CHAPTER 3 : IMAGE AND GRAPHICS

Multimedia Systems

INTRODUCTION

- An image is a spatial representation of an object in 2D or 3D
- In Computer Vision, an image is a digital form of the actual image or picture.
- This is because they are represented by a matrix of numeric digits each represented by a quantized values.
- Digital imaging is the process of creating a digital image, with digital photographs being the most familiar example.
- Digital cameras use a sensor that absorbs light, turns it into digital information, and then allows a computer to recreate that information into an image
- The smallest element in a digital image is known as pixel- Picture Element.

BASIC CONCEPTS (1.DEPTH)

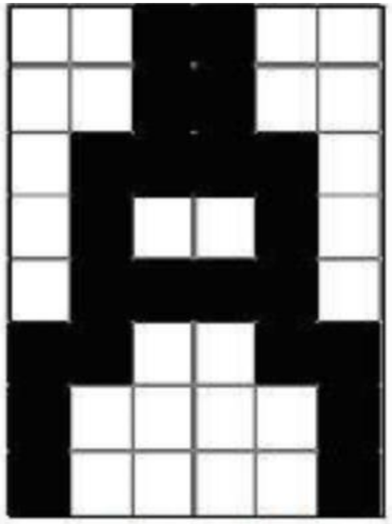
- The depth of an image is the number of bits used to represent each pixel
- If N=1 bit – then 2^N = 2 values : Black and White (Binary Image/ Bitmap Image
- 4 bit – can represent 16 colors, used in low resolution screens .e.g. VGA
- 8-bit grey– can represent 256 shades of grey color.
- 0(Pure black), 255(Pure white)
- 8-bit color (RGB) 256*256*256 = 16,777,216 colors
- 10-bit –RGB: 1024*1024*1024 = 1,073,741,824 colors

BASIC CONCEPTS (1.DEPTH)

- When you shoot in JPEG you automatically create an 8-bit file. A RAW image, on the other hand, creates a 12-bit or even a 14-bit file.
- RAW image : 14 bit
- Correcting minor flaws and enhancing even the smallest of details becomes possible while editing RAW files
- 24-bit True Color
- 32-bit : RGB + Alpha channels (Transparency & Opacity)

RAW VS JPEG

VARIATION OF BITS IN GREYSCALE IMAGE (BANDING EFFECT)



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0	1	0	0	1	0
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1	1	0	0	1	1
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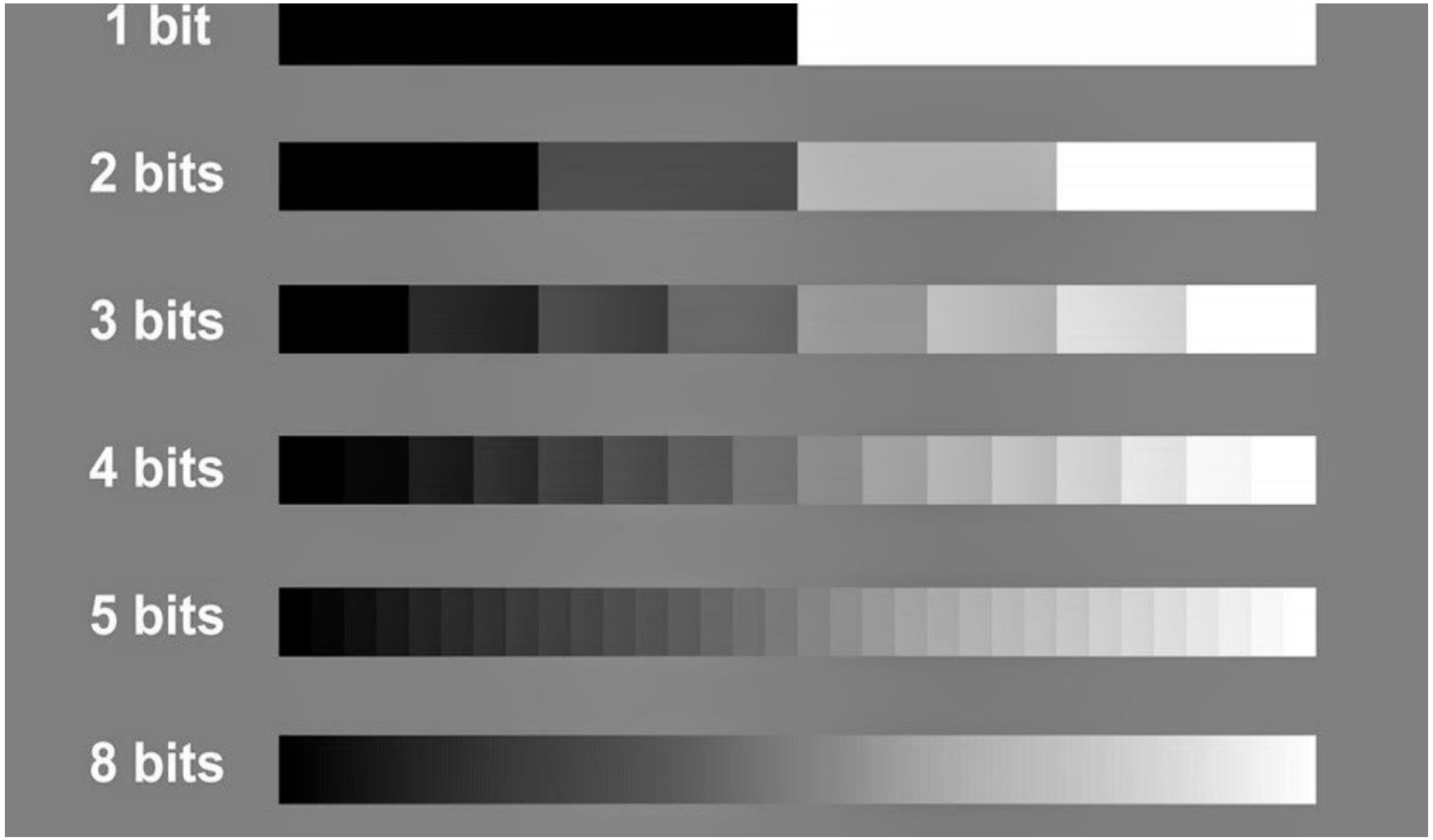
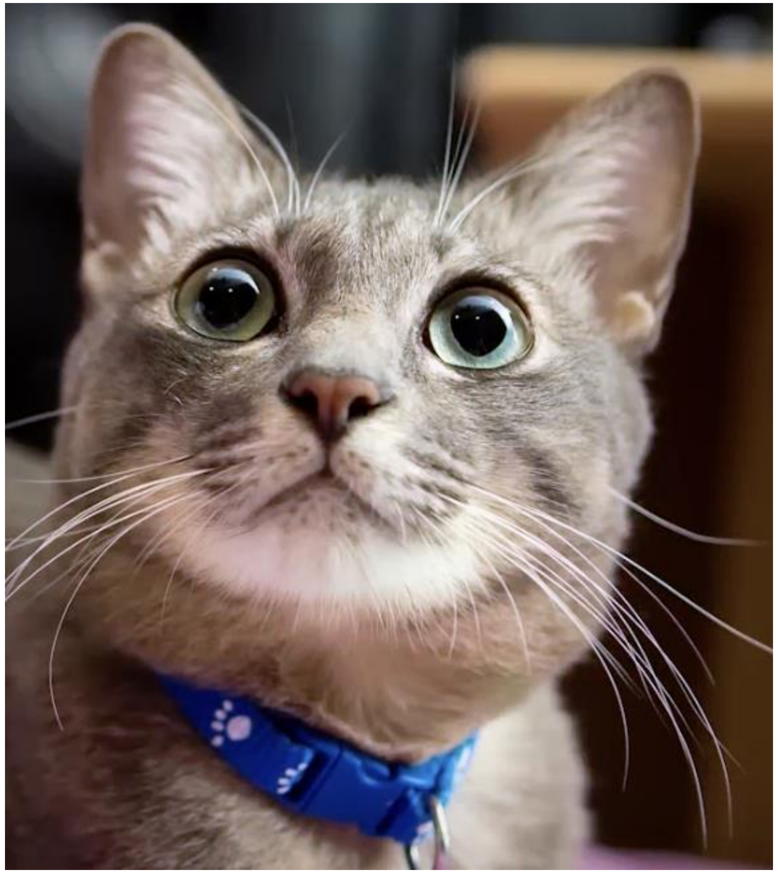
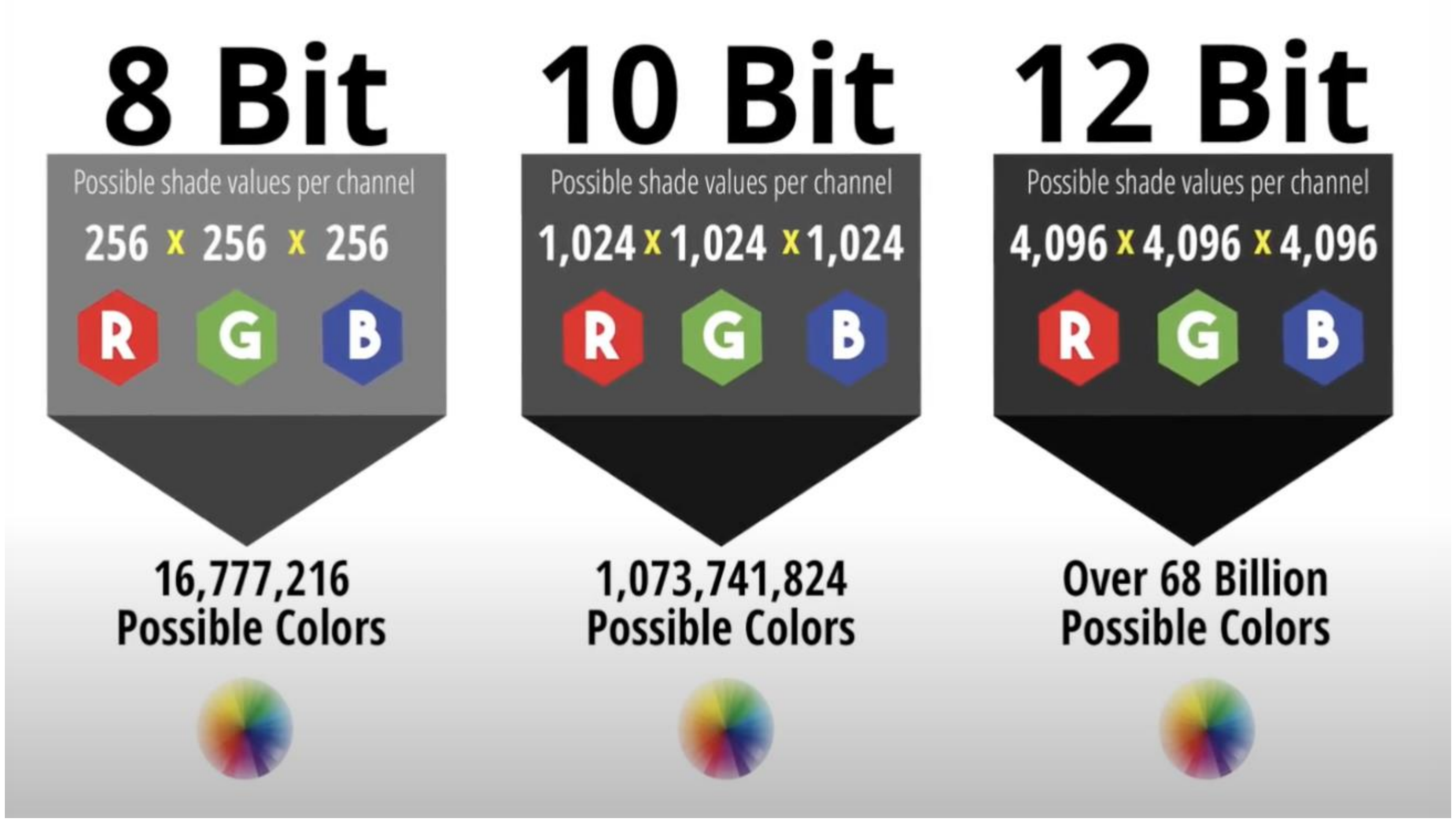
1	0	0	0	0	1



