Digital Image Processing

Color Image Processing

Dr. Muhammad Sajjad

R.A: M. Abbas

Overview

- **Introduction to Color Image Processing**
- **Color Fundamentals**
- **Color Models**
- **RGB Color Model**
- **CMY and CMYK Color Model**
- **HSI Color Model**
- **Pseudocolor Image Processing**
- **Basics of Full-Color Image Processing**

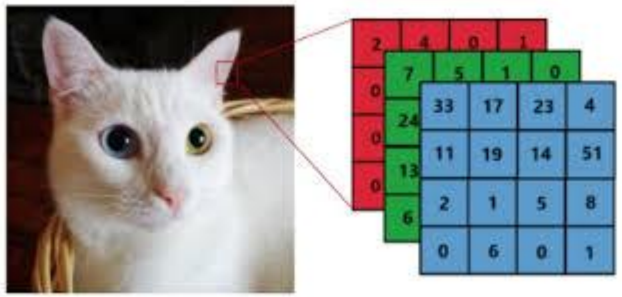
Introduction to Color Image Processing

The process of analyzing and modifying color information in digital images.

Motivation for Color Image Processing

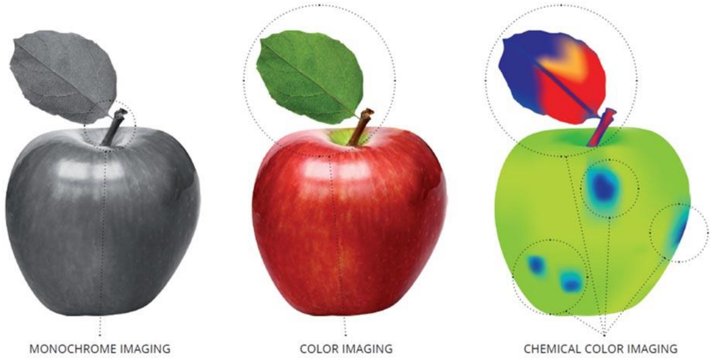
- Color is a powerful descriptor that simplifies object identification and extraction.
- Humans can distinguish thousands of color, but only about two dozen shades of gray.

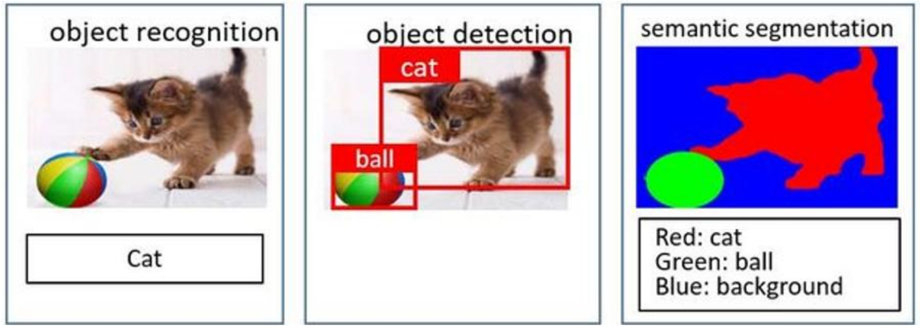
Medical Image Colorization



Two Areas of Color Image Processing

1. **Full-Color Processing:**
   - Uses images captured by full-color devices (e.g., cameras, scanners).
   - Operates on all color components like RGB.
2. **Pseudo color Processing:**
   - Assigns colors to grayscale images for better visualization.
   - Common in medical imaging and satellite imagery.





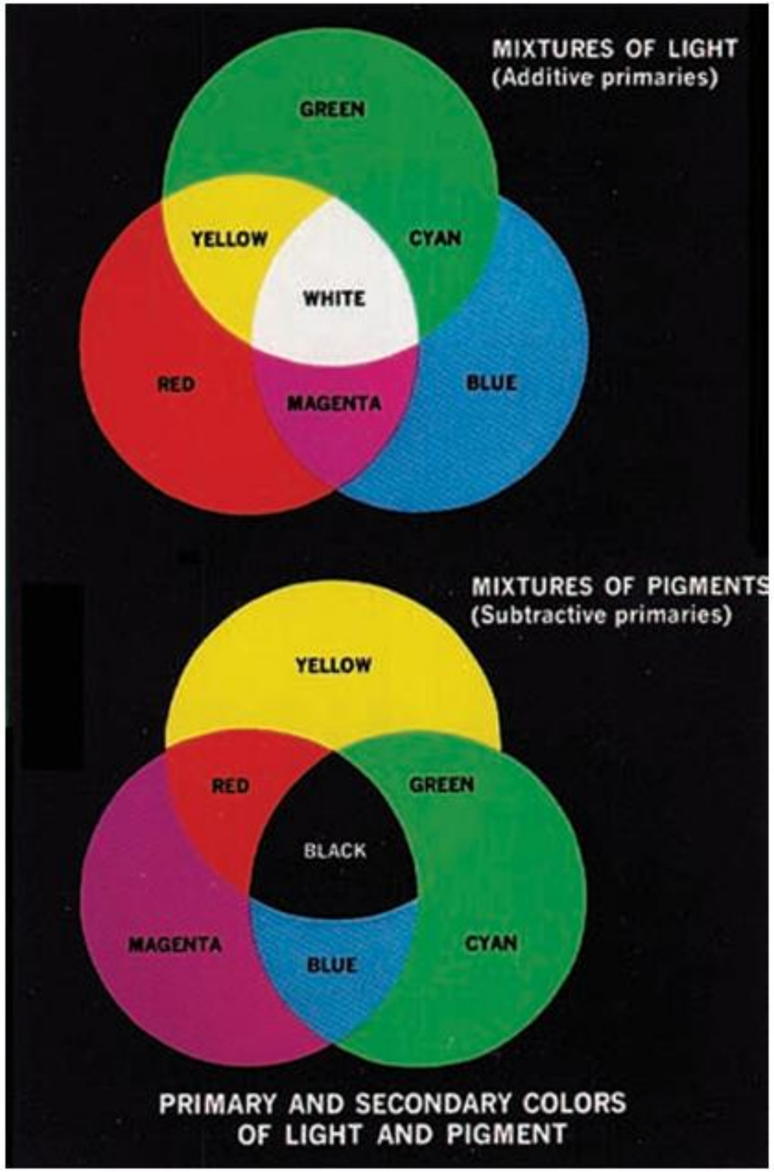
Color Fundamentals

Primary Colors of Light (RGB):

- **Red (R), Green (G), and Blue (B)**
- Mixing RGB produces **secondary colors**:
  - **Magenta** (Red + Blue)
  - **Cyan** (Green + Blue)
  - **Yellow** (Red + Green)
- Combining all three primaries or a secondary with its opposite primary creates white light.

