Unit 3

Images and graphics

Discussion Topics

- Introduction to images and graphics
- Digital Image Representation
- Image and graphics Format
- Image Synthesis, analysis and Transmission

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What is image/graphics ?

- An image is a spatial representation of an object or a 2D/3D scene.
- Abstractly, we can think of an image as a continuous function defining a rectangular region of a plane.

- Image can be of many types:

  i. *Intensity images/optic or photographic images :*

  - ➢ These images are taken with optic sensor where, the image is created by perceiving radiant energy in the electromagnetic band.

  ii. *Range images*

  - ➢ The image is a function of line-of-sight distance from the image sensor to the object in a 3D environment.
  - ➢ Used by range-finding devices

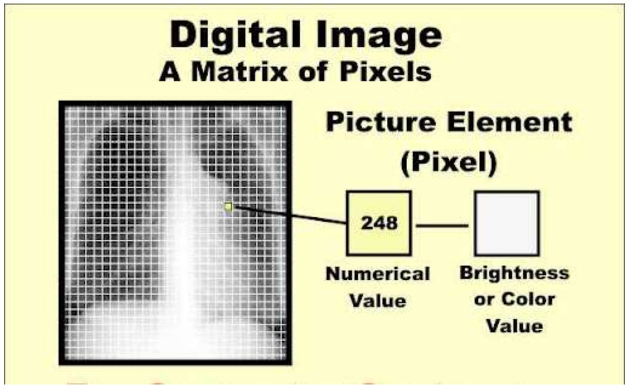
  iii. *Tactile images*

  - ➢ The image represents the sensor deformation caused by the surface of or around an object.
  - ➢ E.g. blind people can read tactile images with finger tips.

- In multimedia applications, images can be used in analog, digital or graphics formats.

Digital image representation

- For intensity images, an image is a function which gives light intensity values at each point over a planar region.
- For computer representation, this function needs to be sampled at discrete intervals.
- The sampling quantizes the intensity values into discrete levels.
- A digital image is represented by a matrix of numeric values each representing a quantized intensity value (pixel).
- Let I be a 2D matrix. Then I(r,c) is the intensity value of the position (pixel) corresponding to row r and column c.

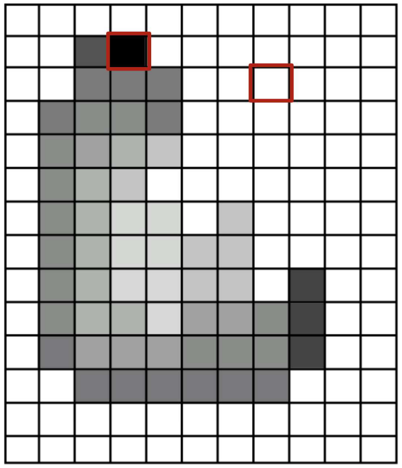


- Main concepts in image representation:
  - ✓ *Pixel*: pixel is the smallest spatial unit of picture. A whole picture is made of many pixels.
  - ✓ *Resolution*: it is the total number of pixels in a digitized image.
  - ✓ *Color*: Color is the visual element of picture. It is the pixel value of intensity image. Visually, the whole picture is the collection of colors of all the pixels. The color levels are also called **grayscale levels** or **color depth**.

    If there are only two color intensity values, we can represent color by one bit (1 for white and 0 for black)

    If we use 8 bits to represent colors then we can have 256 different colors i.e. gray scale levels from 0 (black) to 255(white)

    Similarly, we can have higher color depths.



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255	255	255	255	255	255	255	255	255	255	255
255	255	20	0	255	255	255	255	255	255	255
255	255	75	75	255	255	255	255	255	255	255
255	75	95	95	75	255	255	255	255	255	255
255	96	127	145	175	255	255	255	255	255	255
255	127	145	175	175	175	255	255	255	255	255
255	127	145	200	200	175	175	95	255	255	255
255	127	145	200	200	175	175	95	47	255	255
255	127	145	145	175	127	127	95	47	255	255
255	74	127	127	127	95	95	95	47	255	255
255	255	74	74	74	74	74	74	255	255	255
255	255	255	255	255	255	255	255	255	255	255
255	255	255	255	255	255	255	255	255	255	255
255	255	255	255	255	255	255	255	255	255	255

0 = black; 255 = white

1-bit	black-and-white image, also called *bitmap image*.
4-bit	can represent 16 colours, used in low resolution screens(EGA/VGA)
8-bit	can have 256 colours. The 256 colour images are often known as *indexed* colour images. The values are actually indexes to a table of many more different colours. For example, Colour 3 is mapped to (200, 10, 10).
8-bit grey	256 grey-levels. The image contains only brightness/intensity data without colour information.
16-bit	can have 65536 colours, also known as hi-colour in Windows systems. The 16 bits are divided into 5 bits for RED, 6 bits for GREEN and 5 bits for BLUE.

