# Unit 3: Images and Graphics (5 Hrs.)

1. Uses of images and Graphics
2. Digital Image Representation
3. Image and graphics Format
4. Working with image and graphics
5. Image Synthesis, analysis and Transmission

**#Past Questions**

- **2023 Q4**: What is meant by image analysis? Explain image analysis techniques in detail.
- **2024 Q4**: Difference between bitmap and vector graphics.

### Introduction to Images and Graphics

- An **image** is a visual representation of a real objects or scenes captured using a camera, scanner, or created digitally. **Example**: Photographs, scanned documents, screenshots.

- **Graphics** are computer-generated visual elements such as drawings, illustrations, diagrams, icons, or shapes used to represent ideas and data. **Example:** Logos, charts, infographics, 3D models.

| Aspect | Images 🖼 | Graphics 🎨 |
|---|---|---|
| **Definition** | Visuals captured from the real world. | Visuals created or designed using computer tools. |
| **Source** | Taken using camera, scanner, or screenshot. | Created with software (Photoshop, Illustrator, CorelDraw, CAD). |
| **Nature** | Photographic and realistic. | Illustrative, symbolic, or abstract. |
| **File Types** | JPEG, PNG, TIFF, BMP. | SVG, AI, EPS, GIF, 3D models. |
| **Usage** | Represent real objects, people, or scenes. | Represent ideas, concepts, data, or designs. |
| **Examples** | Photos, scanned documents, selfies. | Logos, diagrams, infographics, charts, animations. |

## 1. Uses of Images and Graphics

Images and graphics serve as visual communication tools. They convey information more effectively than text and are used across multiple domains:

### a. Education

- **Example:** Diagrams in biology textbooks or e-learning apps use labeled graphics for clarity.
- Infographics summarize large content into visual formats.
- Educational animations simplify complex concepts (e.g., photosynthesis or black holes).

### b. Entertainment

- **Example:** In animated films like *Toy Story*, graphics are synthesized using 3D modeling tools like Blender or Maya.
- Video games use real-time graphics rendering for immersive environments.

### c. Medical Imaging

- **Example:** A CT scan shows cross-sectional images of the human body.
- Graphics algorithms help reconstruct 3D models of organs for diagnosis.

**d. Business and Advertising**

- **Example:** Logos, posters, and digital ads rely on high-quality images and branding elements.
- Graphics tools like Adobe Illustrator and Photoshop are used for designing.

**e. User Interfaces (UI)**

- **Example:** Icons for apps (e.g., camera, music, settings) are graphics representing actions.
- Graphics make the UI interactive, attractive, and intuitive.

**f. Geographical Information Systems (GIS)**

- **Example:** Google Earth uses satellite imagery and graphical overlays for mapping.
- Terrain mapping, flood prediction, and agriculture planning use GIS images.

## 2. Digital Image Representation

In digital form, images are made up of a collection of pixels arranged in a grid. Each pixel represents a color or intensity value and together they form the complete image. The entire image is stored in binary format.

**Key Elements**

**1. Pixels (Picture Elements)**

- The smallest unit of a digital image.
- Each pixel has a specific **color and brightness value**.
- More pixels = higher resolution (sharper image).