COLOR IMAGE (RGB)

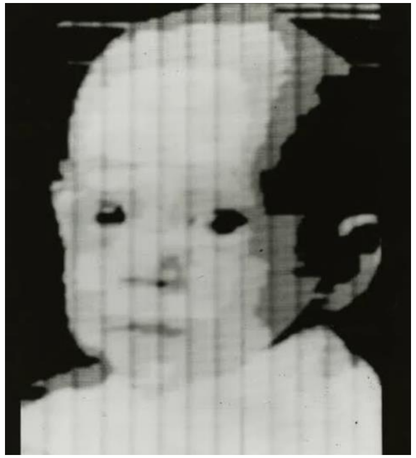


BITS AND POSSIBLE COLORS



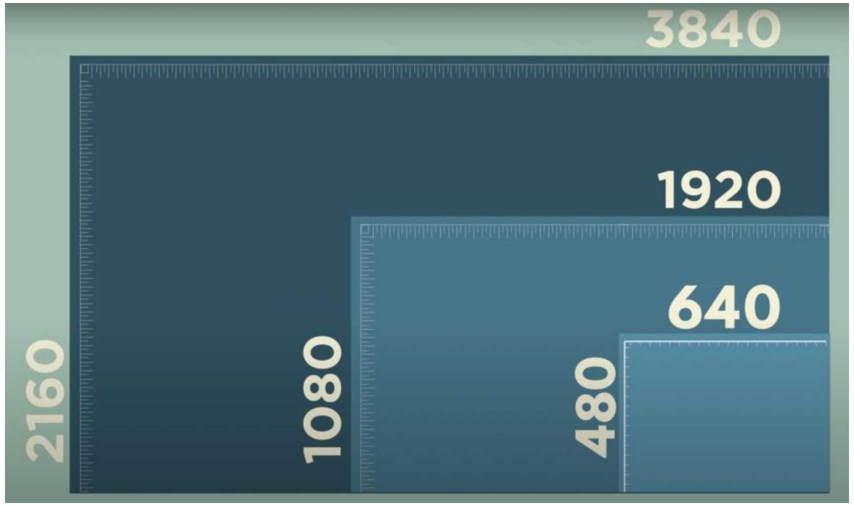
BITS AND POSSIBLE COLORS

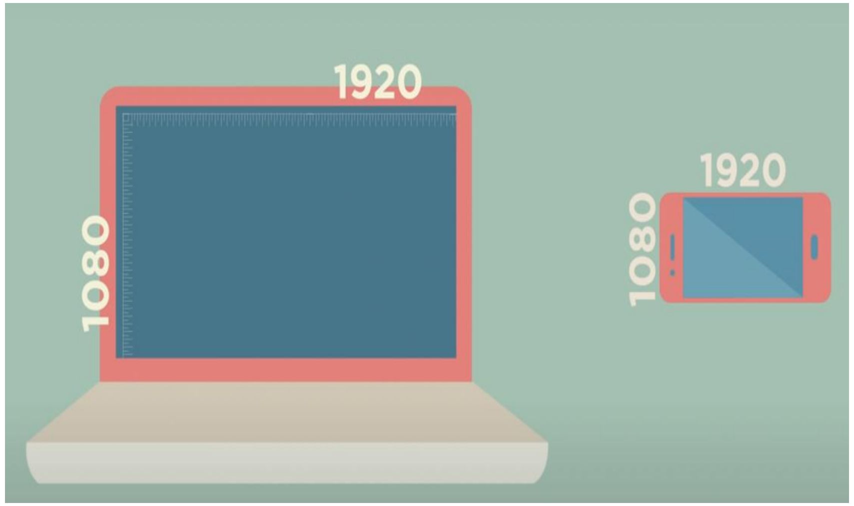
BASIC CONCEPTS (2. RESOLUTION)