24-bit	$2^{24} = 16,777,216$ colours, true colour. Each byte is used to represent the intensity of a primary colour, RED, GREEN and BLUE. Each colour can have 256 different levels.
32-bit	$2^{32} = 4,294,967,296$ (4G). Usually, 3 bytes are used to represent the three primary colours and the fourth byte is used as the *alpha channel*.

RED	GREEN	BLUE	Colour
255	0	0	Red
0	255	0	Green
0	0	255	Blue
255	255	0	Yellow
255	0	255	Magenta
0	255	255	Cyan
127	127	127	Light gray
255	255	255	White
0	0	0	Black


8 bit
16 bit

Image format

There are two different kinds of image formats.

1. Captured image format:

- It is the format that comes out of the image capturing device (e.g. digital camera).
- Captured image is specified by two factors: *spatial resolution*(pixels * pixels) and *color encoding*(bits per pixel).
- Both factors depend on hardware and software for input/output of image.
- Different digital cameras implement different resolution and color combination.

2. Stored image format:

- This is format of images stored in digital storage device.
- When we store an image, we actually store a 2D array of values, in which each value represents the data associated with a pixel in the image.
- For a bitmap image this value is a binary digit.
- For a color image, the pixel value may be a collection of:
  - Three numbers representing the intensities of the red,green and blue components of the color at that pixel
  - Three numbers that are indices to tables of red, green and blue intensities
  - A single number that is an index to the table of color triples.
  - Spectral samples for each color.
- Thus we consider an image as a collection of RGB channels.
- If there is enough storage space, we store image as RGB triples, otherwise, we need to compress the image.
- Some popular stored image file formats are GIF, JPEG, TIFF etc.

Graphics format(vector graphics)

- Graphics image formats are specified through high level graphics primitives and their attributes rather than as pixel matrix.

  Graphics primitives: Graphics primitives are basic geometric shapes that make up an image. They are simply text strings specifying 2D or 3D objects E.g. lines, rectangles, circles, ellipses, polyhedron etc.

  Attributes: Attributes are the properties of primitives. They affect the outcome of the graphical image. E.g. line width, color etc

- Graphics primitives and their attributes represent a higher level of an image representation. i.e. the graphical images are not represented by a pixel matrix.
- This high level representation must be converted to low level representation during image processing.

- Graphics primitives are provided by the software packages known as graphics packages.
- The graphics packages take graphics primitives and attributes and generate either ***bitmap*** (for black and white color pixels)or ***pixmap*** (for color pixels).
- Examples of graphics packages:

  SRGP (Simple raster graphics package)

  PHIGS(programmer's hierarchical interactive graphics)

  GKS(Graphics kernel system)

<u>Advantage of high level primitives</u> :

- Less data needs to be stored for image.
- Easier manipulation of the image.
- Makes it easier for graphics designers and programmers.

<u>Disadvantages</u>

- Needs additional conversion from high level to low level(pixel) representation.

Vector versus Bitmap

Bitmap	Vector graphic
• A bitmap contains an exact pixel-by-pixel value of an image	• a vector graphic contains mathematical description of objects
• A bitmap file is fixed in resolution	• a vector graphic is resolution independent
• The file size of a bitmap is completely determined by the image resolution and its depth	• the file size of a vector graphic depends on the number of graphic elements it contains
• A bitmap image is easier to render	• displaying a vector graphic usually involves a large amount of processing

Colour Systems

Colour is a vital component of multimedia. Colour management is both a subjective and a technical exercise, because:

- Colour is a physical property of light, but
- Colour perception is a human physiological activity.
- Choosing a right colour or colour combination involves many trials and aesthetic judgement.
- Colour is the frequency/wave-length of a light wave within the narrow band of the electromagnetic spectrum (380 – 760nm) to which the human eye responds.

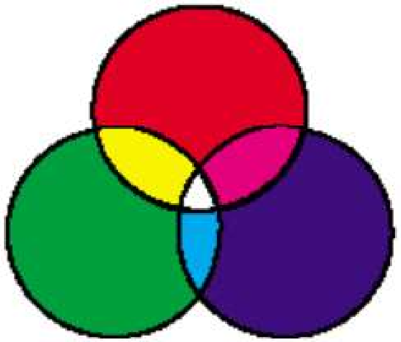
RGB Colour Model

This is probably the most popular colour model used in computer graphics.

It is an *additive* system in which varying amount of the three primary colours, red, green and blue, are added to black to produce new colours.

You can imagine three light sources of the primary colours shine on a black surface. By varying the intensity of the lights, you will produce different colours.

R — Red
G — Green
B — Blue



CMY Colour Model

This model is based on the light absorbing quality of inks printed on paper. Combining three primary colour pigments, Cyan, Magenta and Yellow, should absorb all light, thus resulting in black.

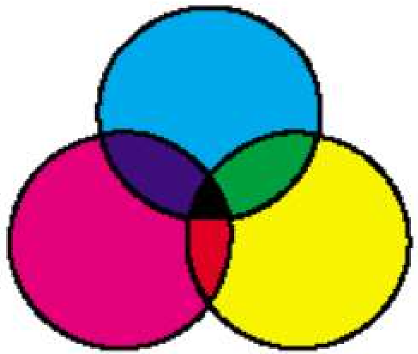
It is a *subtractive* model.