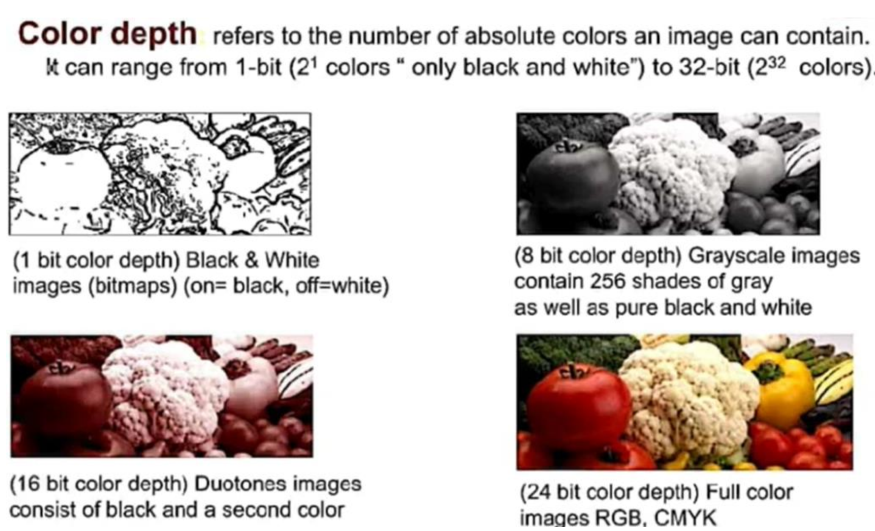
**2. Resolution**

- Number of pixels in width × height (e.g., 1920×1080).
- Higher resolution → more detail but larger file size.

**3. Color Models**

- Defines how colors are represented numerically.
- Common models:
  - **RGB (Red, Green, Blue)** – Additive model used in digital displays. E.g. (255, 0, 0) = Pure Red
  - **CMYK (Cyan, Magenta, Yellow, Black)** – Subtractive model used in printing.
  - **Grayscale** – Each pixel has shades from black (0) to white (255). E.g. B/W photographs

**4. Bit Depth (Color depth)**




- Number of bits used per pixel to represent color.
- Higher bit depth → more color accuracy.
- Common color depth includes:
  - **1-bit** → 2 colors (black & white).
  - **8-bit** → 256 colors.
  - **24-bit** → ~16.7 million colors (True Color).
  - **32-bit** → Includes transparency (alpha channel).
- **Example:** Most photos on smartphones are stored in 24-bit color.

**5. Compression**

- Reduces file size of images.
- **Lossless (PNG, TIFF):** Keeps original quality.
- **Lossy (JPEG):** Some quality is lost for smaller size.

## 3. Image and Graphics Format

Image format refers to **how image data is stored and represented in a file**. It determines File size, Quality and Usability (web, print, editing, etc.)
Formats can be:

- **Compressed** (smaller size, lower/higher quality)
- **Uncompressed** (large size, high quality)
- **Vector-based** (scalable, not pixel-dependent)

**1. Captured Image Format**

This describes how the image is recorded (captured by devices like cameras, scanners).
Two main parameters:

- **Spatial Resolution**
  - Number of pixels in width × height.
  - Example: **640×480**, **1920×1080 (Full HD)**.
  - Higher resolution → sharper image.
- **Color Encoding**
  - Defines how color is represented.
  - Measured in **bits per pixel (bpp)**.
  - Example:
    - 1-bit → Black/White only.
    - 8-bit → 256 colors.
    - 24-bit → 16.7 million colors.

Note: Both depend on **hardware (camera sensor)** and **software (drivers, codecs)**.

**2. Store Image Format**

This defines **how the captured image data is stored** in a file.

- Stored as a **two-dimensional array** of pixel values.
- Each pixel = associated data (color, brightness).

**Example:** In **Bitmap (BMP)** storage, each pixel value is saved as **binary digits (0s and 1s)**.

**Broad Classification of Storage Formats:**

i. **Raster (Bitmap) Images Format:**

Also known as bitmap images, these are composed of a fixed grid of tiny squares called pixels. Photos and scanned images are common examples. When a raster image is enlarged, the individual pixels become visible, making the image appear blurry or "pixelated."

**Common Raster Image Formats**

**JPEG (JPG – Joint Photographic Experts Group)**

JPEG is the most widely used image format for photographs. It uses **lossy compression**, which reduces file size significantly by discarding some image data. This makes it ideal for web use, sharing, and storing photos where small size is preferred over perfect quality.

**Pros:**

- Small file size (saves storage and bandwidth).
- Supported on almost all devices and platforms.
- Ideal for photos and complex images.

**Cons:**

- Quality loss due to compression.
- Not good for images with text, logos, or sharp edges.

