Chapter 3

Image and Graphics

Digital Image

A Digital Image is a numeric representation of a two-dimensional image and is made of picture elements called pixels, arranged in rows and columns.
These numeric values are the intensity or brightness values that are associated with the pixels.

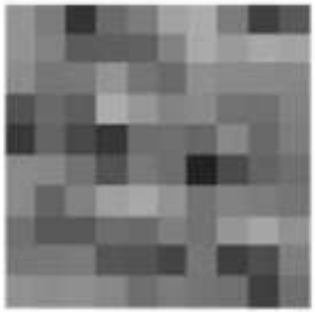
Digital Image

2-dimensional matrix of Intensity (gray or color) values

Set of Intensity values

Image coordinates are integers

$$I(u,v) \in \mathbb{P} \quad \text{and} \quad u,v \in \mathbb{N}.$$

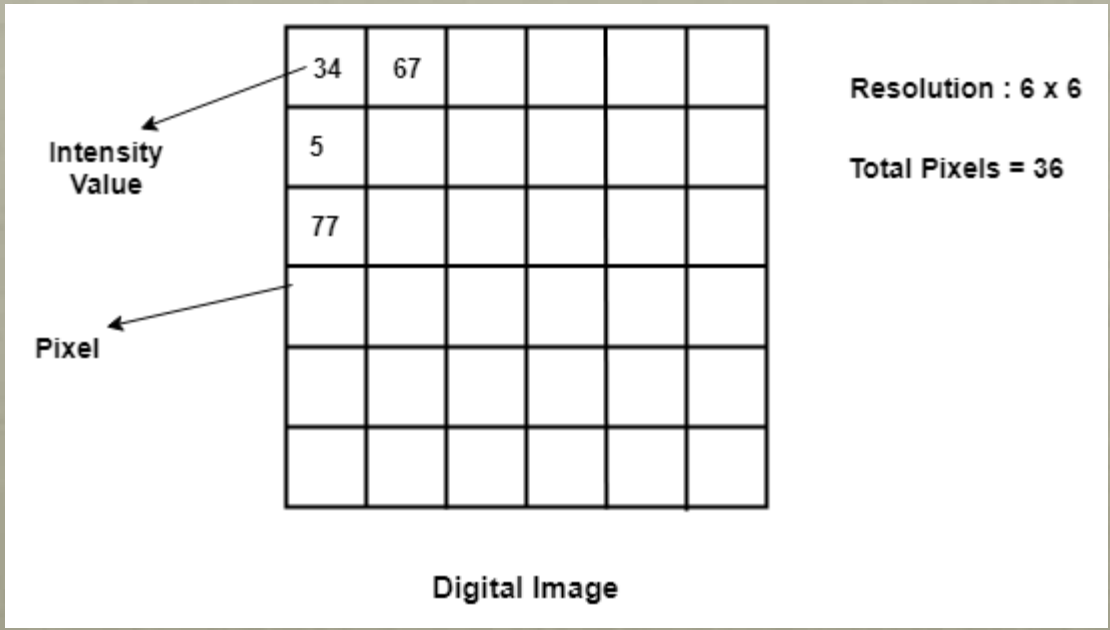


$F(x,y)$

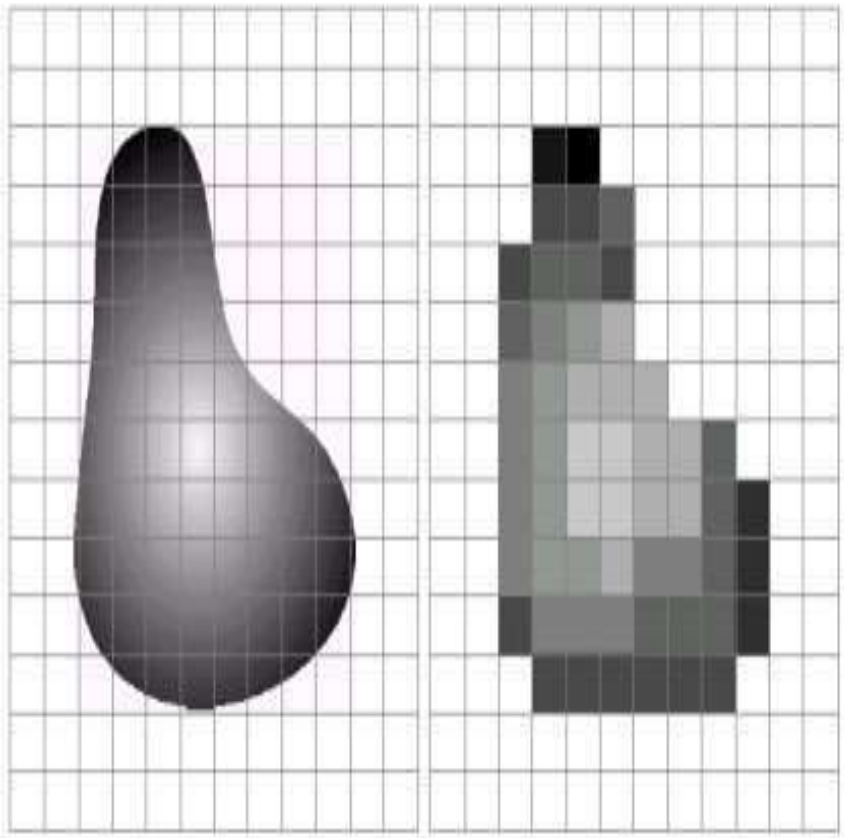
$\rightarrow$

148	123	52	107	123	162	172	123	64	89 ···
147	130	92	95	98	130	171	155	169	163 ···
141	118	121	148	117	107	144	137	136	134 ···
82	106	93	172	149	131	138	114	113	129 ···
57	101	72	54	109	111	104	135	106	125 ···
138	135	114	82	121	110	34	76	101	111 ···
138	102	128	159	168	147	116	129	124	117 ···
113	89	89	109	106	126	114	150	164	145 ···
120	121	123	87	85	70	119	64	79	127 ···
145	141	143	134	111	124	117	113	64	112 ···
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮

$I(u,v)$

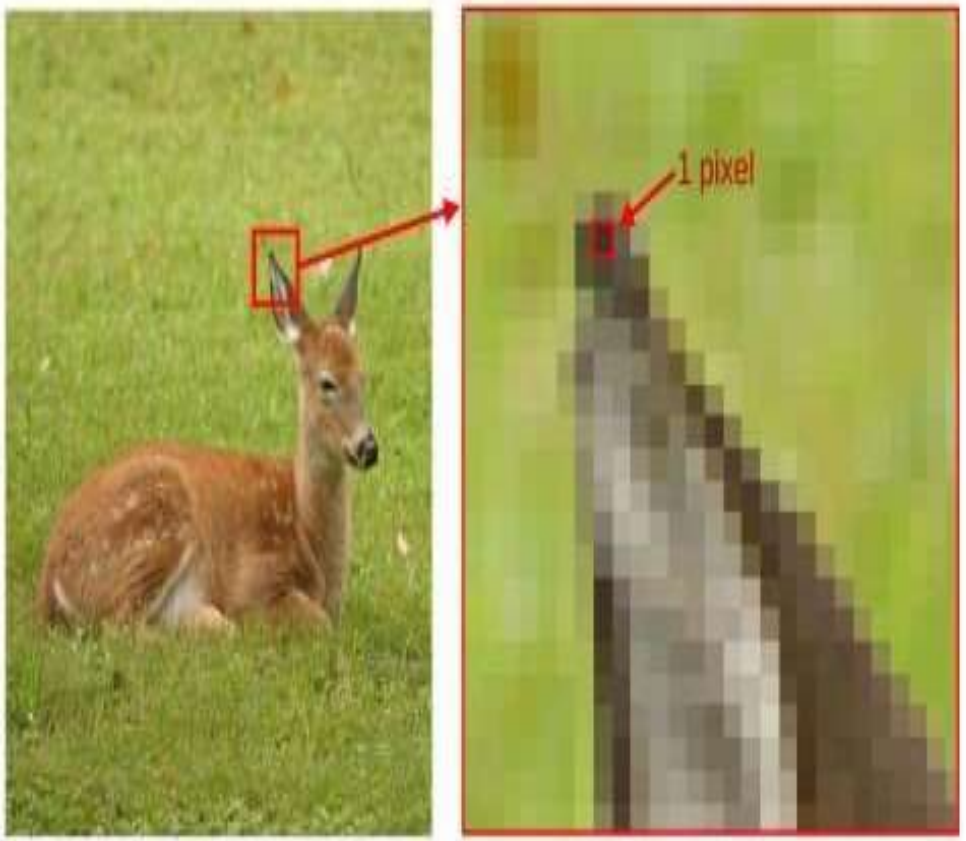

34
67
5
77
Intensity Value
Pixel
Resolution : 6 x 6
Total Pixels = 36
Digital Image

Digital Image



Real image

Digital Image
(an approximation)



Real image

Digital Image
(an approximation)

Digital Image

- Common image formats include:
  - 1 values per point/pixel (B&W or Grayscale)
  - 3 values per point/pixel (Red, Green, and Blue)
  - 4 values per point/pixel (Red, Green, Blue, + “Alpha” or Opacity)

Grayscale

RGB

RGBA

Colour pixels are RGB, meaning they have three pieces of information associated with them, namely the Red, Green and Blue components.
Grayscale pixels have one component, a gray tone derived from a graduate scale from black to white.
A colour pixel is generally 24-bit (3 × 8-bit), and a gray pixel is just 8-bit.
This basically means that a colour pixel has a triplet value comprised of 0……255 for each of red, green and blue components, whereas a grayscale pixel has a single values 0…….255. The figure below compares a colour and grayscale pixel. The colour pixel has the R-G-B value 61-80-136.The grayscale pixel has the value 92.

RGB vs Grayscale

Basic Concepts

- Image is matrix of numeric values given by function I(r,c)
- r and c are row and column of the point
- The point is also called pixel
- I(r,c) is intensity value or gray level at point (r,c)
- Gray scale for monochrome(single color black/white) picture is 0 and 1
- Gray scale for 8 bit image is 0 to 255.