The value of each primary colour is assigned a percentage from the lightest (0%) to the darkest (100%).

Because all inks contain some impurities, three inks actually produce a muddy brown, a black colour is added in printing process, thus CMYK model.

Note: the primary colours in RGB and CMY models are complementary colours.

C — Cyan
M — Magenta
Y — Yellow



HSB Colour Model

This model is based on the human perception of colour.

The three fundamental characteristics of colours are:

Hue — is the wavelength of the light. Hue is often identified by the name of the colour. It is measured as a location on the standard colour wheel as a degree between $0°$ to $360°$.

Saturation — is the strength or purity of the colour. It represents the amount of gray in proportion to the hue and is measured as a percentage from 0%(gray) to 100%(fully saturated).

Brightness — is the relative lightness or darkness of the colour. It is measured as a percentage from 0%(black) to 100%(white).

YUV Colour Model

This model is widely used in encoding colour for use in television and video.

The theory behind this model is that human perception is more sensitive to brightness than any chrominance information, so a more suitable coding distinguishes between luminance and chrominance.

The Y-signal encodes the brightness information. Black-and-white television system use this channel only.

The U and V channels encode the chromatic information. The resolution of the U and V channels is often less than the Y channel for the reason of reducing the size.

Y,U and V are not abbreviations.

Y = luminance
U=Blue projection
V = Red projection

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Computer image processing

- Computer graphics concerns the two aspects:

1. *Image synthesis*: It is the process of pictorial synthesis(generation) of real or imaginary objects from their computer-based models.
2. *Image analysis*: The analysis(recognition) of scenes is the converse process. i.e. the reconstruction of the models from pictures of objects.

Image synthesis

- Images can be generated in two ways:
  1. By capturing real analog image and digitizing it.(reproducing natural image)
  2. By using graphics technology (producing artificial image)
- Here, we will focus on image generation via graphics systems
- Image synthesis is the process of synthesizing (generating) images.
- E.g. The computer user interfaces (GUI) are synthesized images.
- Image synthesis is necessary for visualizing 2D or 3D objects.
- Some application areas of image synthesis are:
  - *User interfaces*
  - *Office automation and electronic publishing*
  - *Simulation and animation for scientific visualization and entertainment*

- Interactive computer graphics are the means of producing artificial images.
- With the help of interactive graphics systems, we can make picture of concrete, real world objects as well as abstract, synthetic objects(e.g. mathematical surfaces in 4D).
- Graphics are not confined to static pictures. They can be dynamically varied. E.g. an object can be moved or view around an object can move, the shape, color and other properties can be changed etc.
- Interactive graphics technology contains H/w and s/w for user-controlled graphics dynamics.

Image synthesis using graphics systems

- Graphical images are generated using interactive graphics systems.
- This graphics system consists of a set of components in order to accomplish the image synthesis. The set of components constitute the *framework for graphics system.*
- The framework of interactive graphics system contains four components:

Application program
Application database
Graphics system
Graphics input/output hardware

Fig: Interactive graphics system framework

Application program handles user input. It produces views sending a series of graphics output commands to the graphics system. The commands contain detailed description of what is to be viewed and the attributes describing how the objects should appear.

Application database stores the application model. It stores the description of primitives and attributes. The application program traverses the database to extract data using query system. The extracted data is put in a format to send to graphics system

Graphics system is responsible for actually producing picture. It is the intermediate component between application program and hardware. It contains graphics library or package.

Hardware is responsible for receiving user input and producing output.

Input H/W: touch panels,trackballs, data glove etc.