Primary Colors of Pigments (CMY):

- **Cyan (C), Magenta (M), and Yellow (Y)**
- Mixing CMY produces **secondary colors**:
  - **Red** (Magenta + Yellow)
  - **Green** (Cyan + Yellow)
  - **Blue** (Cyan + Magenta)
- Combining all three pigment primaries or a secondary with its opposite primary produces black.



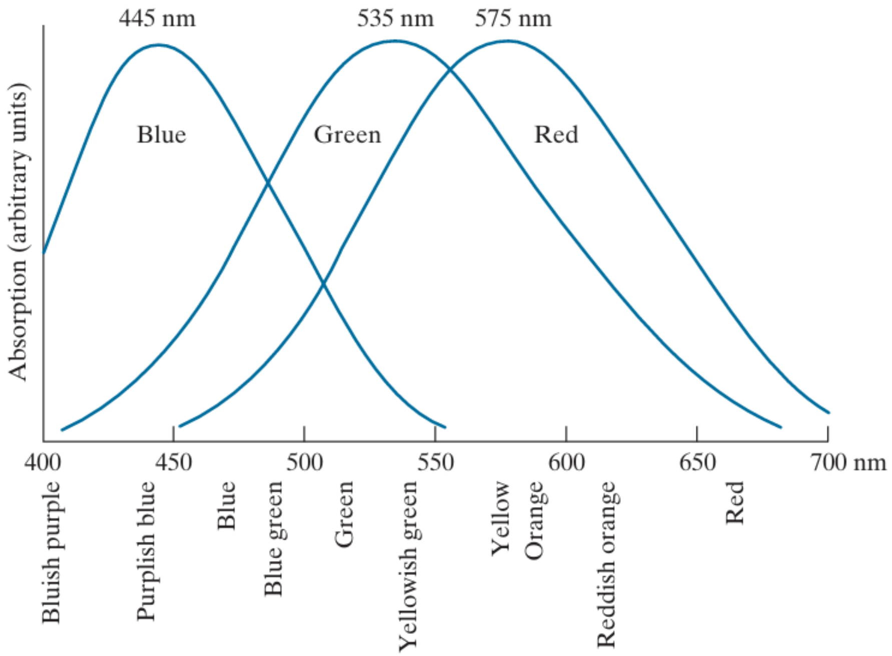
Color Fundamentals

Additive Color Model: Used in displays, combines light (e.g., RGB in screens).

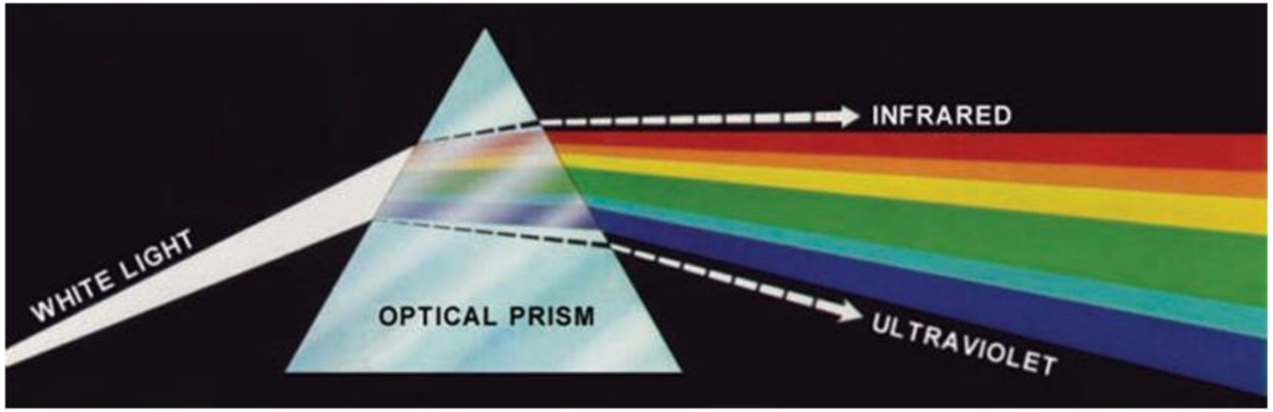
Subtractive Color Model: Used in printing, combines pigments (e.g., CMY in printers).

Human vision is trichromatic, perceiving colors through **cone cells** sensitive to red, green, and blue wavelengths.

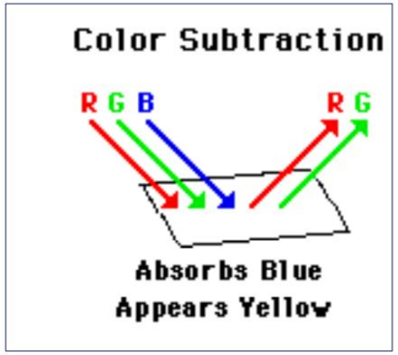
White light splits into colors through a prism, showcasing the visible spectrum.

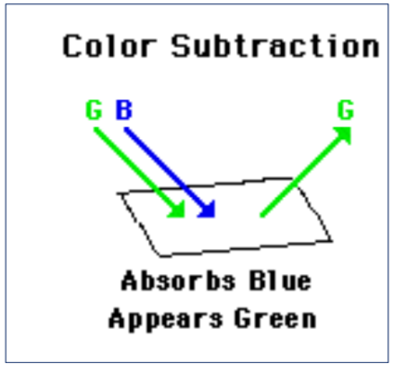


Absorption of light by the red, green, and blue cones in the human eye as a function of wavelength.