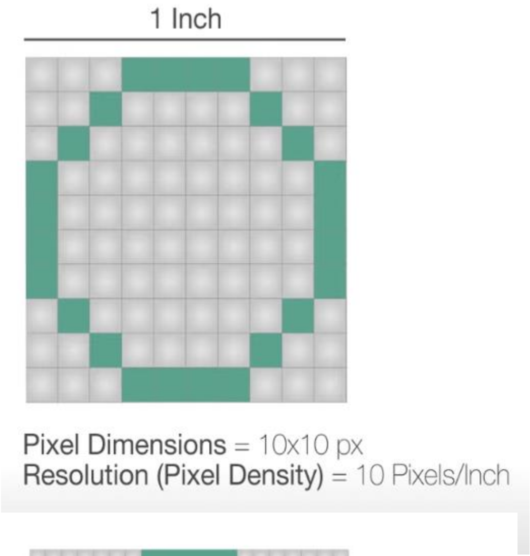


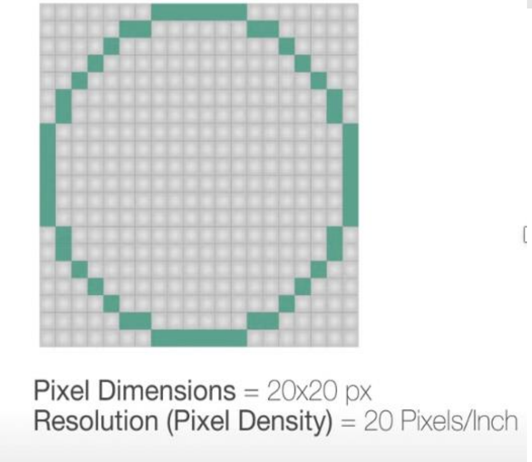
- We use pixels to measure the size of an image by length and height.
- The more pixels in an image, the higher its resolution, and typically the finer its level of detail.
- Black & white photo of baby appears in the first digital image made on a computer in 1957 showed researcher Russell Kirsch's baby. **176x176 pixels**
- Today's standard HD image would measure 1920x1080 pixels.
- In practice, that means you can zoom in more closely on a high-resolution image before details begin to blur and individual pixels become perceptible.
- Higher-resolution images have more pixels per inch, so they can be printed at larger sizes before they lose detail.

RESOLUTION AND DENSITY



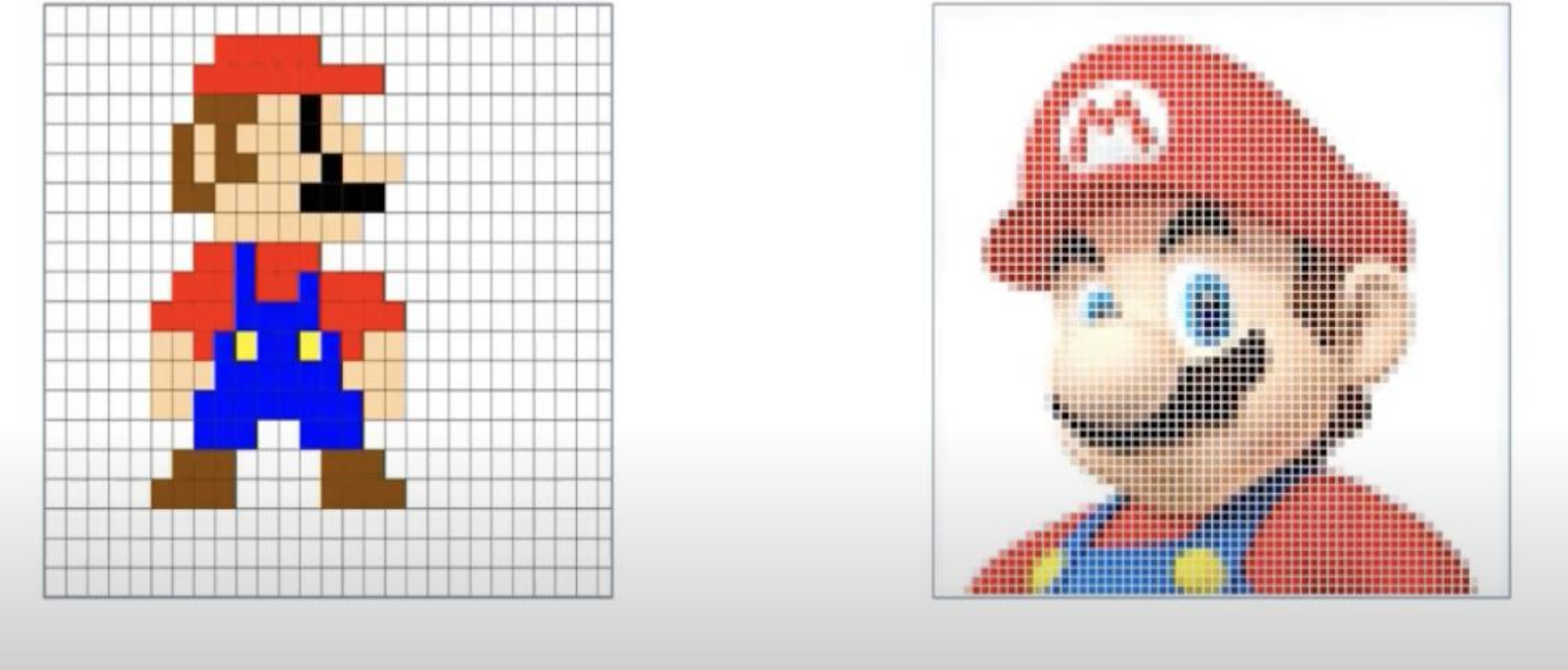




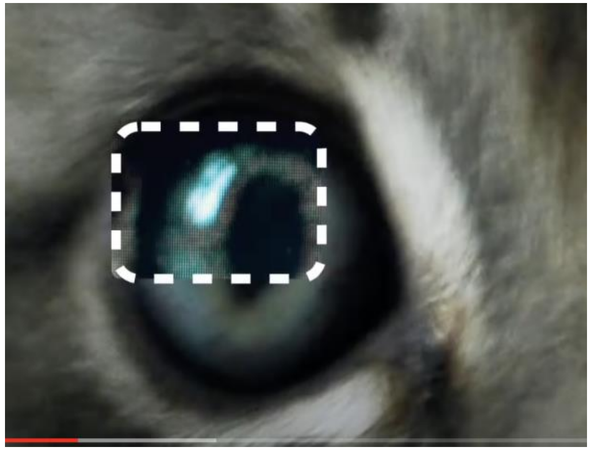


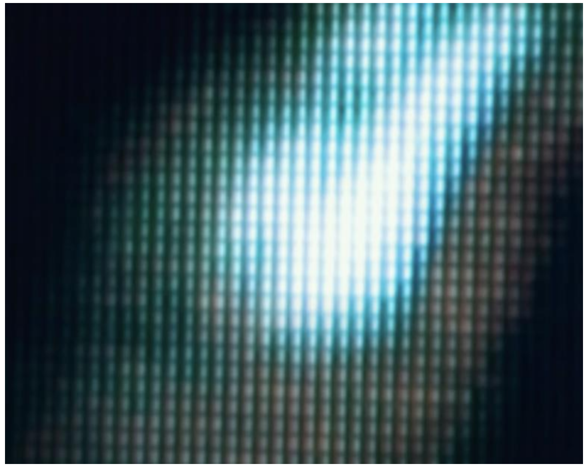
- A 1080p resolution on a **24-inch monitor** has lower PPI compared to the same resolution on a **13-inch laptop** because the pixels are spread over a larger area on the bigger screen.