Output H/W: raster display,

More on raster display

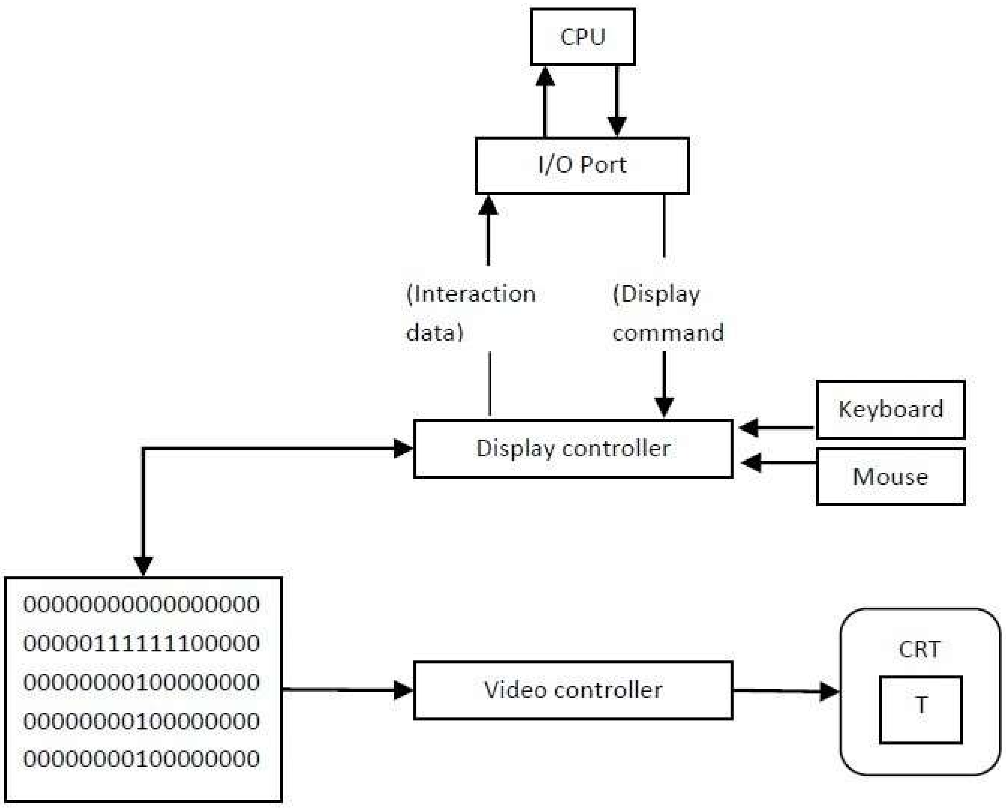


Fig: Architecture of raster dispaly

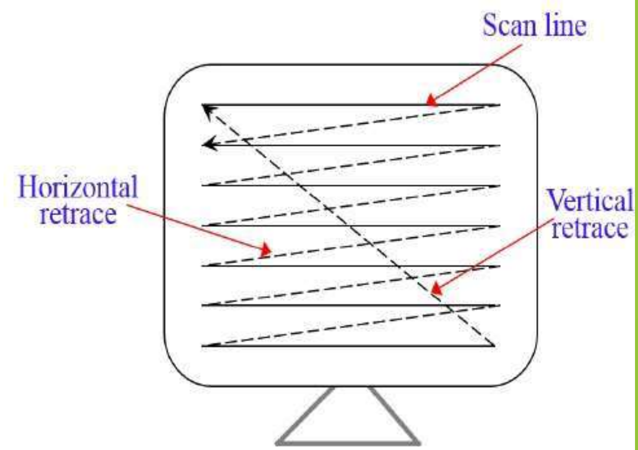


Fig: Raster scan

Dithering

- During image processing (especially image generation), graphics systems often use a technique called dithering.
- In computer graphics, dithering is an image processing operation used to create the illusion of color depth in images with a limited color palette. Colors not available in the palette are approximated by a diffusion of colored pixels from within the available palette.
- In simple words, Dithering is the attempt to approximate a color from a mixture of other colors when the required color is not available.
- For example, dithering occurs when a color is specified for a Web page that a browser can't support. The browser will then attempt to replace the requested color with an approximation composed of two or more other colors it can produce.
- Dithering is being heavily used for printing photos in Newspapers and Magazines for long time.

- Dithering is based on human's perception of an image:

"Our eyes can distinguish fine details when viewing large area very closely. But when we view a very small area from a sufficient large viewing distance, our eyes average fine details within the small area and record only the overall intensity of the area."

e.g., See the figure A .

In figure A, red and blue are the only colors used but, as the red and blue squares are made smaller, the patch appears purple!.

- The phenomenon of apparent increase in the number of available intensities by considering combine intensity of multiple pixels is known as half toning.
- The half toning is commonly used in printing black and white photographs in newspapers, magazines and books.

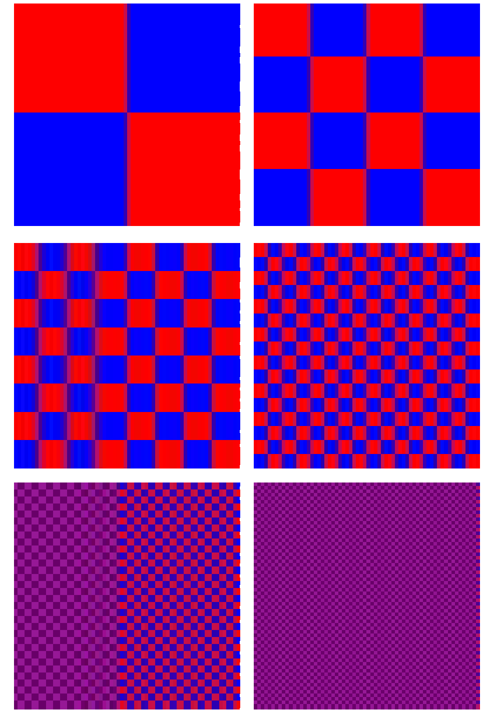


Figure A

Figure B

In figure B, we have a grayscale image represented in 1-bit black-and-white with dithering. Note that the image has been produced with only black and white color. Both images are same. But we get illusion of more grayscale depth in the smaller picture. Because our eyes average the color when viewing from distance.