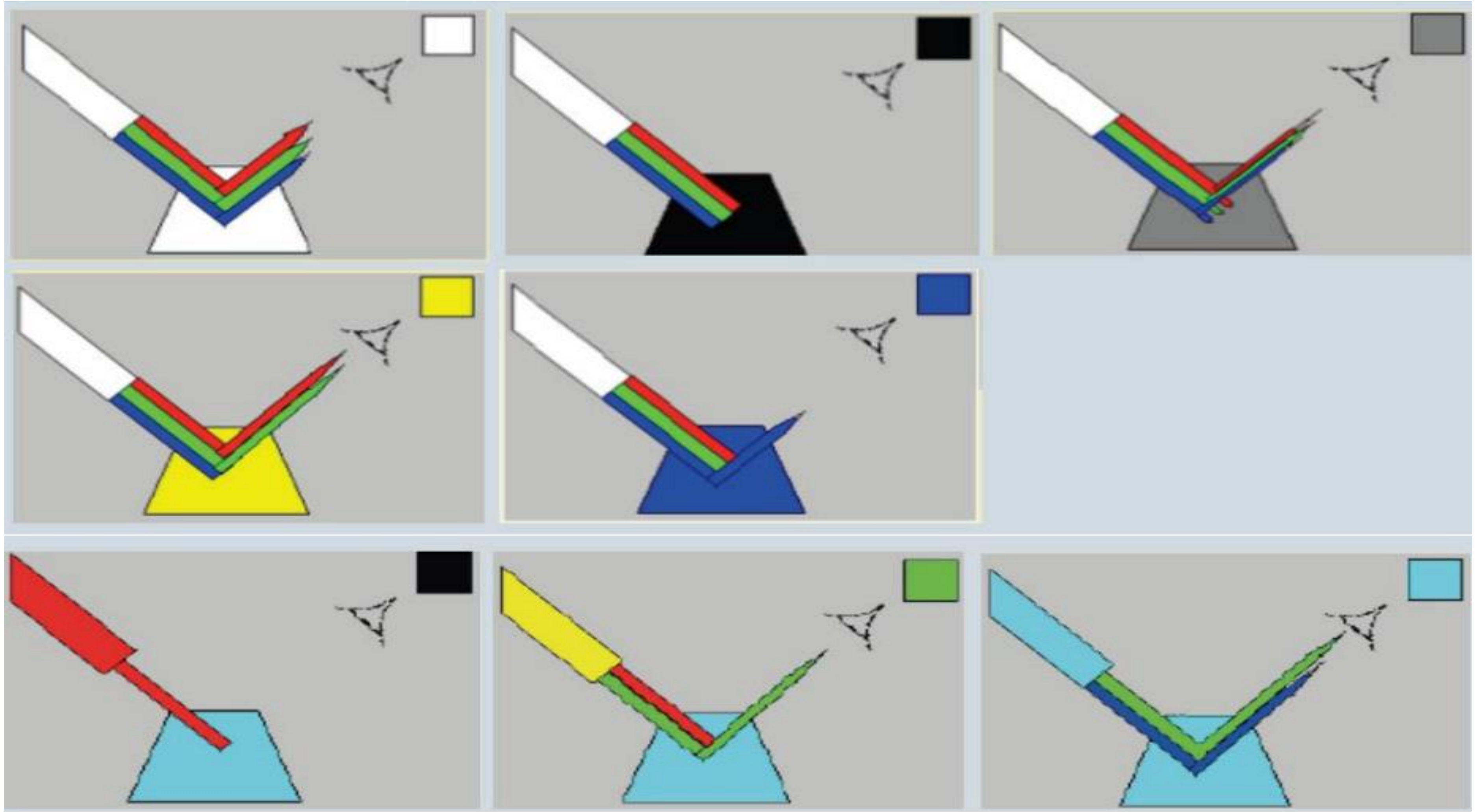
Color spectrum seen by passing white light through a prism.





Color Fundamentals

Light Reflection and Dispersion Across Colored Surfaces



Color Models

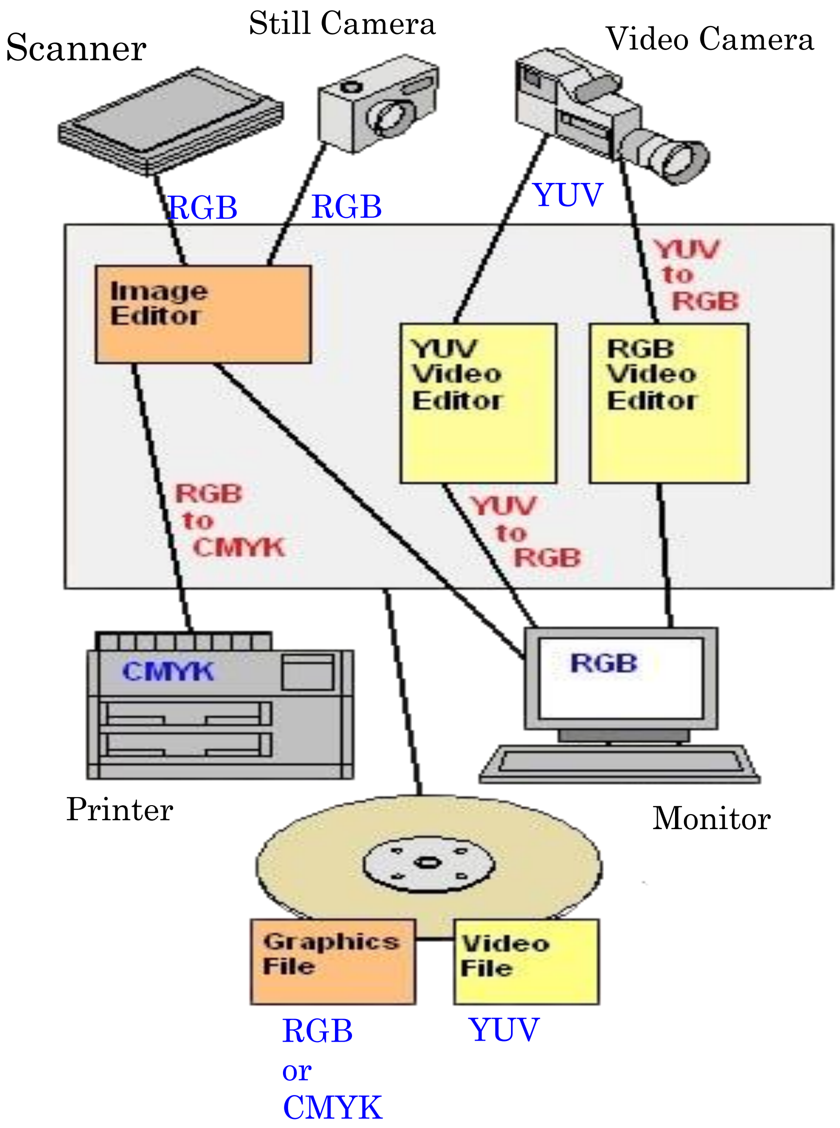
Purpose of Color Models:

- A color model (or color space/system) standardizes the specification of color.
- It defines:
  1. A coordinates system.
  2. A subspace where each color corresponds to a unique point.