**PNG (Portable Network Graphics)**

PNG is a **lossless compression** format, meaning it preserves all image quality. It supports **transparency**, making it very popular for logos, cutouts, and web graphics. It is not as small as JPEG, but ensures crisp quality.

**Pros:**

- No quality loss (lossless).
- Supports transparent backgrounds.
- Great for text, icons, and graphics.

**Cons:**

- Larger file size than JPEG.
- Not ideal for very large or complex photos.

**GIF (Graphics Interchange Format)**

GIF is a **lossless format** but limited to **256 colors**, making it unsuitable for rich photos. Its biggest strength is **support for animations**, widely used for memes, banners, and short clips.

**Pros:**

- Supports animations.
- Lossless for simple graphics.
- Widely supported on the web.

**Cons:**

- Limited to 256 colors (poor for photos).
- Larger size compared to modern formats like MP4 for animations.

**BMP (Bitmap)**

BMP is one of the oldest formats, storing images in **uncompressed raw pixel data**. It preserves high quality but produces extremely large files. Today, it’s rarely used outside legacy applications.

**Pros:**

- Very simple format, easy to process.
- Preserves exact pixel data.

**Cons:**

- Extremely large file size.
- Not suitable for modern web or storage needs.

**TIFF (Tagged Image File Format)**

TIFF is a **high-quality, usually lossless format** widely used in printing, publishing, and professional photography. It can store multiple layers and image details, making it suitable for editing and archiving.

**Pros:**

- Excellent quality for professional use.
- Lossless (no data loss).
- Supports multiple images in one file.

**Cons:**

- Very large file size.
- Not supported by all software (especially on the web).

**ii. Vector Graphics Format:**

These images are not made of pixels. Instead, they are created from mathematical formulas that define points, lines, and curves. Because they are based on these equations, **vector images** can be scaled to any size without losing quality or becoming pixelated. This makes them ideal for logos, illustrations, and fonts that need to be used at various sizes, from a business card to a billboard.

**Common Vector Graphic Formats**

**SVG (Scalable Vector Graphics)**

SVG is a **vector-based format** used mainly for web graphics, icons, and illustrations. It is resolution-independent, meaning it scales perfectly without losing quality. Since it is XML-based, it can also be edited with code.

**Pros:**

- Scalable without losing quality.
- Small file size.
- Editable using text or vector tools.

**Cons:**

- Not suitable for complex photos.
- Requires rendering software for viewing.

**AI (Adobe Illustrator File)**

AI is a proprietary **vector format** used in Adobe Illustrator. It is the industry standard for logos, illustrations, and professional graphic design.

**Pros:**

- Fully editable with layers, effects, and typography.
- High-quality for print and design.
- Standard in professional design workflows.

**Cons:**

- Requires Adobe Illustrator.
- Not universally supported outside Adobe ecosystem.

**EPS (Encapsulated PostScript)**

EPS is a vector format traditionally used in publishing and printing. It can include both raster and vector data, but is mostly used for scalable graphics like logos.

**Pros:**

- High-quality scalable graphics.
- Supported in professional printing.

**Cons:**

- Outdated compared to PDF and SVG.
- Limited editing flexibility.