Another example: See the following picture.

Original image

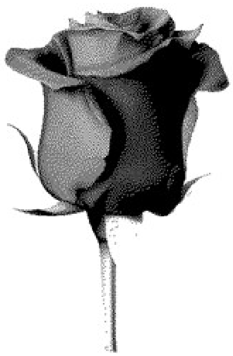


Image having Dithering effect

When enlarged, we can see the dithering dots.

- Without dithering, the RHS image would have pitch black appearance for the dark red region and full white for the light red region of the red rose.
- But because of dithering, the image appears smooth having more grayscale levels (intermediate intensities between black and white)

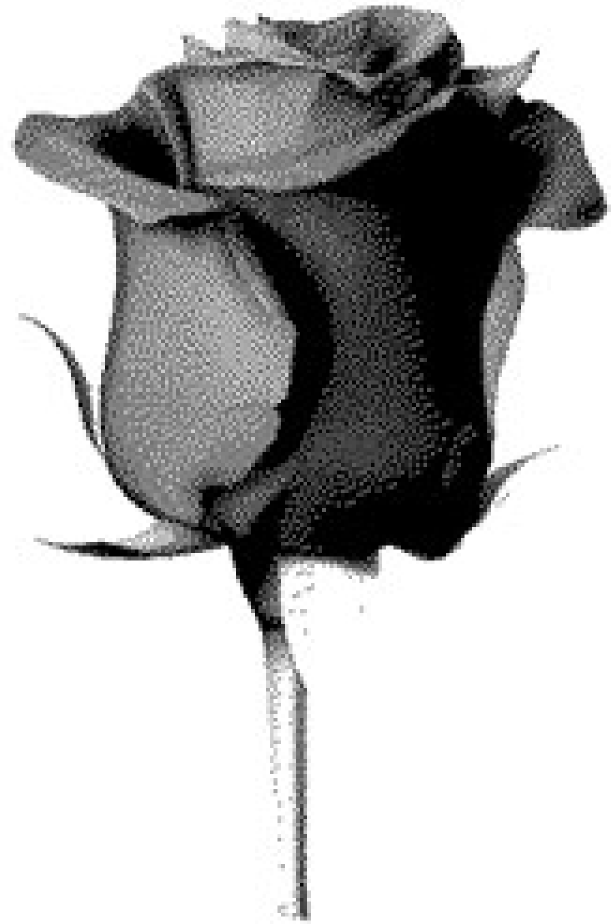


Image having Dithering effect

Original image
with 8-bit
grayscale levels

image with 1-bit
grayscale levels
without dithering

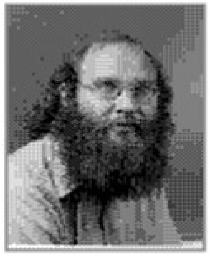


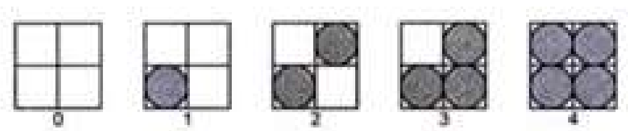
image with 1-bit
grayscale levels
with dithering

Question: What actually the dithering process did in the earlier pictures (figure B and the rose image)?

Answer: It simply added the black dots in the white pixels! (and probably added white dots in the black)

Dithering technique

1. *Monochrome dithering technique*
   - First the total pixel area is divided into dither matrices.
   - Each dither matrix contains matrix of pixels.
   - Different combinations of the dots are obtained by blackening the pixels.
   - For example: consider a dither matrix of size 2X2. Then we can have five different intensity levels as shown in figure.



- To obtain n^2 intensity levels, it is necessary to set up an n*n dither matrix

2. *Color dithering technique*
   - The idea of monochrome dithering technique can be extended for the multiple colors.
   - For example, suppose we have 3-bit color depth with only available colors red, blue and green.
   - Then we can use a pattern area of 2X2 to obtain 125 colors as follows:
     - Each pattern can display five intensities for each color (as in monochrome dither). Hence total color combinations will be 5*5*5 = 125

There are three types of dithering methods:

- Random dither: Dithering is done randomly. Dithering appears as a noise
- Ordered dither: In ordered dither, uniform dithering is done to generate intensity variations with a one-to-one mapping of points in a scene to the display pixel.
- diffuse dither: Ordered dither (repeated use of same dot pattern for particular shade) may result in uniformly repeated patterns. To avoid this effect, diffusion dither is used. The dithering effect from the current pixel is diffused in the neighboring pixel.