Types of Color Models:

1. **Hardware-Oriented Models:**
   - RGB: Used in color monitors and Video Cameras.
   - CMY/CMYK: Used in color printing.
2. **Application Oriented Models**
   - HIS: Matches human perception of color.

Color Space Conversion



Color Models

RGB Color Model

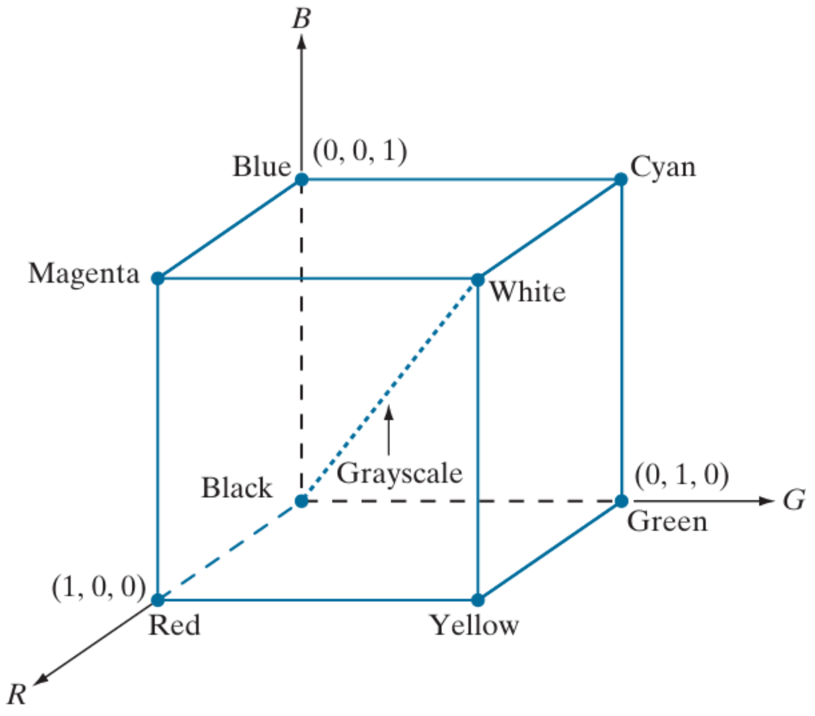
- Represents color as a combination of three primary colors: Red (R), Green (G), and Blue (B).
- Based on a Cartesian coordinates system with a cube representing the color space.

Primary Colors: Red, Green, and Blue at three corners of the cube.

Secondary Colors: Cyan, Magenta, and Yellow at three other corners.

Pixels Depth:

- Each pixel is represented by three 8-bit values (R, G, B).
- Pixel Depth: 24 bits (8bits x 3 channels).
- Total Colors: $2^{24} = 16{,}777{,}216$