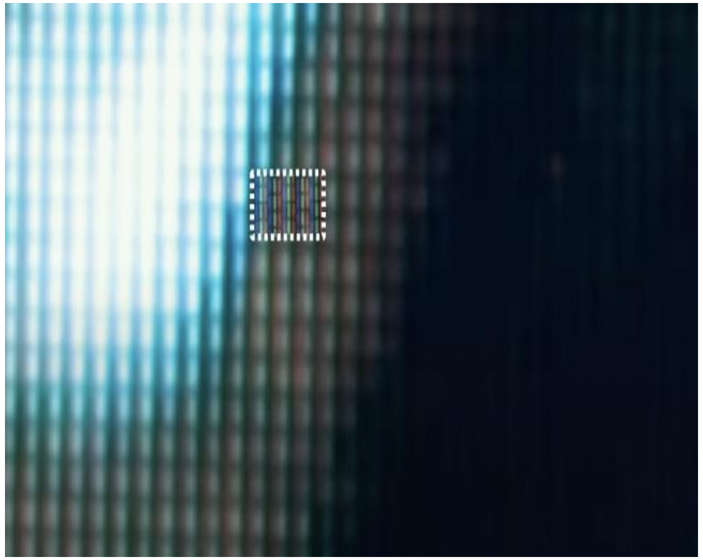
RESOLUTION



RGB EXAMPLE







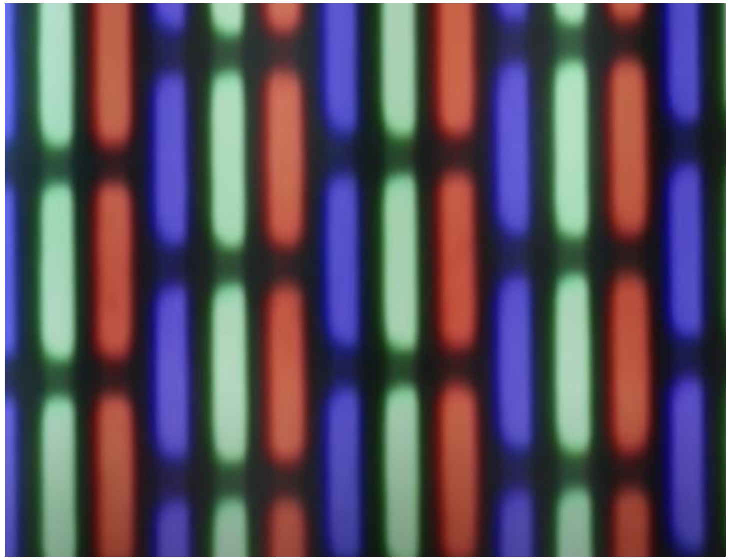


IMAGE SIZE

- Computer storage is less of a concern today, but image size still matters for such things as how many photos a camera can hold or how long it takes to send a picture to or from a mobile phone.
- Because a digital image is an array of pixels, three things determine its size:
  - The width of the image in pixels
  - The height of the image in pixels
  - The *pixel depth*, or number of bits used to represent one pixel.
- Total image size, in bits, is simply the product of these three quantities:
- $S = w \times h \times d$ where *S* is the image size in bits, *w* is its width in pixels, *h* is its height in pixels, and *d* is its depth in bits

EXAMPLE

- Consider a digital photograph that is 1748 pixels wide by 1240 pixels high and uses 8 bits for each of the red, green, and blue primary colors in each pixel.
- This photo’s pixel depth is the total number of bits in one pixel, or 8 + 8 + 8, i.e., 24.
- The total number of bits in the photo is then 1748 × 1240 × 24 = 52,020,480 bits.
- Since one byte is 8 bits, dividing by 8 gives the size in bytes, a more conventional unit of the size of digital documents: 52,020,480 ÷ 8 = 6,502,560, or about 6 megabytes.

IMAGE FORMATS

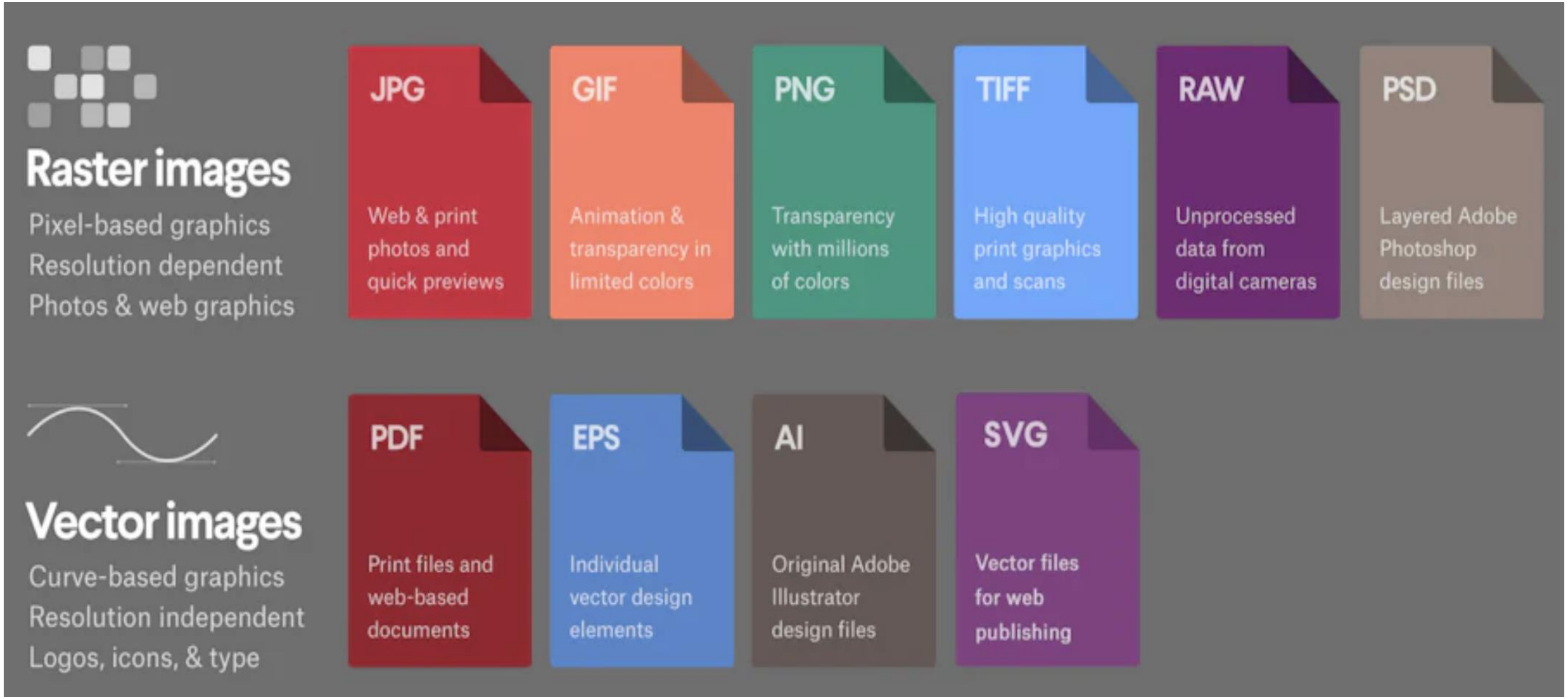


IMAGE FORMATS

- **TIFF (.tif, .tiff)**
- TIFF or Tagged Image File Format are lossless images files meaning that they will not lose any image quality or information (although there are options for compression), allowing for very high-quality images but also larger file sizes.
- Compression: Lossless - no compression. Very high-quality images.
  Best For: High quality prints, professional publications, archival copies
  Special Attributes: Can save transparencies
- **Bitmap (.bmp)**
- BMP or Bitmap Image File is a format developed by Microsoft for Windows. There is no compression or information loss with BMP files which allow images to have very high quality, but also very large file sizes. Due to BMP being a proprietary format, it is generally deprecated in favor of TIFF files.
- Compression: None
  Best For: High quality scans, archival copies

IMAGE FORMATS

- <u>**JPEG (.jpg, .jpeg)**</u>
- JPEG, which stands for Joint Photographic Experts Groups is a “lossy” format, meaning that the image is compressed to make a smaller file. The compression does create a loss in quality but this loss is generally not noticeable. JPEG files are very common on the Internet and JPEG is a popular format for digital cameras - making it ideal for web use and non-professional prints.