Bitmap Image

- Each pixel's gray value is either 0 or 1
- Each pixel requires 1bit
- 640 x 480 bit mapped image requires 37.5 KB storage

1 byte = 8 bits
1 kilobyte = 1024 bytes
1 megabyte = 1024 kilobytes
1 gigabyte = 1024 megabytes
1 terabyte = 1024 gigabytes

Grayscale Image

- Each pixel is usually stored as a byte (value between 0 to 255)
- A dark pixel may have a value of 10; a bright one may be 240
- A 640 x 480 greyscale image requires over 300 KB of storage.

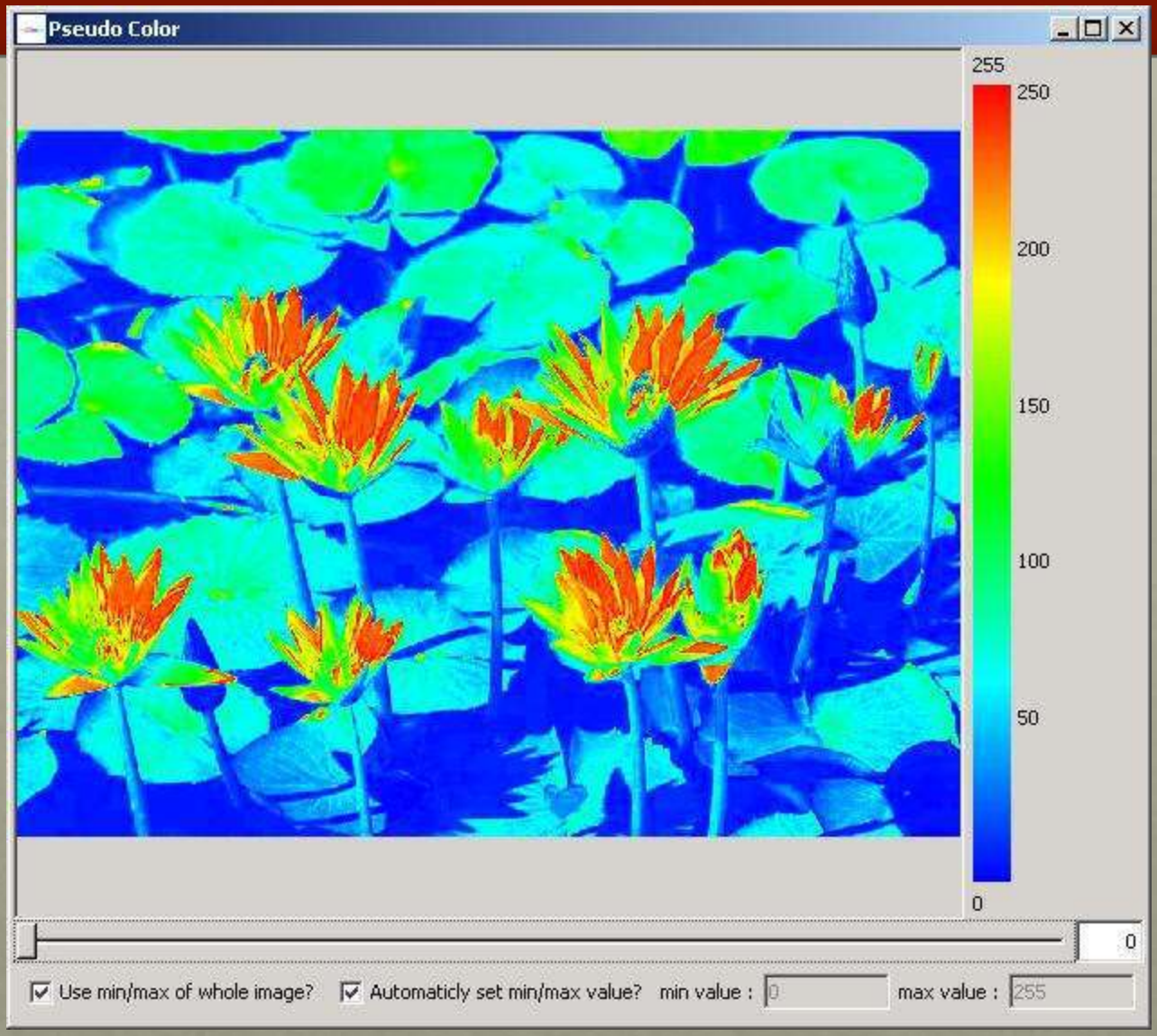
Lenna (or **Lena**) is a standard test image used in the field of digital image processing starting in 1973, It is a picture of the Swedish model Lena Forsén, shot by photographer Dwight Hooker.