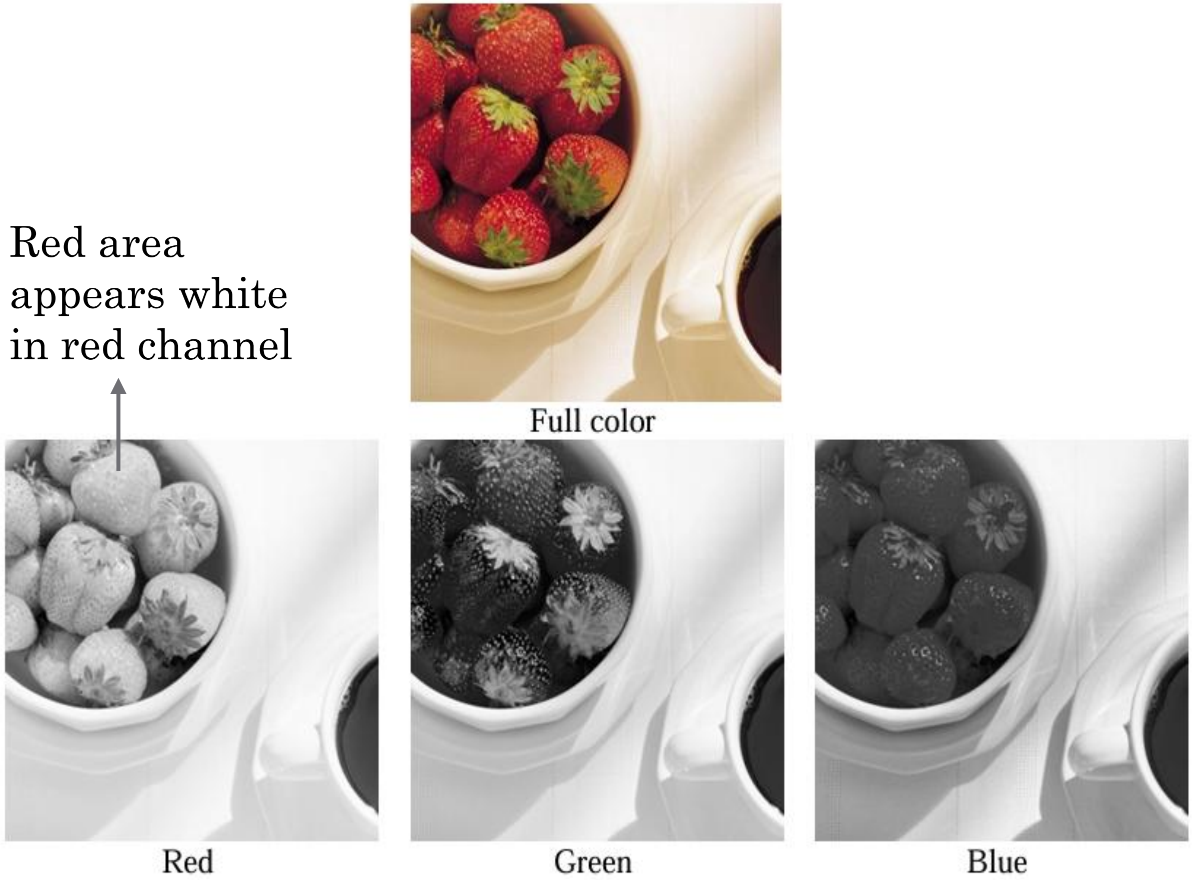


A 24-bit RGB Color Cube

Color Models

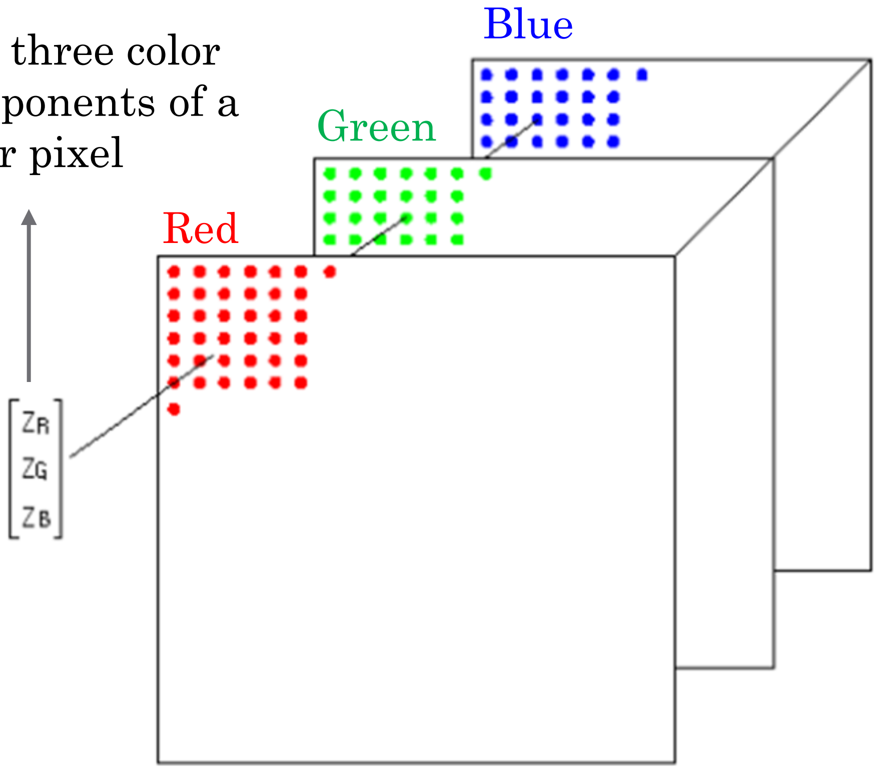
RGB Color Model

Red area appears white in red channel



RGB Color Channels of a Full-Color Image

The three color components of a color pixel



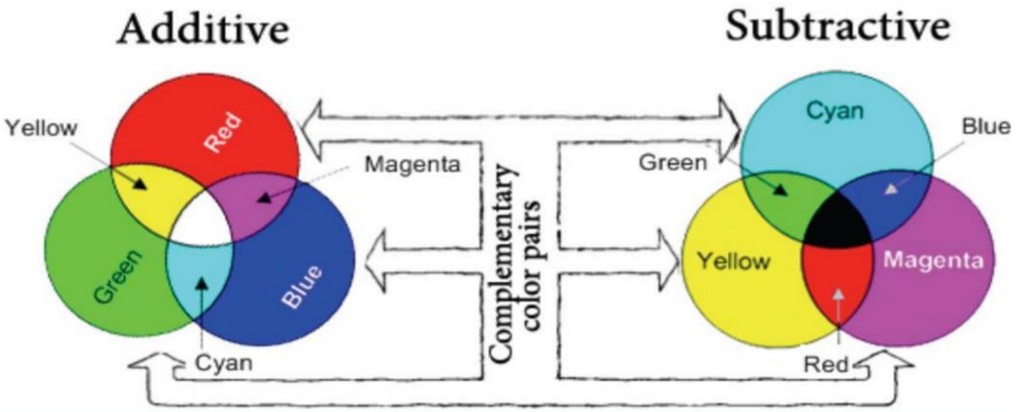
Scheme of RGB color image

Color Models

CMY and CMYK color Models

Secondary Colors of Light

- Cyan, magenta, and yellow are secondary colors and primary pigment colors.
- Printing devices use CMY data or convert RGB to CMY.



$$\begin{bmatrix} C \\ M \\ Y \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} - \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

Limitations of CMY

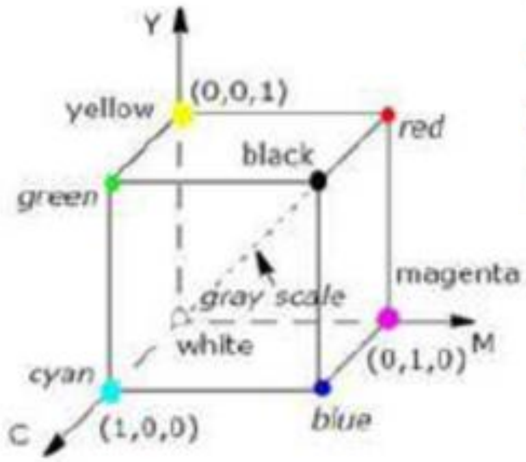
- Equal CMY amounts should create black but result in muddy brown due to pigment impurities.

$$R' = R/255$$
$$G' = G/255$$
$$B' = B/255$$
$$\mathbf{K} = 1 - \max(R', G', B')$$
$$\mathbf{C} = (1 - R' - \mathbf{K})/(1 - \mathbf{K})$$
$$\mathbf{M} = (1 - G' - \mathbf{K})/(1 - \mathbf{K})$$
$$\mathbf{Y} = (1 - B' - \mathbf{K})/(1 - \mathbf{K})$$

CMYK Color Model

Why Black (K)?