  Compression: Lossy - some file information is compressed or lost
  Best For: Web Images, Non-Professional Printing, E-Mail, Powerpoint
  Special Attributes: Can choose amount of compression when saving in image editing programs like Adobe Photoshop

IMAGE FORMATS

- **GIF (.gif)**
- GIF or Graphics Interchange Format files are widely used for web graphics, because they are limited to only 256 colors, can allow for transparency, and can be animated. GIF files are typically small in size and are very portable.
- **Compression:** Lossless - compression without loss of quality
  Best For: Web Images
  Special Attributes: Can be Animated, Can Save Transparency
- **PNG (.png)**
- PNG or Portable Network Graphics files are a lossless image format originally designed to improve upon and replace the gif format. PNG files are able to handle up to 16 million colors, unlike the 256 colors supported by GIF.
- **Compression:** Lossless - compression without loss of quality
  Best For: Web Images
  Special Attributes: Save Transparency

IMAGE FORMATS

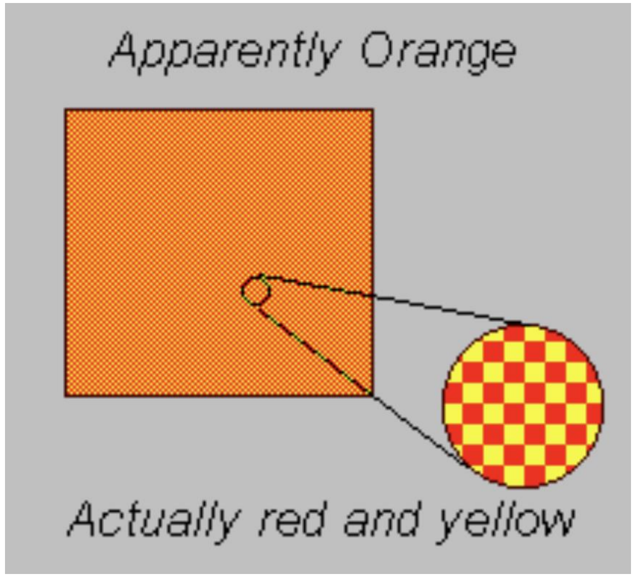
- **RAW Image Files (.raw, .cr2, .nef, .orf, .sr2, and more)**
- RAW images are images that are unprocessed that have been created by a camera or scanner. Many digital SLR cameras can shoot in RAW, whether it be a .raw, .cr2, or .nef. These RAW images are the equivalent of a digital negative, meaning that they hold a lot of image information, but still need to be processed in an editor such as Adobe Photoshop or Lightroom.
- **Compression:** None
  Best For: Photography
  Special Attributes: Saves metadata, unprocessed, lots of information

DITHERING

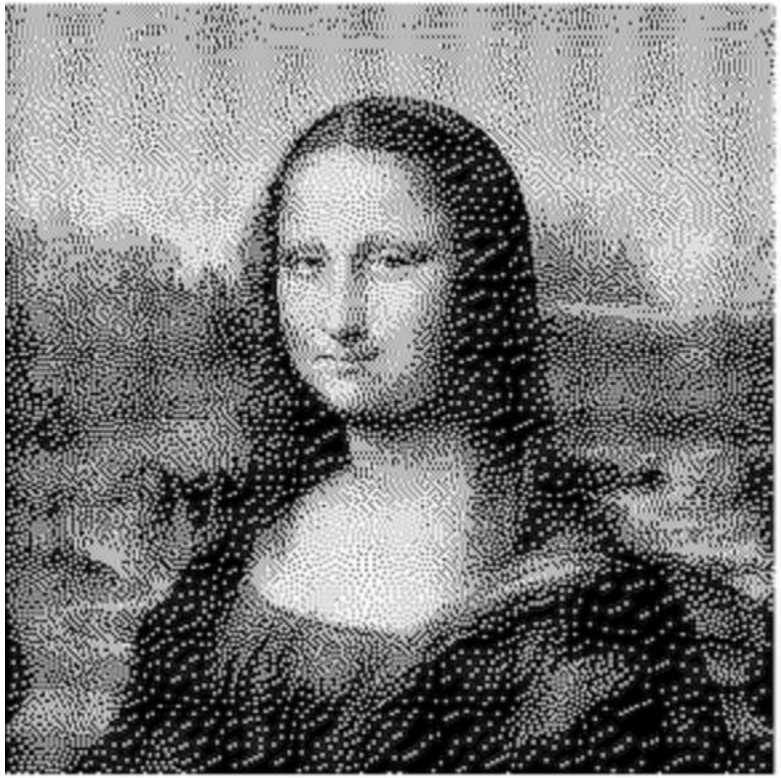
- Dithering in image processing is a technique used to simulate colors or shading.
- The basic concept behind dithering is adding noise, or additional pixels, to a digital file
- In graphics, dithering adds random patterns of pixels to improve the image quality while avoiding banding.
- In its earlier uses in newspapers, comic books, and other printed media, dithering would be applied to images to create levels of simulated grayscale by strategic placement of black dots. Using the dithering process would give a smooth image with gray shades even though printing presses only supported black ink.
- Comic books and other color printing worked similarly, but to simulate more shades of color than the limited palette printing presses had.

DITHERING..CONTD

- Using dithering in image processing not only reduces banding of colors and shading, which creates a smoother finished image, but it also reduces the file size.
- If we view a very small area from a sufficiently large viewing distance, our eyes will average the overall detail and record only the overall intensity of that area.
- This phenomenon is also called Halftoning.