Original image with 8-bit grayscale levels


image with 1-bit grayscale levels with random dithering

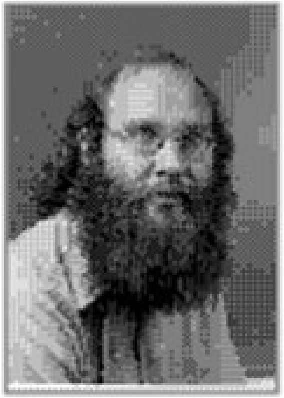


image with 1-bit grayscale levels with ordered dithering (observe the patterns)

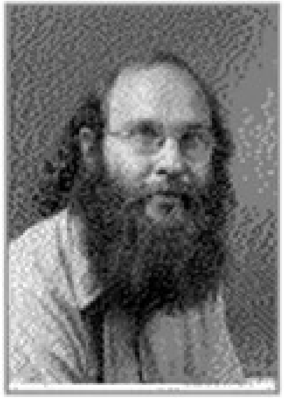


image with 1-bit grayscale levels with diffuse dithering

Image synthesis

- Image analysis is concerned with techniques for extracting descriptions from the images that are necessary for higher-level scene analysis methods.

Until now, we have treated a picture as a 2D matrix pixel which shows a pixel position and its value. But this knowledge by itself conveys almost no information related to recognition of an object such as:

- the description of shape of the object
- The object’s orientation
- The measurement of any distance about the object
- Whether the object is good or defective

- The image analysis technique deals with above aspects and many more including
  - Perceived brightness and color
  - Partial/complete recovery of image
  - Location of discontinuities corresponding to objects in the scene
  - Finding uniform regions in the scene.

Application areas of image analysis

- Image analysis is important in many areas:
  - Aerial surveillance
  - Analysis of images gathered from space probes
  - Health care (X-ray, ultrasonography, CT-scan image analysis)

- Following are the subareas where image analysis is important.
  - *Image enhancement:* Deals with improving image quality by eliminating noise (extraneous pixels or missing pixels) or by enhancing contrast.
  - *Pattern detection and recognition:* Deals with detecting and classifying standard patterns and finding distortions from the actual patterns. e.g. Optical Character Recognistion(OCR)
  - *Scene analysis and computer vision:* Deal with recognizing and reconstructing 3D models of a scene from several 2D images. e.g., industrial robots can sense relative sizes, shapes, positions and colors of objects. Another example is Fully automated car.

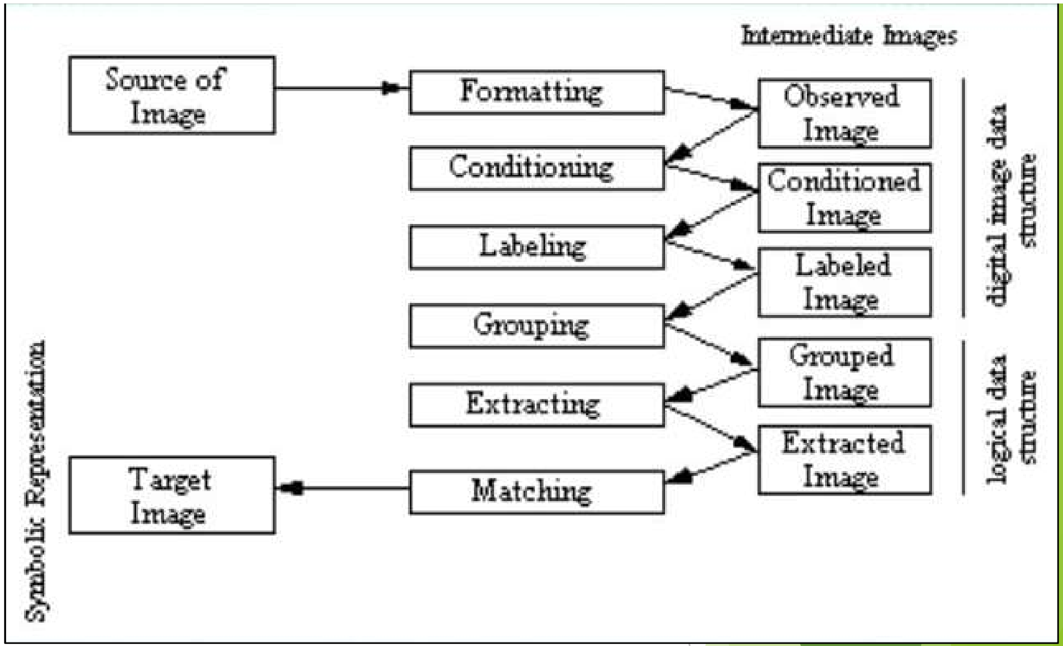
Steps in Image recognition

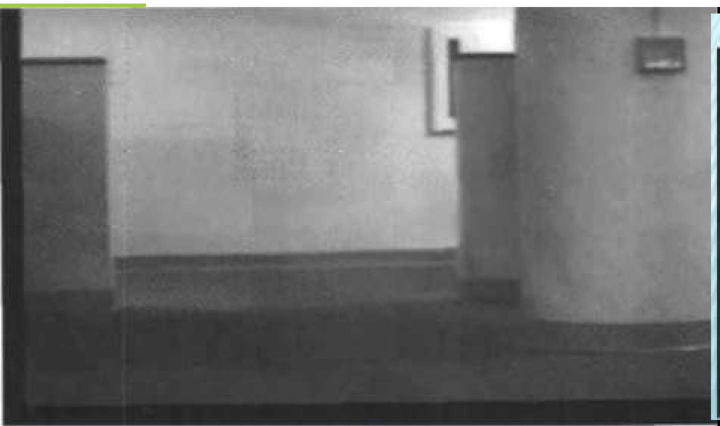
1. **Formatting**:

- Formatting means capturing an image from a camera and bringing it into a digital form.
- After formatting, we get a digital representation of an image in the form of pixels.