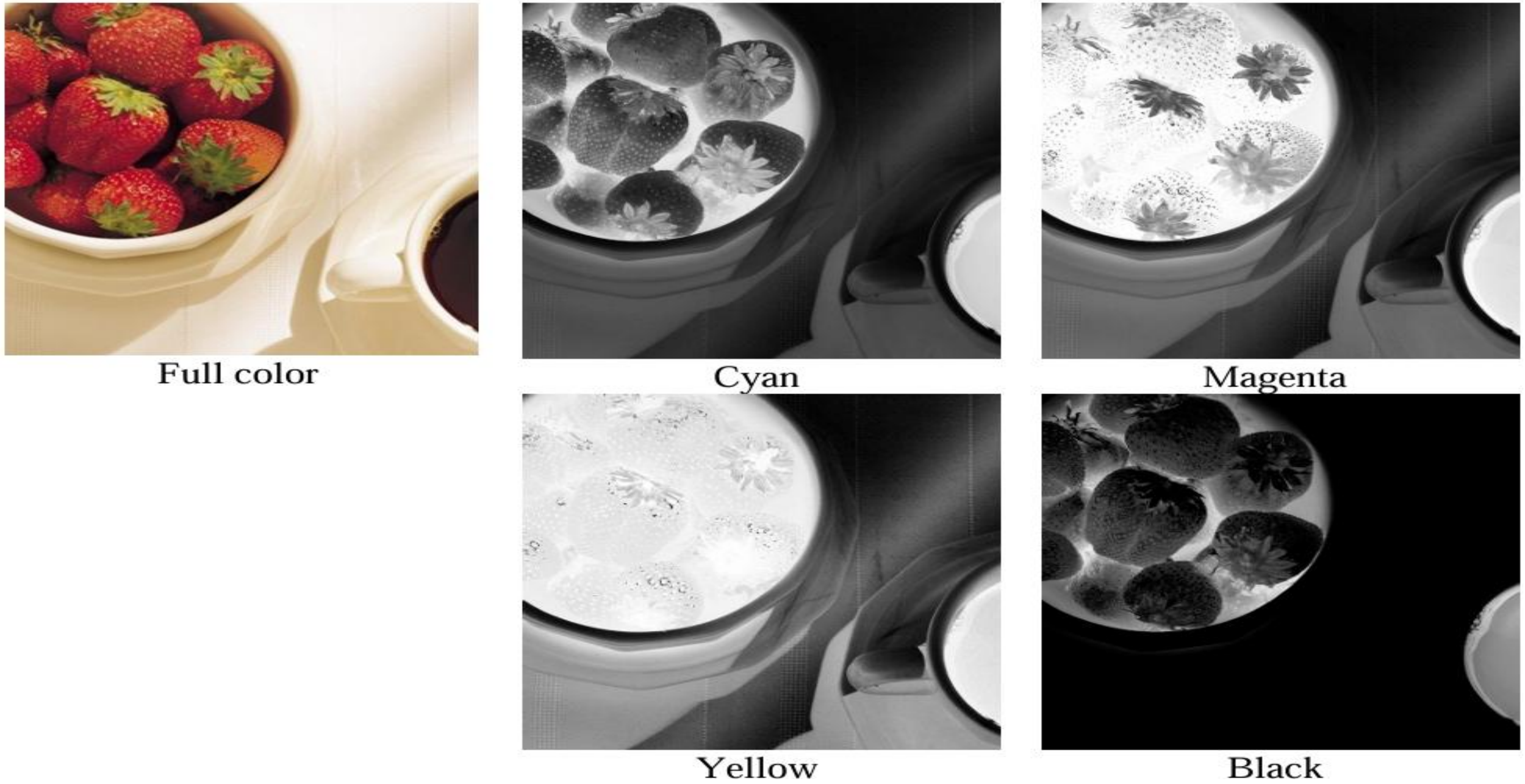
- Added to produce true black in printing.
- Widely used in four-color printing: Cyan, Magenta, Yellow, Black.



Color Models

CMY and CMYK color Models

A full-color image and its CMYK component images



Color Models

The HSI Color Model

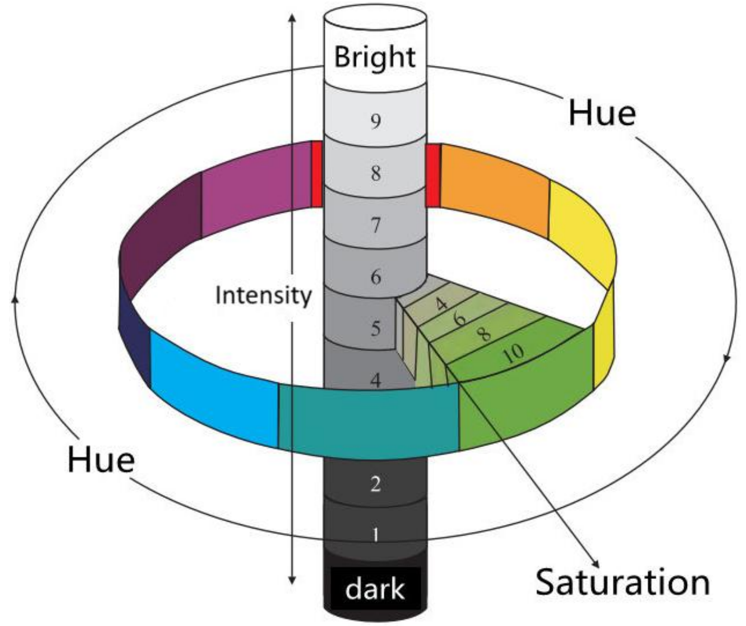
- Decouples intensity from color information for natural and intuitive color representation.

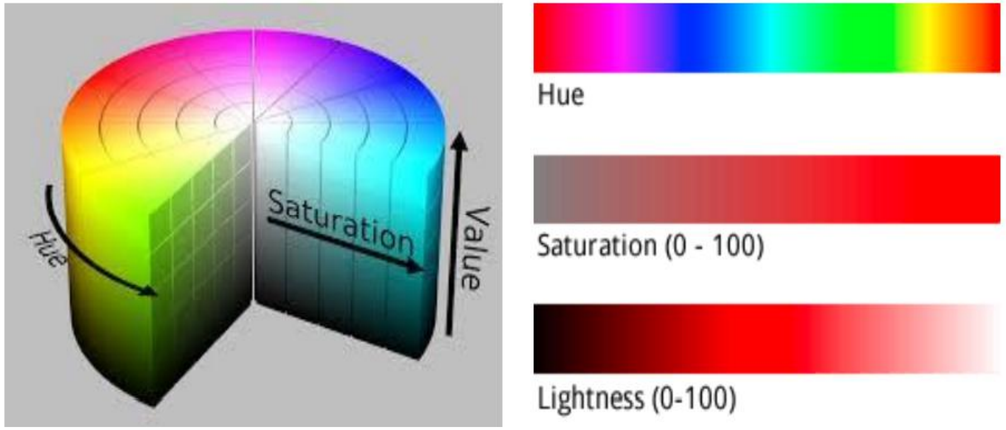
Components:

- **Hue (H)**: Describes the pure color (e.g., red, yellow, blue).
- **Saturation (S)**: Measures color purity (dilution with white light).
- **Intensity (I)**: Represents brightness (achromatic notion).