24 bit color image

- Each pixel is represented by three bytes (e.g., RGB)
- Supports 256 x 256 x 256 (16,777,216) possible colours
- A 640 x 480 24-bit colour image is 921.6 KB large
- Some colour images are 32-bit images,
  - the extra byte of data for each pixel is used to store an **alpha** value representing special effect information

Pseudo vs true color

- 8-bit (pseudo) color image
  - One byte for each pixel
  - Support 256 colors
  - A 640 X 480 8-bit color image requires 307.2 KBytes
- 24-bit (true) color image
  - Three bytes for each pixel
  - Support 256X256X256 colors
  - A 640 X 480 24-bit color image requires 921.6 KBytes


Pseudo Color
255
250
200
150
100
50
0
0
Use min/max of whole image?
Automaticly set min/max value?
min value :
0
max value :
255

Captured Image Format

- Specified by two main parameters
- Spatial resolution (pixel x pixel) and color encoding (bits per pixel
- SPARC station captures images at 320 x 240
- Color encoding may be 1bit, 8bit, or 24bit

Stored Image Format

- Image is stored in the form of two dimensional array of values
- Binary value for bitmap and red, green, blue components for color image
- It is good to store RGB triples.
- Color image of size 640x480 of 24 bit requires 900K

Graphics image format

Graphics image formats are specified through:

- *graphics primitives*: lines, rectangles, circles, ellipses, text strings (2D), polyhedron (3D)
- *attributes*: line style, line width, color affect.

Graphics primitives and their attributes represent a higher level of an image representation. The graphics package determines which primitives are supported.

Advantages:

+ Reduction of the graphical image data
+ Easier manipulation of graphical images.

Disadvantage:

- Additional conversion step from graphical primitives and attributes to its pixel representation

Formats:

- SRGP (Simple Raster Graphics Package), one way conversion to bit-/pixmap
- PHICS (Programmer's Hierarchical Interactive Graphics Systems) and
- GKS (Graphical Kernel System) only image representation is in pixmap

Image processing

- Broad classes are image synthesis, image analysis
- Image synthesis can be done with the help of computer graphics
- Computer graphics is drawing pictures, lines, charts with the help of computer
- Image synthesis is integral part of GUI

Image processing

- Used for 2D, 3D and higher dimensional objects
- Some of e.g. that uses graphics are
- GUI windows system with icons and menu items
- Office automation, desktop publishing

Image Processing

Simulations and animation for scientific visualization and entertainment

- Graphics can contain dynamics also

Motion Dynamics: Moved with respect to a stationary or dynamic observer, e.g. flight simulator

Update Dynamics: objects are changed in shape, color or other properties, e.g. deformation of an in-flight aeroplane structure

Image Processing

- Non-interactive computer graphics: passive, no communication between user and computer graphics.
- User has no control over the graphics.
- Screen saver
- Interactive involves communication between user and computer graphics

Interactive Graphics Systems

- Video digitizer captures analog signal (NTSC, PAL) and create a digital signal
- Digital images are used for image recognition and video conferencing.
- Focus on image generation via graphics system
- Generates graphics images

- For e.g., SRGP uses QuickDraw raster graphics and MIT's X windows system for output

Interactive Graphics Systems

- Its important components are
  application model
  application program
  graphics system
  graphics hardware

Components of interactive graphics systems

Application model

- represents data or objects to be pictured (stored in an application database)
- stores graphics image formats and connectivity relationships of the components
- should be application specific and independent of any particular display system
- converts image database representations to the graphics system format

Application program

- handles user inputs by sending commands to the graphics system describing *what* to display and *how* this objects should appear

Graphics system

- intermediary component between application programs and the display
- effects an output transformation from objects in the application model
- effects an input transformation from user actions to application
- consists of output subroutines collected in a graphics package to display images