2. **Conditioning**:

- In an observed image, the actual informative pattern is always disturbed by uninteresting variations.
- In simple words, in an image, there are uninteresting features either because they were introduced in the image during the digitization process or they are part of background.
- Conditioning tries to estimate the actual informative pattern in the observed image.
- The major conditioning tasks are:
    - Suppression of noise (suppressing random unpatterned variations) and
    - Background normalization (suppressing uninteresting patterned variations).





Original (observed) image

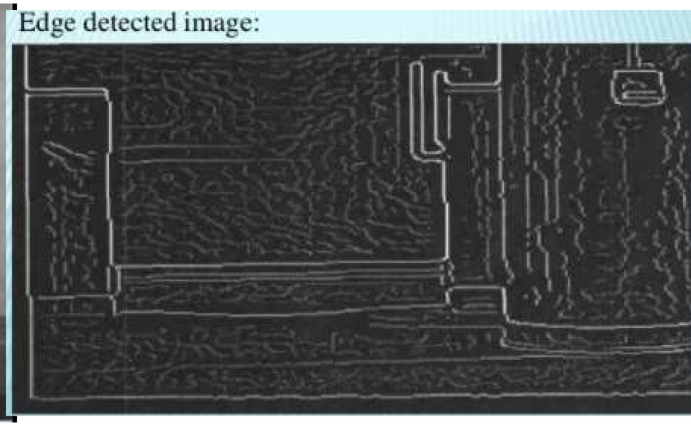


Image after preliminary edge detection

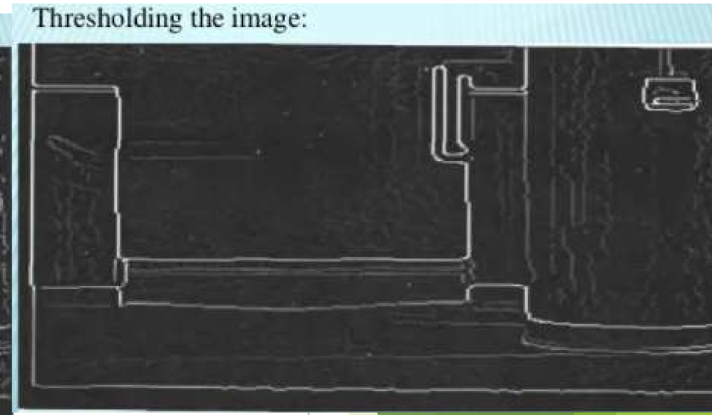


Image after removing non-significant edges

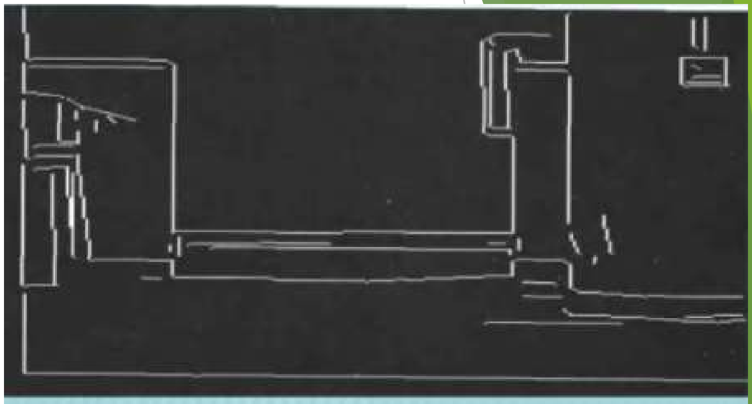
Fig: This example shows intermediate images during edge detection step of image recognition process.

3. Labeling:

- Labeling is based on the idea that the informative pattern has structure as the spatial arrangement of events (sets of connected pixels).
- Labeling determines what kinds of spatial events each pixel participates in.
- Patterns are usually composed of adjacent pixels which share some property that determines that they are part of the structure.
- An example of labeling is ***Edge detection***. (see the figure above)

4. **Grouping**

- Grouping turns edges (represented as individual pixels) into line by determining that different edges belong to the same spatial event.
- It identifies maximal connected sets of pixels participating in the same kind of event.
- A grouping operating where edges are grouped into lines is called line-fitting (as shown in fig).