Why Use HSI?

- Matches human color perception (hue, saturation, brightness).
- Simplifies processing by separating intensity from color information.





Color Models

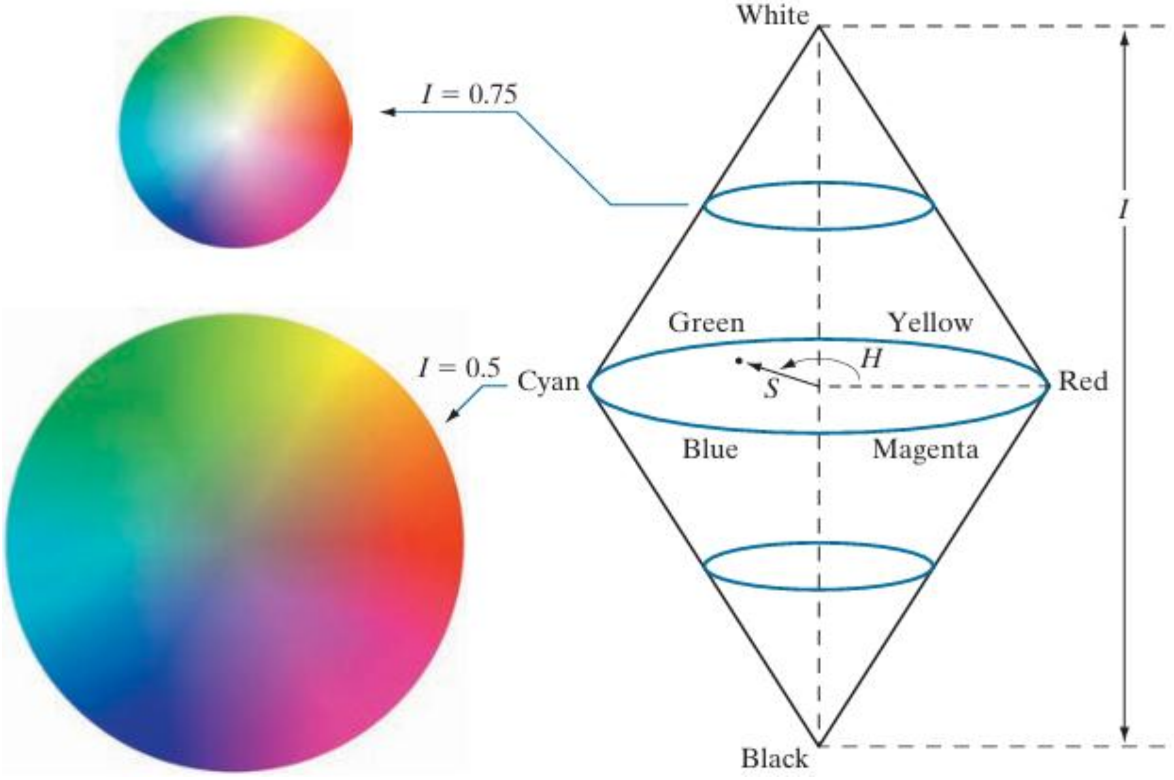
The HSI Color Model

Representation in HSI Space:

- **Hue**: Measured in degrees (0° = red, 120° = green, 240° = blue).
- **Saturation**: Length of vector from the origin to the color point.
- **Intensity**: Grayscale axis value.

Hexagonal Shape:

  - Primary colors separated by 120°.
  - Secondary colors 60° apart.
  - Other representations include triangles or circles.



Color Models

The HSI Color Model

A full-color image and its HSI component images

Pseudocolor Image Processing

Definition: Converts grayscale images into color images by assigning colors to specific intensity ranges.

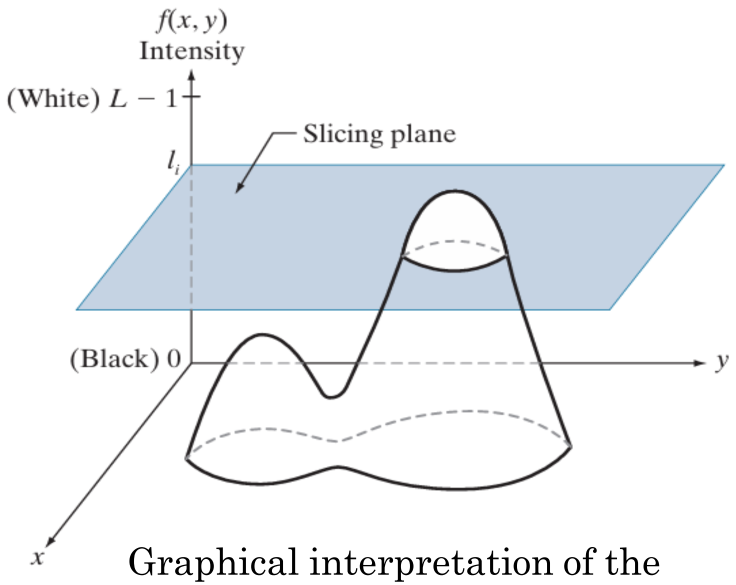
Purpose: Enhances human visualization and interpretation of grayscale images.