Graphics hardware

- receives input from interaction devices and outputs images to display device

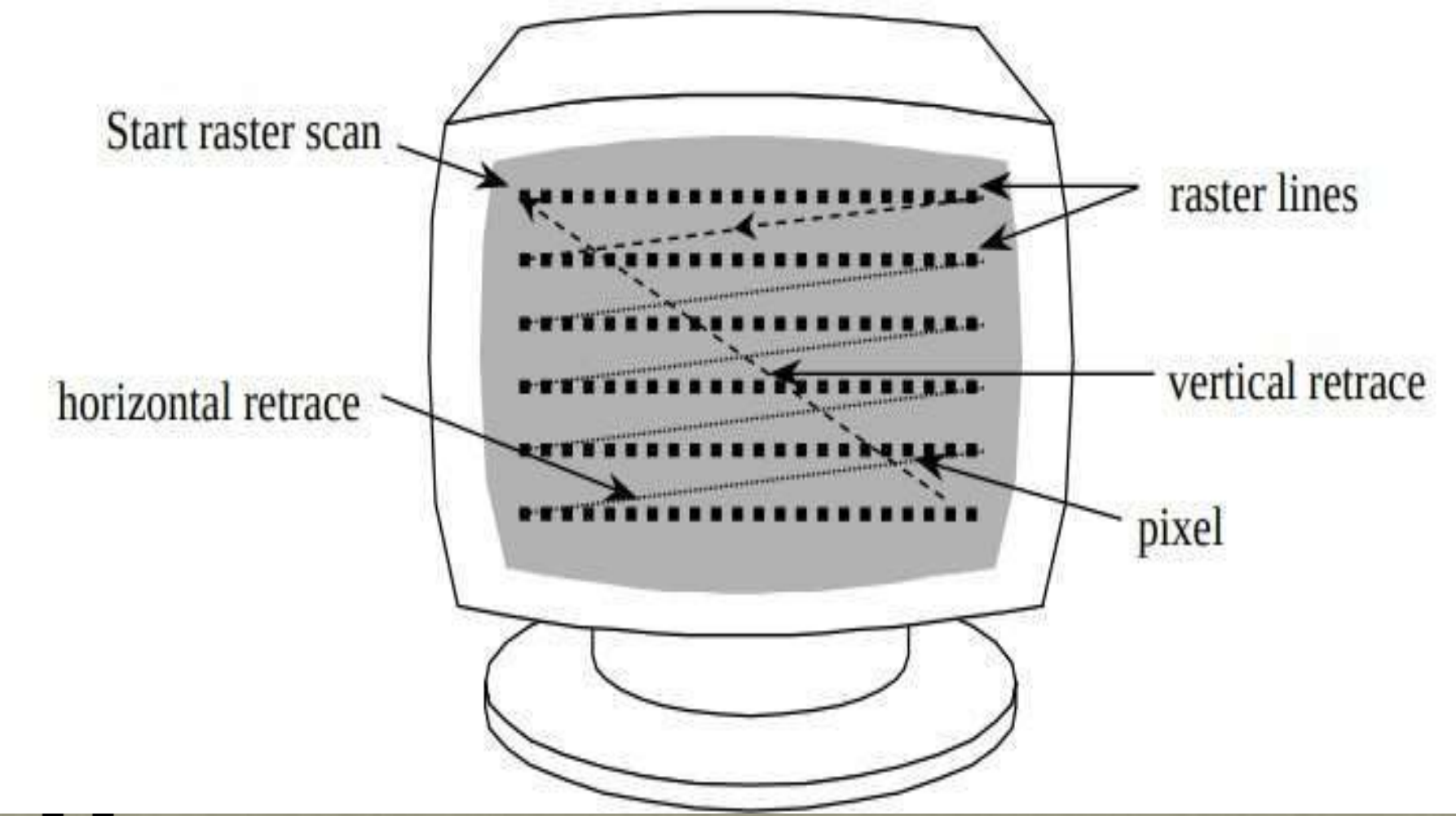
Components of interactive graphics systems

Input: mouse, keyboard, data tablet, touch-sensitive panel on the screen (2D input)

track-balls, space-balls, data glove etc. (3D and higher-dimensional input)