5. **Extracting:**

- The extracting operation computes a list of properties for each group of pixels.
- The extracted properties might be centroid, area, orientation, spatial gray tone etc.
- Extraction can also measure topological or spatial relationship between two or more groupings. e.g., to determine whether two groups touch, or close to each other etc

6. **Matching:**

- After completion of the extracting operation, the events on the image have been identified and measured, but they still have no meaning.
- Various measurements are done (e.g. between two parts of object, angle between two lines, or area of part of objet) to identify whether the object pattern is similar to a known object.
- An example of matching is "template matching" which involves comparing each object in the image to a previously stored samples (Templates) and choosing the best match.

Example:

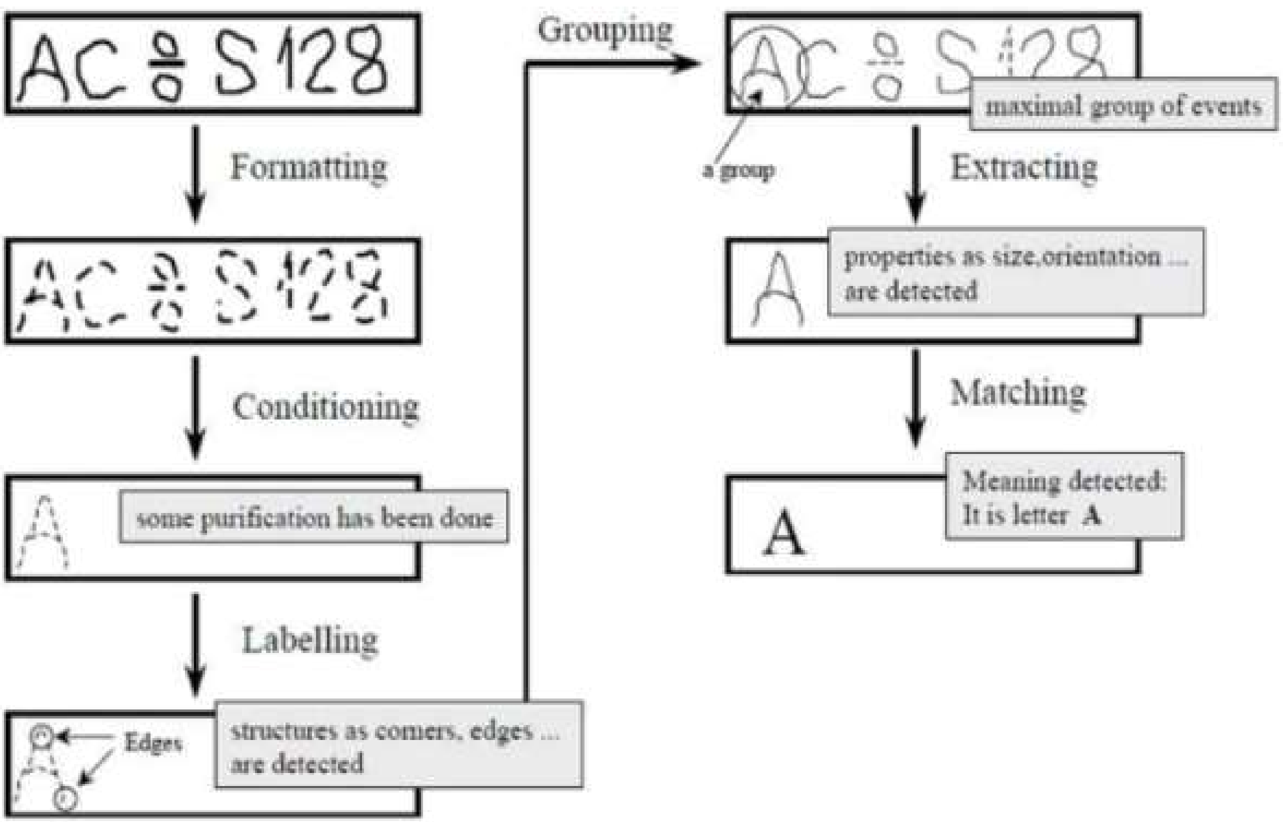

AC S128
Formatting
Conditioning
some purification has been done
Labelling
Edges
structures as corners, edges ...
are detected
Grouping
maximal group of events
a group
Extracting
properties as size,orientation ...
are detected
Matching
Meaning detected:
It is letter A
A

Image Transmission

- Image transmission deals with the transmission of digital images through computer networks.
- Image transmission has some special requirements:
  - *The network must accommodate bursty data transport. Because images tend to be of large data size*
  - *The transmission must be reliable (no loss of data during transmission)*
  - *There is no concern about time-dependence.*
- Images can be transmitted in three ways

Raw image data transmission

- The image is generated through digitizer and transmitted in digital format.
- The size required is :

  *Size = spatial_resolution * pixel_quantization*

Compressed image data transmission

- The image is compressed before transmission
- Methods such as JPEG, MPEG etc can be used to downsize the image.
- The size and quality of the compressed image depends on particular compression technique used.

Symbolic image data transmission

- The image is represented through symbolic data as image primitives (e.g. 2D or 3D geometric representation), attributes and other control information.
- This image representation is used in vector graphics.

End of unit 3

Thank you!