Key Techniques

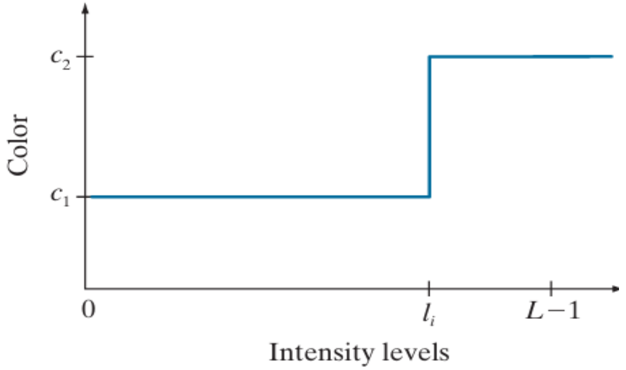
1. **Intensity Slicing:**
   - Divides the grayscale intensity range into intervals using threshold planes.
   - Assigns a specific color to each interval.

$$if\ f(x,y) \in l_k, let\ f(x,y) = c_k$$

2. **Color Mapping (Color Coding)**
   - Maps grayscale value to colors based on predefined or dynamic color scales.



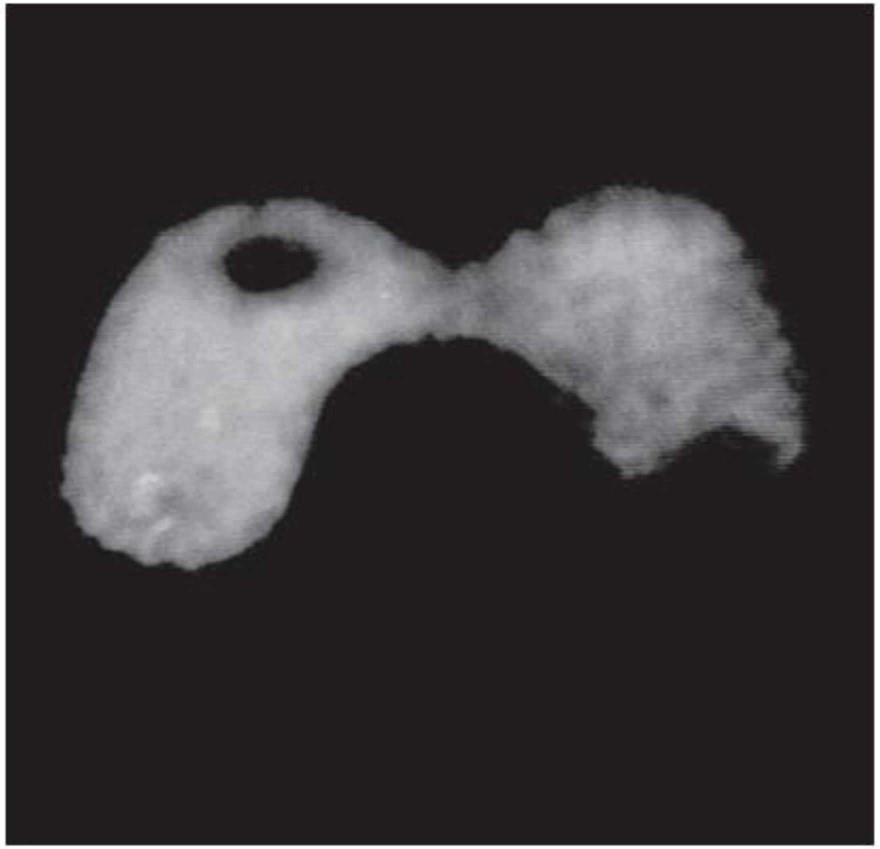
Graphical interpretation of the intensity- slicing technique.



An alternative representation of the intensity- slicing technique

Pseudocolor Image Processing

Intensity Slicing:



Grayscale image of the Picker Thyroid Phantom.

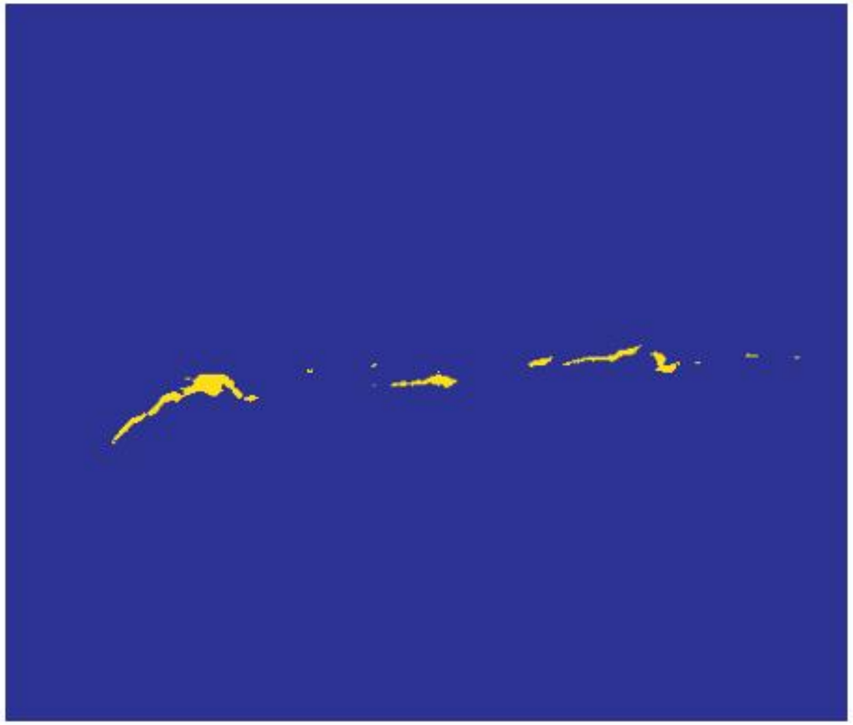
Result of intensity slicing using eight colors.

Pseudocolor Image Processing

Example: Color Coding in Weld X-rays

Problem: Cracks saturate sensors, producing an intensity value of 255 in an 8-bit image, indicating defects.

X-ray of a weld shows cracks and porosities as bright streaks.



Color coding highlights defects at level 255 for better visibility.

Basics of Full-Color Image Processing

Full-color processing methods:

- Process each color channel separately, then combine.
- Process color pixels directly.

Color Transformation

$$g(x,y) = T[f(x,y)]$$

$$s_i = T_i(r_1, r_2, \ldots, r_n) \quad i = 1,2,3,\ldots,n$$

Modifying the intensity of color image in RGB color space

$$s_i = 0.7(r_i) \quad i = 1,2,3$$

Original Image

Original Image

Thank You