Output: raster display

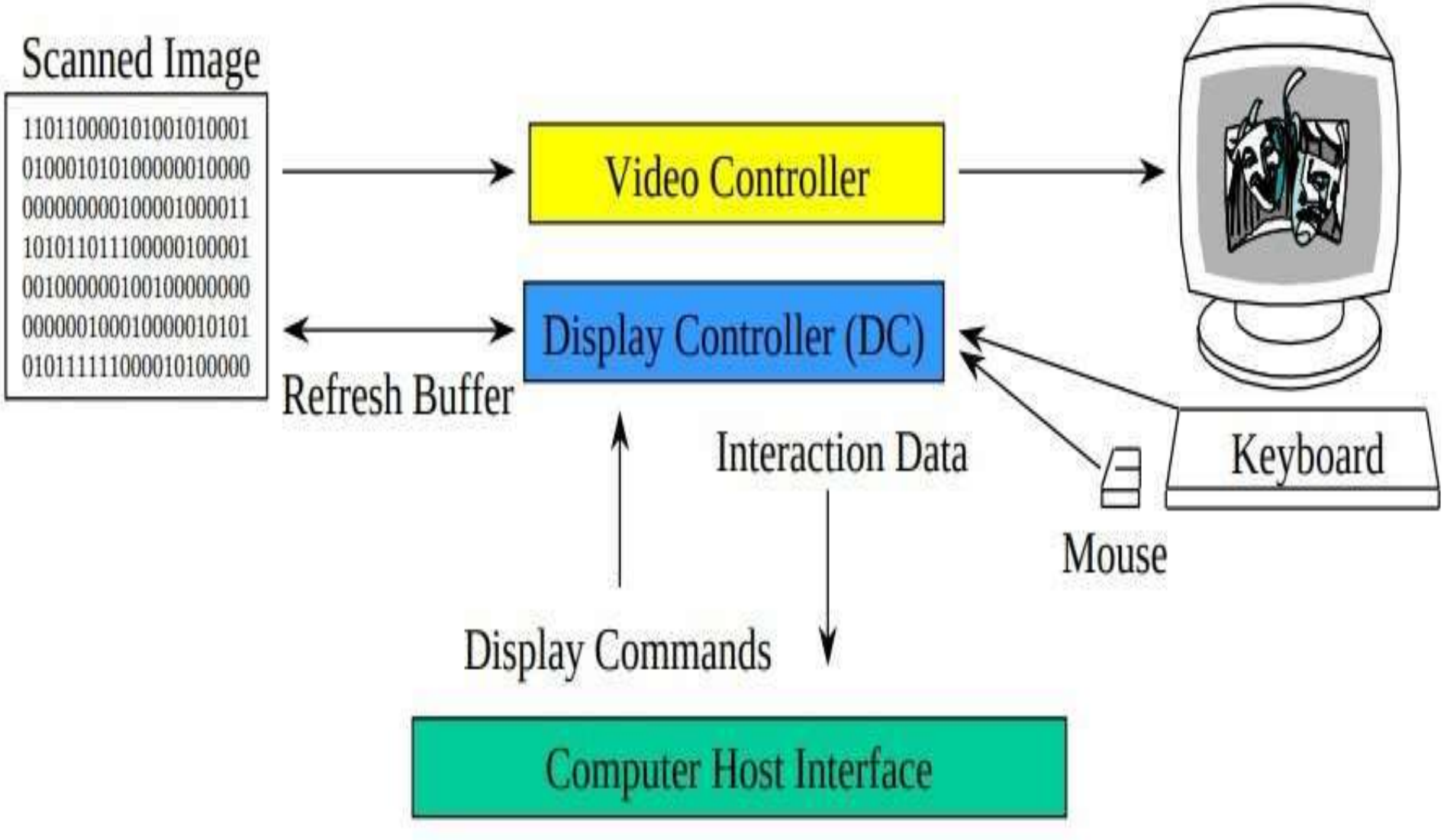
Raster Display



Raster Display

- Raster Display employs CRT panel for display
- Has rows of phosphor dots
- At the back of CRT, electron guns exists
- Phosphor dots glow when hit by electrons from electron gun
-

Raster Display Architecture



Raster Display

- Electron beam moves across screen, one row at a time from top to bottom
- Picture information is stored in refresh buffer
- Display controller receives and interprets sequence of output commands
- In personal computer, display controller exists as software component.

Raster Display

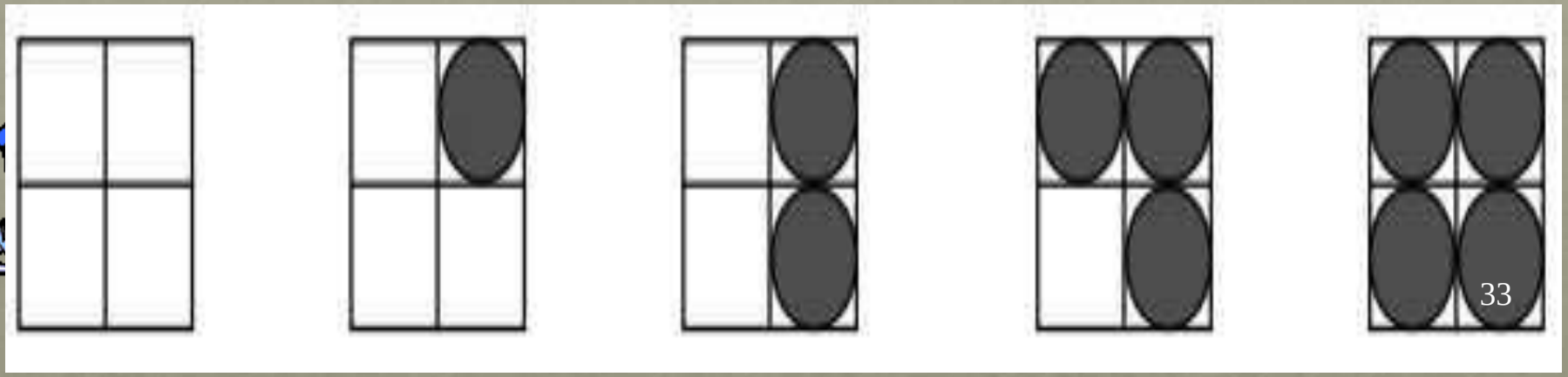
- Video controller can read refresh buffer and produce actual image on the screen
- Electronic beam turn on and turn off the phosphor spots according to image information
- After scanning each row, electronic beam comes back to the start point of next row
- It is called horizontal retrace

Dithering

- Improves quality of images.
- Creates illusions of the color that is not present actually.
- Done by random arrangement of pixels
- If a pixel is replaced by mxn dither matrix (array of dots), levels of intensities can be 0 to mxn.

Dithering

- 2x2 dither matrix can represent 5 intensity levels
- Consider red, blue, green channels of a pixel
- If each channel is replaced by 2x2 dither matrix, then it can represent 5x5x5 = 125 colors



Dithering

Image Processing

- Algorithms that alter input image to create new image
- Extracts image descriptions for higher level analysis of image
- Description can be shape of object, position, orientation etc
-

Image Processing

- computation of perceived brightness and color
- partial or complete recovery of 3D data in a scene
- location of discontinuities corresponding to objects in a scene
- characterisation of the properties of uniform regions in a image

Image Processing application

- Aerial surveillance photographs
- Slow scan television images of the moon
- X-ray images
- Computerized axial tomography scans(CT scan)
-

Image Processing application

- Image enhancement
- Pattern recognition
- Scene analysis
- Computer vision

Image Processing application

Example: Traffic scenes taken by a camera installed in a car

Problems: Is there a traffic sign visible?
Which traffic sign?
Is a moving car in front of our car?
Which type of car?
Which relative speed to our speed?

