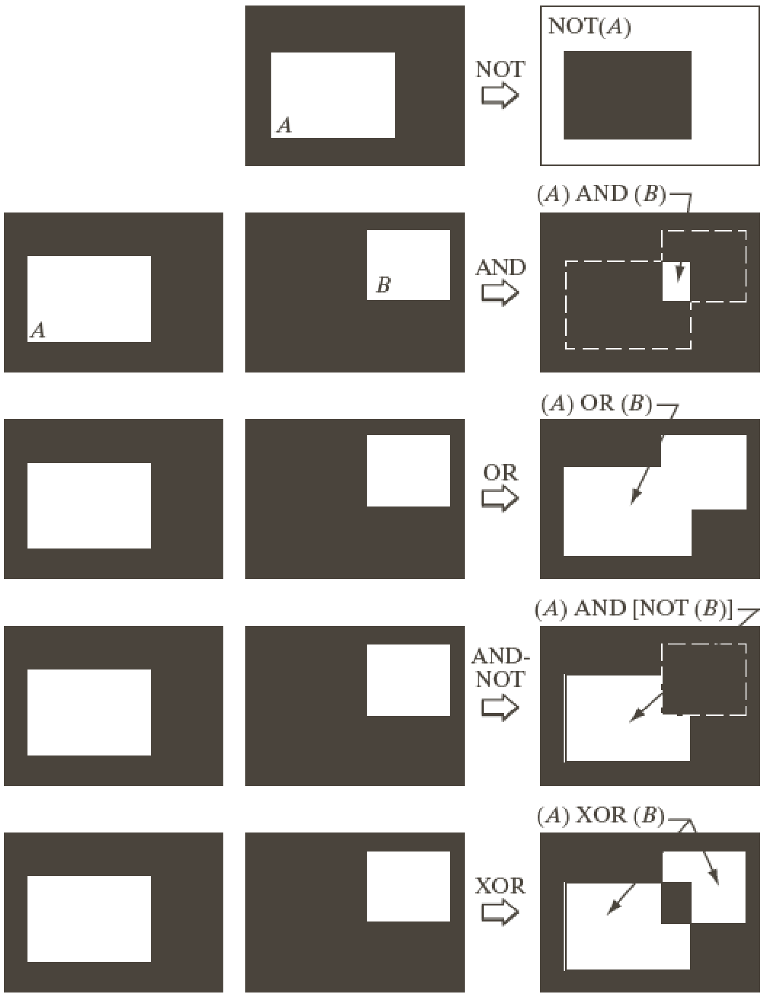
- Set of gray levels V = {1}



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

Logical Operations (Binary Images)





References

- Some Slide material has been taken from Dr M. Usman Akram Computer Vision Lectures
- CSCI 1430: Introduction to Computer Vision by James Tompkin
- 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, 2002
- 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
- Computer Vision A modern Approach by Frosyth
- http://www.cs.cmu.edu/~16385/s18/