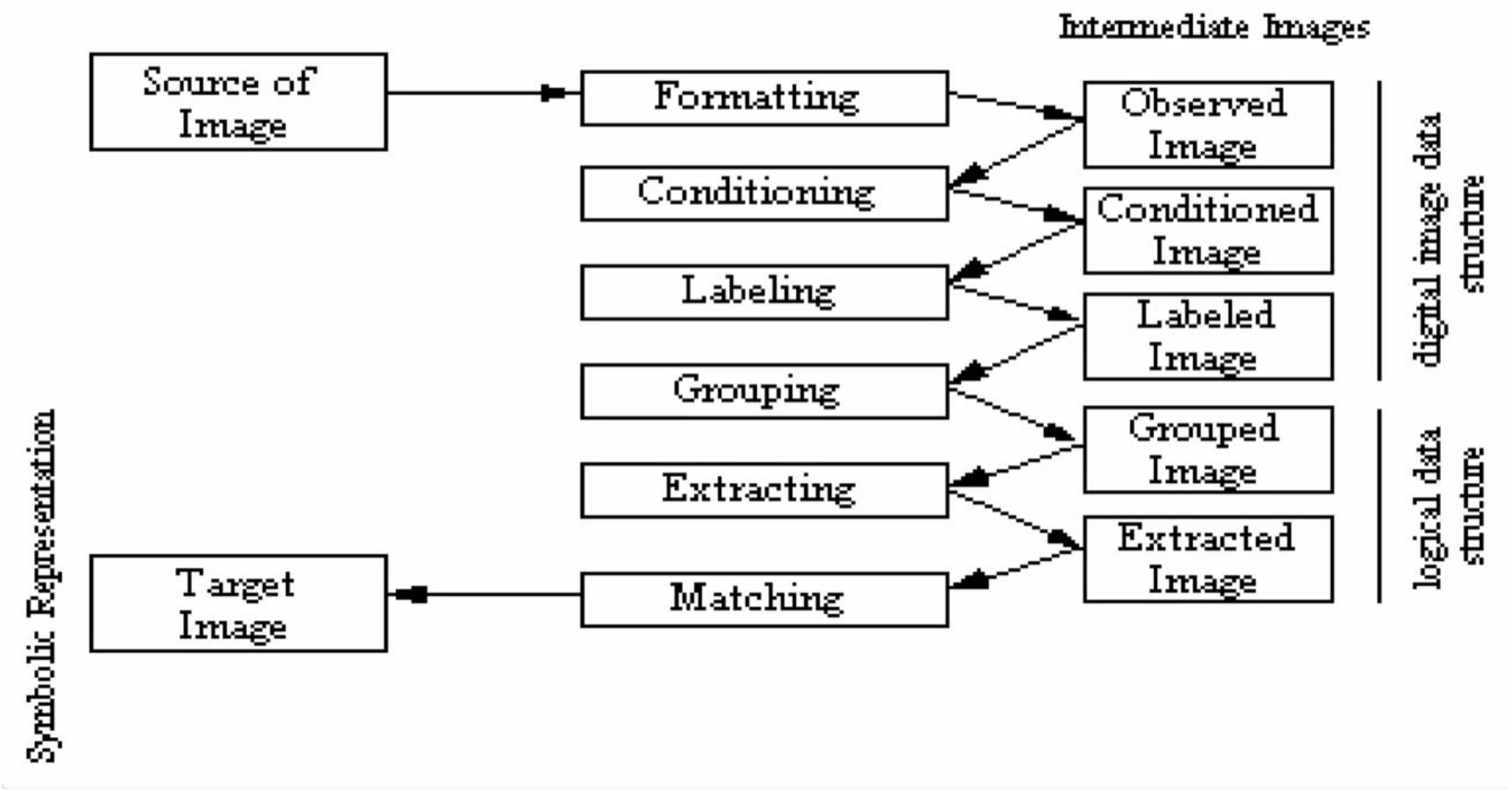
DITHERING_EXAMPLE



: 16-COLOR TO 5 COLOR

DITHERING RESULT OF 5 COLOR

IMAGE RECOGNITION STEPS



1. FORMATTING

- The **Formatting** step in the image recognition process is a crucial preprocessing stage where the raw input image is prepared for further analysis. It ensures that the image is in a standardized and usable format for the subsequent processing steps.
- **Objective**: Standardize the image for subsequent processing.
- **Output**: The *Observed Image*.
- This step involves preprocessing tasks such as:
  - Resizing the image to fit the expected input dimensions.
  - Converting color formats (e.g., RGB to grayscale).
  - Handling compression artifacts or noise.

KEY TASKS IN THE FORMATTING

- **1. Image Resizing**
- Ensures the image matches the required dimensions of the system.
- Example: If a neural network requires input images of size 224×224, all images must be resized accordingly.
- **2. Color Space Conversion**
- Converts the image to a specific color space, depending on the application.
- Common transformations:
  - **Grayscale conversion**: Reduces color complexity by converting a 3-channel RGB image to a single channel.
  - **Binary conversion**: Converts to black-and-white using thresholding for simple applications like OCR.

KEY TASKS IN THE FORMATTING

3. Cropping or Padding

- Cropping:
  - Removes unwanted areas from the image, focusing on the region of interest (ROI).

- **4. File Format Conversion**

- Converts the image into a compatible file format (e.g., from BMP or TIFF to PNG or JPEG).
- Reduces file size if necessary without losing critical information.

- **5. Resolution Adjustment**

- Adjusts the resolution of the image to balance between processing speed and quality.
- Low-resolution images are faster to process but may lose details critical for tasks like object recognition.

KEY TASKS IN THE FORMATTING

- **6. Noise Removal**
- Preliminary noise filtering may occur to remove pixel artifacts caused by compression or environmental factors.
- Techniques:
  - Median filtering (to handle salt-and-pepper noise).
  - Smoothing filters (e.g., Gaussian blur).

BENEFITS OF THE FORMATTING STEP

- Reduces computational overhead by standardizing inputs.
- Improves processing accuracy by eliminating irrelevant information (e.g., unnecessary borders, noise).
- Ensures compatibility with image recognition algorithms and models.

2. CONDITIONING

- The **Conditioning** step is a critical stage in the image recognition process, where the formatted image is enhanced to improve the quality and extractability of its features. This step optimizes the image to make it more suitable for feature extraction and subsequent analysis.
- **Objective**: Enhance image quality and optimize it for feature extraction.
- **Output**: The *Conditioned Image*.
- Common techniques:
    - Noise reduction (e.g., Gaussian smoothing).
    - Contrast adjustment or histogram equalization.
    - Edge enhancement for better feature visibility.

KEY TASKS IN THE CONDITIONING

- 1. **Noise Reduction: Using Filters**
- 2. **Contrast Enhancement e.g.** Histogram Equalization
- 3. **Edge Enhancement**
- 4. **Illumination Correction e.g.** Correcting shadows in a photograph to reveal obscured details.
- 5. **Geometric Transformations:** Scaling, Rotation
- 6. **Thresholding**
- 7. **Normalization e.g.** Standardizes pixel intensity values across the image to maintain consistency.

BENEFITS OF CONDITIONING

- **Enhanced Features**: Makes key image components more prominent.
- **Improved Accuracy**: Reduces errors in feature extraction and recognition.
- **Robustness**: Compensates for variations in image quality or acquisition conditions.
- **Consistency**: Ensures uniform processing across diverse image datasets.

3. LABELING

- It is a crucial stage where the processed image is segmented into meaningful regions or components, each of which is labeled for further analysis. This step often bridges the gap between raw image data and symbolic representations, making it fundamental for understanding and interpreting the image content.
- **Objective**: Assign identifiers or labels to distinguish different regions or objects in the image.
- **Output**: The *Labeled Image. Processes* involved: Segmentation: Dividing the image into meaningful regions (e.g., foreground and background).
- Labeling objects within these regions for further analysis.

APPLICATIONS OF LABELING

- 1: **Medical Imaging**: Identify and label different tissues or abnormalities.
- 2: **Autonomous Driving**: Detect and label objects in a road scene.
- 3. **Satellite Imaging**: Identify and label regions of interest (e.g., buildings, forests, water bodies).

BENEFITS OF LABELING

- **Facilitates Object Recognition**: Clearly distinguishes different objects or regions in the image.

- **Supports Feature Extraction**: Labeled data can guide subsequent steps like grouping and matching.

- **Improves Model Training**: Labeled datasets are essential for training supervised learning models.

4. GROUPING

- This step bridges the gap between low-level features (e.g., individual pixels or labeled regions) and high-level understanding (e.g., objects, patterns, or scenes).
- **Objective**: Cluster similar components or regions of the labeled image.
- **Output**: The *Grouped Image*.
- Steps:
  - Combine related pixels or regions based on features like color, texture, or shape.
  - Group objects that are part of the same entity (e.g., merging parts of a car into a single object).