Image Enhancement

- Improves image quality by eliminating noise
- Or by enhancing contrast
- For e.g. x-ray images

Pattern detection and recognition

- Detects and classifies standard patterns
- Finds distortions from the patterns
- For e.g. static and dynamic recognition with OCR
- Recognizing characters at the moment of writing is easier than scanned characters
- Because dynamic recognizer records the sequence, direction, speed, pressure for each character

Computer vision

- Deals with recognizing and reconstructing 3D models of a scene from several 2D images
- For e.g. robot sensing size, shape, position and color of objects.

Image recognition

- To recognize an object like cup, we should have pixel information of the object
- Must know which pixels in the spatial configuration are part of object
- It helps to distinguish special markings, lines curves, surfaces or boundaries
- Difficulty of object recognition depends upon kind of object, background, imaging sensor etc

Image recognition

- Simple corner extraction could identify image

Image recognition steps

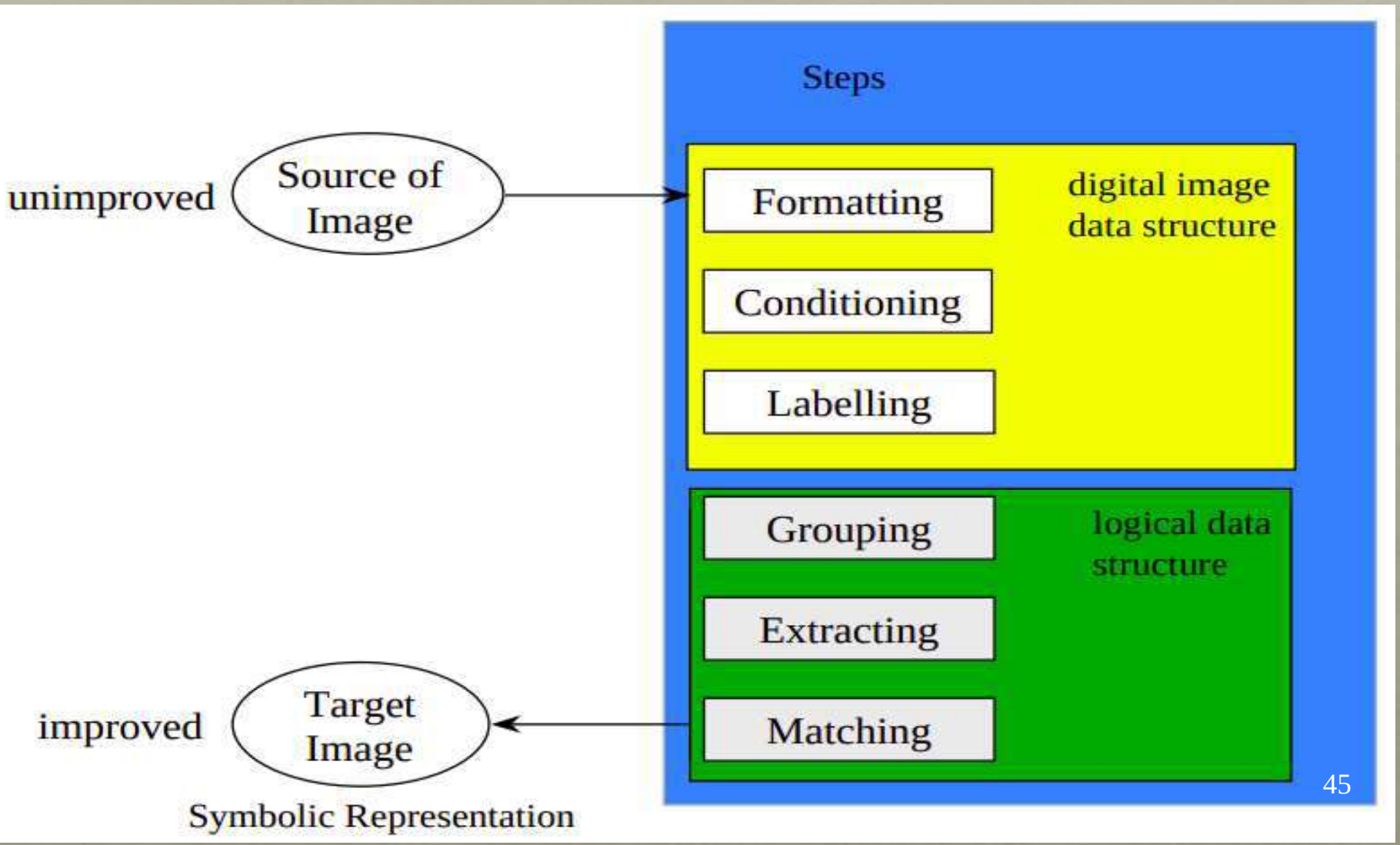


Image recognition steps

- Formatting:
  capturing of an image and transforming to a digital representation
- Conditioning
  image may contain uninteresting features due to noise or background.
  Informative patterns may be modified by random variations
  conditioning suppresses such features and highlight interesting parts of image.