**PDF (Portable Document Format)**

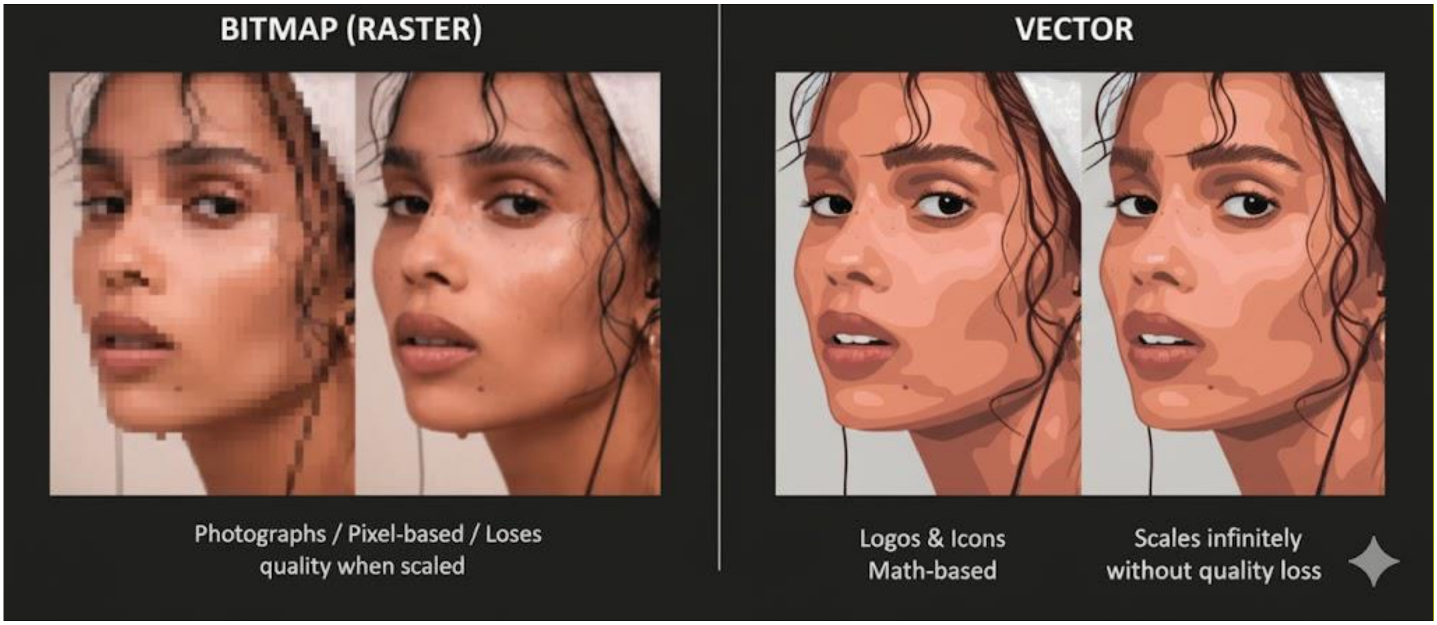
PDF is a versatile format that can contain **text, raster images, and vector graphics** in one file. It is widely used for documents, e-books, and designs that must look the same across devices.

**Pros:**

- Universally supported across platforms.
- Can store both images and text together.
- Preserves layout and fonts.

**Cons:**

- Editing is limited without specialized tools.
- Large files if not compressed.




| **Aspect** | **Raster(Bitmap) Graphics** | **Vector Graphics** |
|---|---|---|
| **Composition** | Made up of pixels arranged in a grid | Made up of mathematical curves, lines, and shapes |
| **File Size** | Generally larger due to pixel data | Typically, smaller due to mathematical representation |
| **Scalability** | Loses quality and becomes pixelated when scaled up | Can be scaled infinitely without loss of quality |
| **Best Suited for** | Detailed images with subtle color gradations like photos | Logos, illustrations, icons, and drawings with clear edges |
| **Editing Software** | Adobe Photoshop, GIMP, PaintShop | Adobe Illustrator, CorelDRAW, Inkscape |
| **Common Formats** | JPEG, PNG, GIF, TIFF | SVG, AI, EPS, PDF |
| **Printing** | Challenging with limited spot colors | Easily adapted to different printing needs |

## 4. Working with Images and Graphics

Working with images and graphics involves understanding the types of image formats, choosing the right software for your task, and knowing how to acquire and optimize images.

1. **Acquire the image:** You can get images by creating them from scratch in a graphics program, scanning a physical photograph, taking a photo with a digital camera, or downloading stock images. When using downloaded images, always respect copyright and licensing.

2. **Edit the image:** Perform manipulations like cropping, resizing, color correction, and removing backgrounds using the appropriate software. For the best results, use dedicated graphics software rather than editing within a document editor like Word.

3. **Optimize for your needs:** The optimal resolution and file format depend on the final use.