KEY TASKS IN THE GROUPING

- **1. Proximity-Based Grouping**
- Groups regions or objects based on their spatial closeness.
- **Techniques**:
  - **Clustering**:
    - Uses algorithms like K-means or DBSCAN to group nearby regions.
  - **Nearest Neighbor**:
    - Links components based on the shortest distance between them.
- **Example**: Grouping dots in a scatter plot into clusters to form a recognizable shape.

5. EXTRACTING

- The **Extracting** step in the image recognition process is focused on isolating and obtaining meaningful information or features from the grouped or labeled image data.
- **Objective**: Isolate critical features or objects of interest.
- **Output**: The *Extracted Image*.
- Methods: Feature extraction: Identifying and preserving key attributes (e.g., edges, corners, blobs).
- ROI (Region of Interest) extraction: Focus on specific areas in the image containing valuable information.

STEPS OF THE EXTRACTING

1. **Feature Derivation**:
   Extracts meaningful features (e.g., shapes, textures, edges) that represent objects in the image.
2. **Region Extraction**:
   Isolates specific areas or objects from the image based on prior grouping or segmentation.
3. **Dimensionality Reduction**:
   Reduces the complexity of the image data while retaining important information.
4. **Preparation for Matching or Classification**:
   Prepares the extracted data for use in decision-making or pattern recognition tasks.

6. MATCHING

- The **Matching** step in the image recognition process is the final phase, where the features or objects extracted from the image are compared against a reference dataset, symbolic representation, or predefined template to identify or classify the image.
- **Objective**: Compare the extracted features or objects with a known reference or *Target Image*.
- **Output**: Symbolic Representation. This step involves : Template matching: Comparing with predefined patterns.
- Using symbolic data (logical representations) to recognize or classify objects.
- Matching could also rely on algorithms like neural networks or statistical methods for higher accuracy.

BENEFITS OF THE MATCHING

- **Accurate Identification**: Matches extracted features to specific patterns or objects with high precision.

- **Enables Decision-Making**: Provides conclusive results for tasks like object recognition or classification.

- **Supports Automation**: Facilitates automated systems by matching features without human intervention.

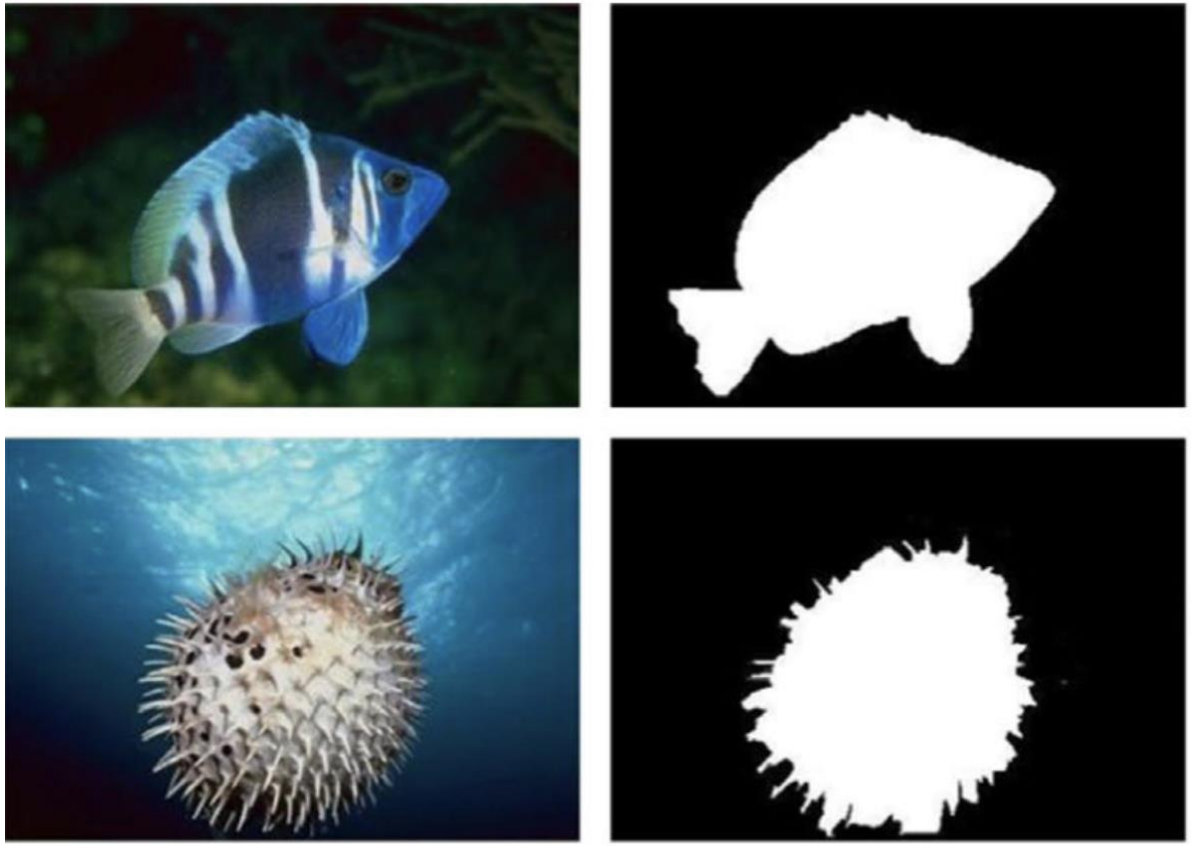
SEGMENTATION

EDGE DETECTION

In **edge-based segmentation,**

- an **edge** filter is applied to the **image**,
- pixels are classified as **edge** or non-**edge** depending on the filter output, and
- pixels which are not separated by an **edge** are allocated to the same category.

BINARY THRESHOLDING



EDGE DETECTION

Edge Detection

Basic Idea:

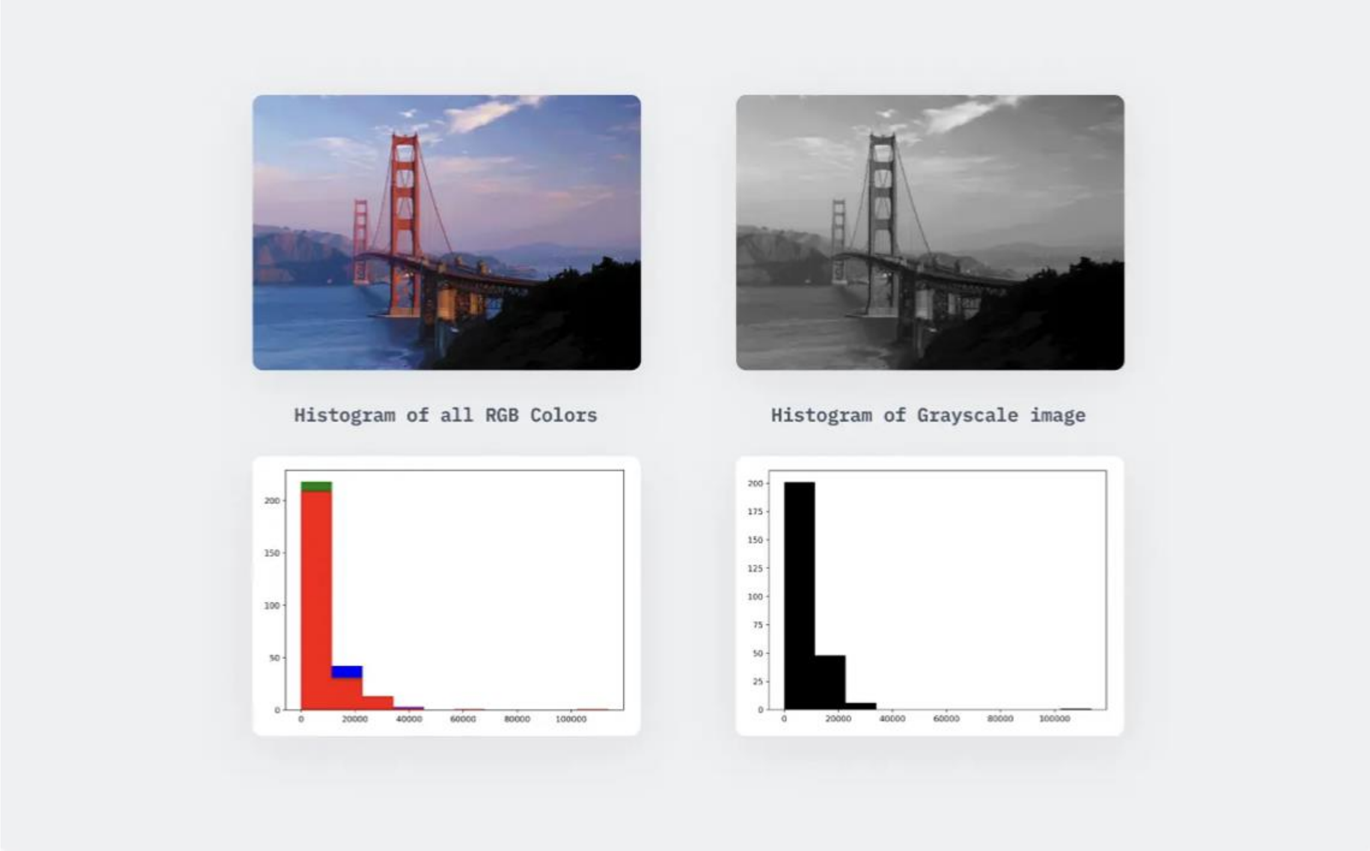
* Look for a neighborhood with strong signs of change