Image recognition steps

- Labeling:
  - assumes informative pattern has structure
  -analysis adjacent pixels, we can determine structure like edge
  -edge detection identifies continuous adjacent pixels that differ greatly in intensity or color.
  - threshold filters out insignificant edges.
  - corner detection is done in similar way
  - edge and corner are labeled

Image recognition steps

- Extraction:
  -computes list of properties for each group of pixels
  -for e.g. centroid, area, orientation, spatial moments, gray tone moments, spatial-Grey tone, number of holes, average curvature
  -describes topographical relationship between different groups

Image recognition steps

- Matching:
  -compares each object in the image with previously stored models
  - determines best matching

Image recognition steps

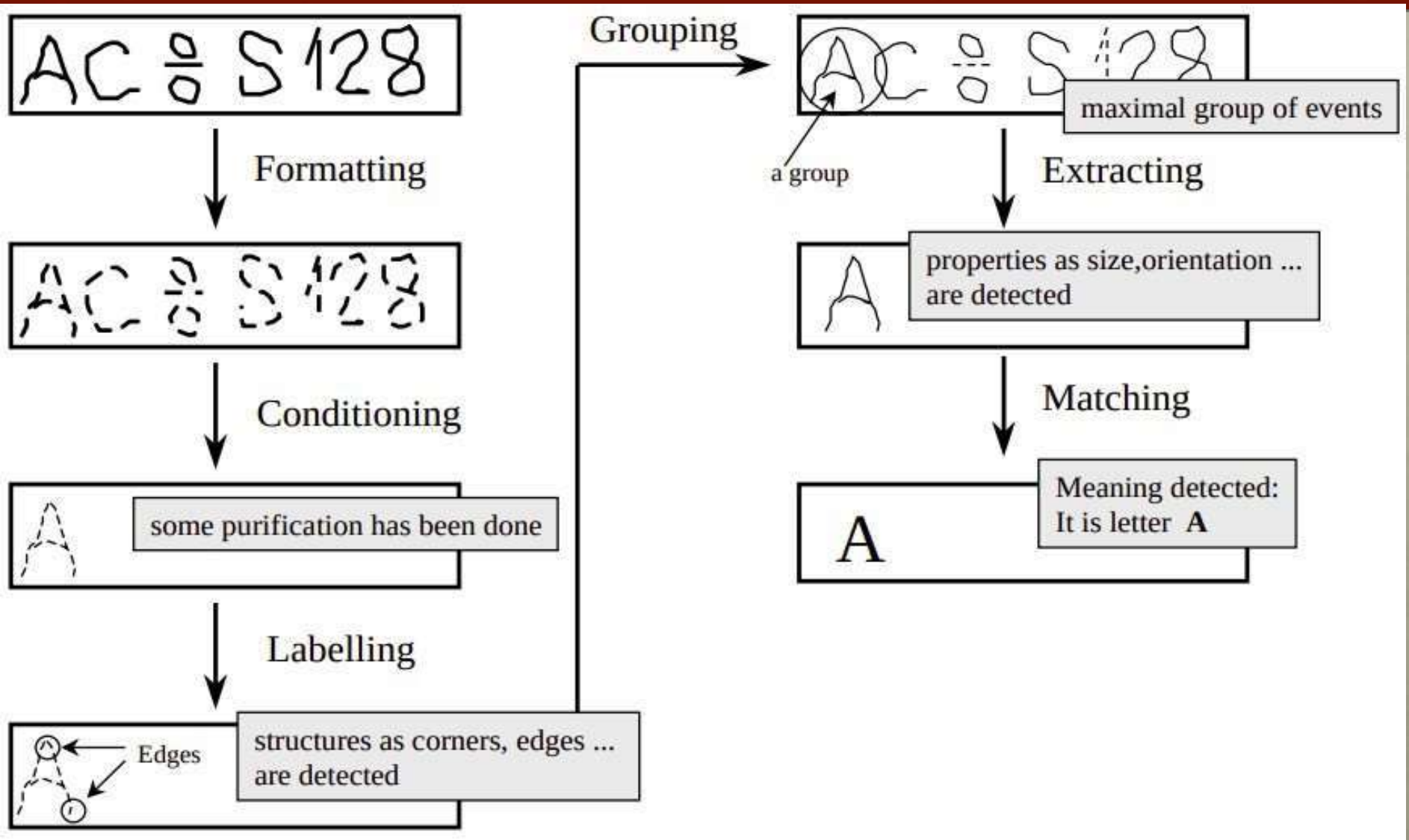


Image Transmission

- Network must accommodate bursty data transport due to large size of images
- Requires reliable transport
- Time dependence is not dominant characteristic of he image

Format for transmission

- Raw image;
  - generated by video digitize
  - transmitted digitally
  - size= resolution* quantization
  -640 x 480 with quantization of 8 bits per pixel requires 307.2MB
- Compressed image
  - image is compressed and transmitted
  - compressed formats are JPEG and MPEG
  -size depends upon compression method and rate

Format for transmission

- Symbolic image:
  - represented through symbolic data
  -such as 2Dgeometric representation, attributes and other control information
  - image size is equal to structure size