   - **For web and screen use:** Lower-resolution images (72–96 dpi) result in smaller file sizes and faster load times. PNG and JPEG are common formats.
   - **For print:** High-resolution images (300+ dpi) are needed to ensure sharpness and quality on paper.

4. **Insert into a document:**

   - Use the "Insert" or "Place" function to add images to documents, presentations, or websites.
   - For documents, control text wrapping to specify how the text flows around your image.
   - To prevent text and images from becoming misaligned, manage how objects are layered (e.g., "bring to front" or "send to back") and anchored within the document.

5. **Cite your sources**: When using images or graphics created by others, always provide a citation in your document and reference list to avoid plagiarism

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## 5. Image Synthesis, Analysis, and Transmission

### Computer Image Processing

**Image Processing** is the method of converting an image into a digital form and performing certain operations on it to get an enhanced image or extract some useful information from it.
It concerns the following three principles.

- **Image synthesis** (generate)
- **Image Analysis** (recognize)
- **Image Transmission**

### a. Image Synthesis

**Image synthesis** is the process of **creating new images** from scratch or from existing data using computer algorithms. It allows us to create pictures on a computer based on instructions or data.

In other words, it's about **generating artificial images** that look real or represent something meaningful.

## Applications of Image Synthesis

Image synthesis plays a crucial role in many fields:

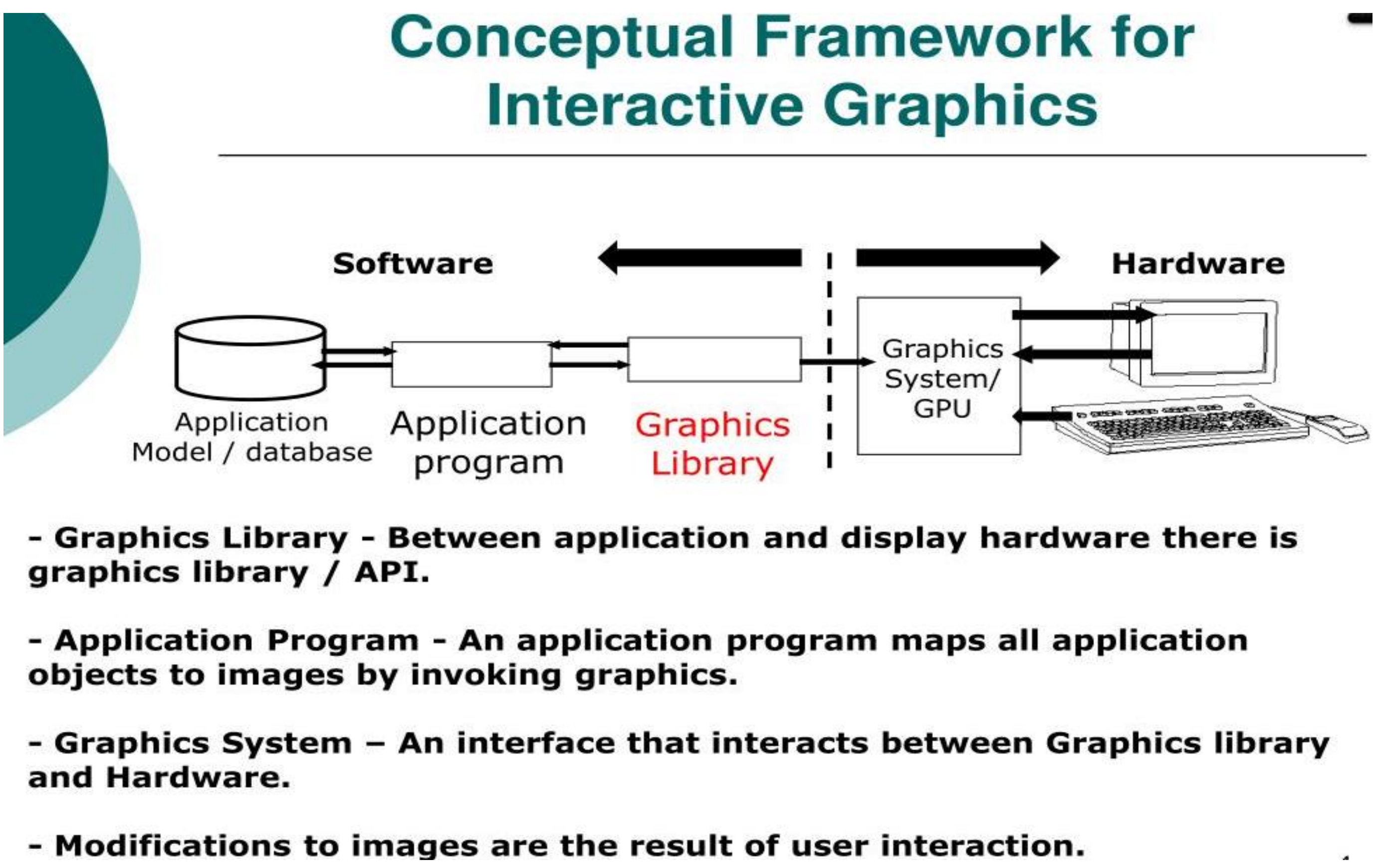
- **User Interfaces:** It's used to create graphical elements like menus, icons, and objects for navigation in computers and workstations.
- **Office Automation and Electronic Publishing:** It helps generate printed and digital documents with tables, graphs, and graphics.
- **Simulation and Animation for Scientific Visualization and Entertainment:**
  - **Scientific Visualization** involves generating images to show the behavior of real or simulated objects, such as in medical imaging or weather forecasting.
  - **Entertainment** uses Computer-Generated Images (**CGI**) for animated movies or video games.
- **Medicine:** Used for drug discovery or training objectives by simulating medical images.
- **Engineering:** Used for designing and building virtual environments or prototypes for product testing.
- **Art and design:** For developing original artistic styles and investigating creative potential.