Issues to consider:

* Size of the neighborhood?
* What metrics represent a "change"?

12	90	89	86	87	82
10	12	88	85	83	84
9	15	12	84	84	88
12	14	10	82	88	89
11	17	16	12	88	90
10	16	15	17	89	88

HISTOGRAM



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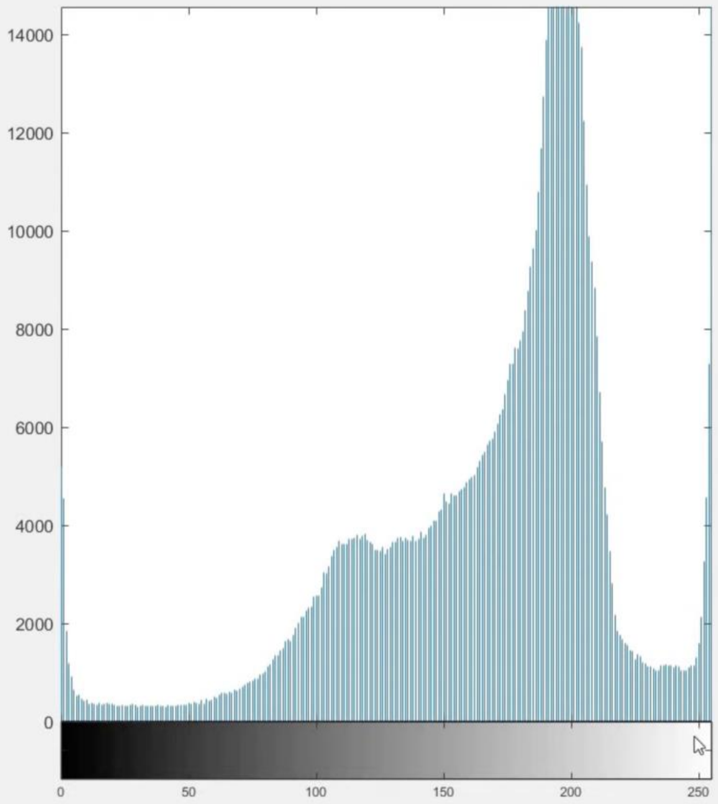
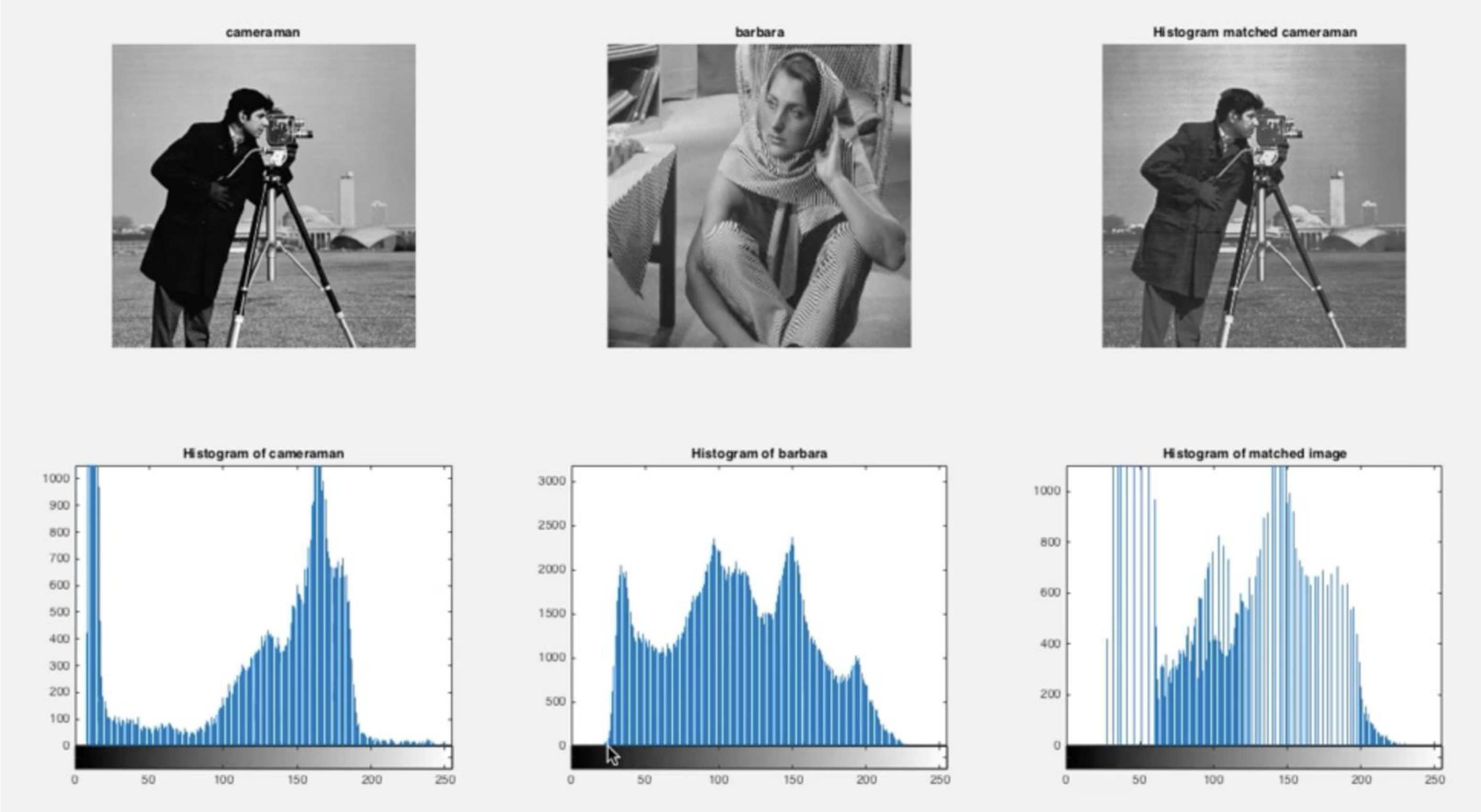


HISTOGRAM


cameraman
barbara
Histogram matched cameraman
Histogram of cameraman
Histogram of barbara
Histogram of matched image

END OF CHAPTER 3