## Dynamic in Graphics

Graphics can be **dynamically varied**, meaning pictures are not confined to static images. A user can control animation by adjusting speed, view, or amount of detail.

The two forms of dynamic in graphics are:

1. **Motion dynamic:** This allows objects to be moved and enabled relative to an observer. The object can remain stationary while the view around it moves, or both the objects and the camera/view can move.
2. **Update dynamic:** This is the actual change of the **shape, color, or other properties of the objects** being viewed.



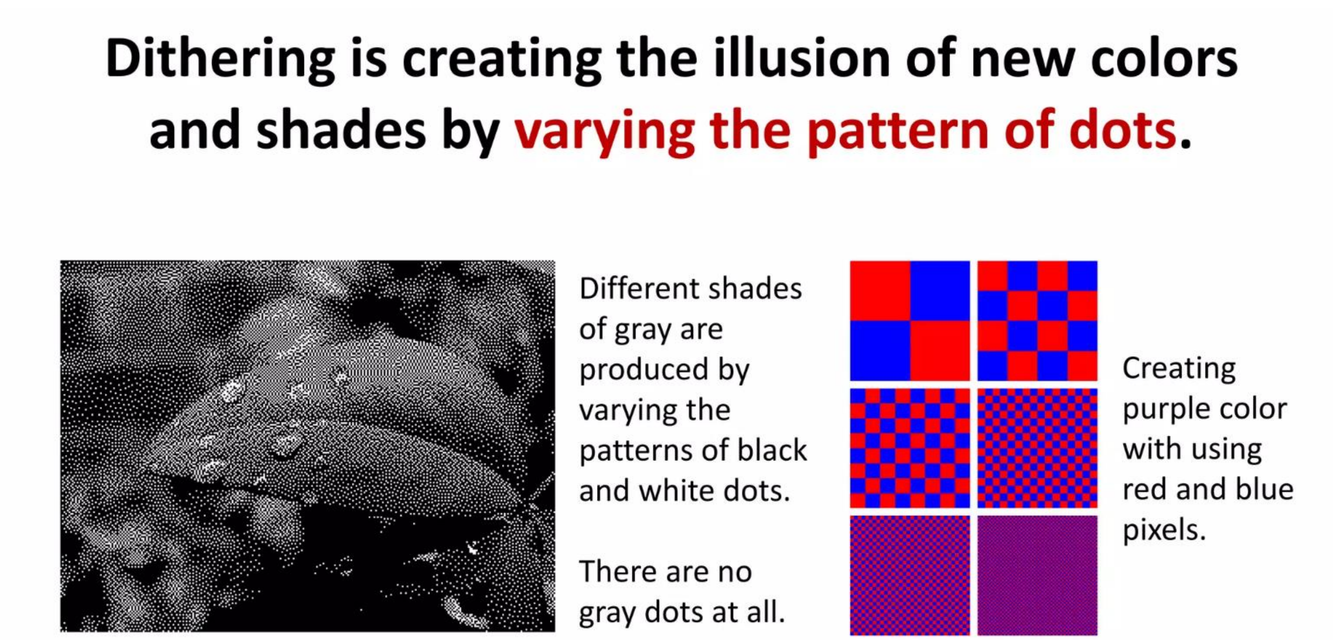
**Techniques Used:**

- **Procedural modeling** (rule-based image generation)
- **Rendering** (turning 3D models into 2D images)
- **Generative AI models** (e.g., GANs, diffusion models)
- **Ray tracing** (simulating light reflection to create realistic images)

**Dithering**

*Dithering* is a technique to increase the number of colours to be perceived in an image. It is based on human eye's capability for *spatial integration*, that is, if you look at a number of closely placed small objects from a distance, they will look like merged together.

Dithering technique groups a number of pixels together, say 4, to form a cluster. When viewed from sufficient distance, the individual pixel will not be distiguishable. The cluster will look like a single block of a colour different from the individual pixel.




**b. Image Analysis**

Image analysis refers to the extraction of meaningful information from digital images using digital image processing techniques. It involves tasks such as object recognition, image segmentation, motion detection, and medical scan analysis. Image analysis is an important field in computer science that allows computers to automatically study images and obtain useful information from them.

Image analysis includes image enhancement, pattern detection and recognition and scene analysis and computer vision.

- **Image enhancement** deals with improving image quality by eliminating noise (extraneous or missing pixels) or by enhancing contrast.
- **Pattern detection and recognition** deal with detecting and clarifying standard pattern and finding distortions from these patterns.

- **Scene analysis and computer vision** deal with recognizing and reconstructing 3D models of a scene from several 2D images.

There are so many different techniques used in automatically analyzing images. Each technique may be useful for a small range of tasks. Examples of image analysis techniques in different fields are –

1. **2D and 3D Object Recognition** – Identifies and classifies objects in 2D images or 3D scenes (e.g., face or car detection).
2. **Image Segmentation** – Divides an image into regions or objects for easier analysis (e.g., separating foreground and background).
3. **Motion Detection / Single Particle Tracking** – Detects and tracks movement of objects or particles across frames in a video.
4. **Video Tracking** – Continuously follows moving objects in video sequences (used in surveillance or sports analysis).
5. **Optical Flow** – Measures the motion of pixels between video frames to estimate movement direction and speed.
6. **Medical Scan Analysis** – Processes medical images (like MRI, CT) to detect diseases, tumors, or abnormalities.
7. **3D Pose Estimation** – Determines the 3D orientation and position of an object or person from 2D images or videos.

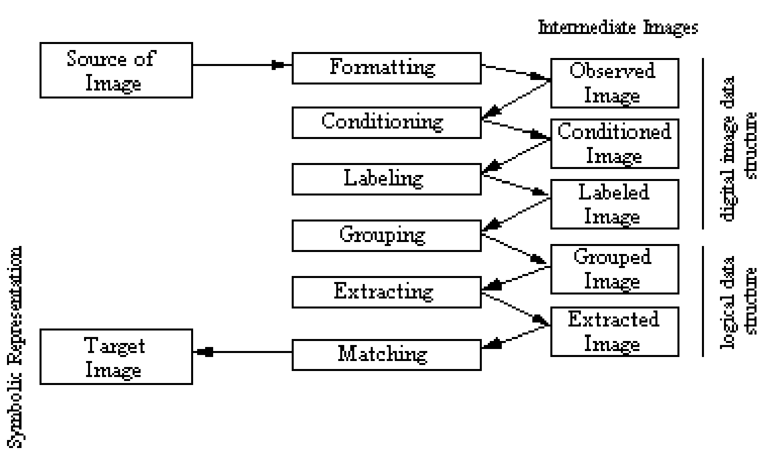
### Image Recognition

**Image Recognition** refers to identifying specific objects or patterns within an image by comparing the visual data to known patterns or models.

**To recognize an object, a system will:**

- Analyze pixel patterns (spatial arrangement).
- Infer position and orientation.
- Match the object with a known template or model.

### Steps in Image Recognition




### 1. Image Formatting

- Converts the captured image into **digital form** suitable for processing (digitization).

**2. Conditioning**

- Removes **noise** or **unwanted background features**.
- Enhances the **important or informative parts** of the image for clearer analysis.

**3. Labeling**

- Detects **edges** or regions with similar properties.
- Uses **edge detection** and **thresholding** to identify and label significant structures (e.g., object boundaries, corners, shapes).

**4. Grouping**

- Combines related labeled elements (like edges) into **larger structures** (like lines or regions).
- Switches from a **pixel-based** representation to a **logical data structure** that represents spatial relationships.

**5. Extracting (Feature Extraction)**

- Calculates **properties** of each group — such as area, centroid, shape, orientation, curvature, etc.
- Also records **spatial relationships** between objects (e.g., touching, overlapping, relative position).

**6. Matching**

- Compares extracted objects with **stored models or templates**.
- Identifies and classifies the objects by finding the **best match**.

### c. Image Transmission

Image transmission is the transmission of digital images through computer network. There are several requirements on the network when images are transmitted.

- The network must support bursty(large) data transport because image transmission is bursty.
- Image transmission requires reliable transport.
- Time dependence is not a necessary factor for the image transmission.

Image size depends on the image representation format for transmission. Several possibilities are:

1. **Raw image data transmission:** Image is generated through a video digitizer and transmitted in its digital format. The size can be measured as :

- Size = Spatial resolution × Pixel quantization

**E.g.** Transmission of an image with a resolution of 640×480 pixels and pixel quantization of 8 bit per pixel requires transmission of 307,200 bytes through the network.

**2. Compressed image data transmission:** In this case, the image is generated through a video digitizer and compressed before transmission. Several compression techniques such as JPEG or MPEG are used to down size the image.

**3. Symbolic image data transmission :** In this case, the image is represented through symbolic data representation as image primitives (e.g. 2D or 3D geometric representation), attributes and other control information. This image representation method is used in computer graphics. Image size is equal to the structure size, which carries the transmitted symbolic information of the image.

**Steps in Image Transmission:**

1. **Image Encoding:**
   - Convert the image into binary data for transmission.
   - Apply compression to reduce file size (e.g., JPEG, PNG).
2. **Transmission:**
   - Send the encoded data through a medium (Wi-Fi, fiber optics, etc.).
3. **Decoding at Receiver:**
   - Reconstruct the image from the received data.
4. **Error Detection & Correction:**
   - Ensure that transmission errors (due to noise/interference) are fixed.

**Example:** Sending a photo via WhatsApp or uploading an image on Instagram involves compression and transmission.

When you send a photo on WhatsApp:
1. It is **compressed** (image synthesis not involved).
2. **Transmitted** over the internet (image transmission).
3. The receiver's device **decodes and displays** it.

## Techniques Used:

- **Image compression:** JPEG, PNG, HEIF
- **Transmission protocols:** TCP/IP, HTTP, FTP
- **Error correction:** CRC, Hamming code
- **Encryption:** For secure image transfer