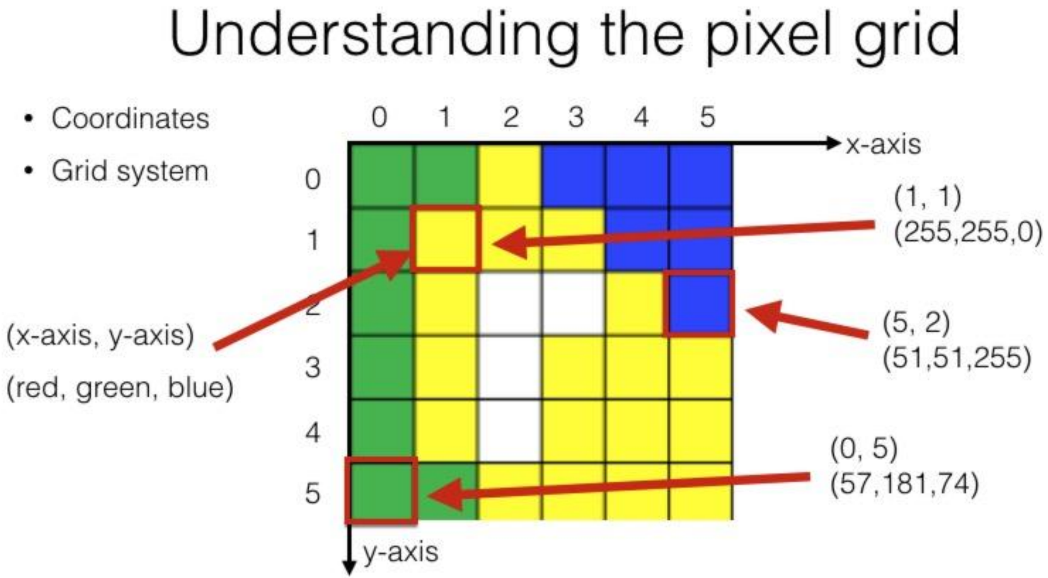
Computer Graphics

COMP 321 - February 2024
Module 2 - Image Representation, Digital Color, and Basic Image Processing Algorithms

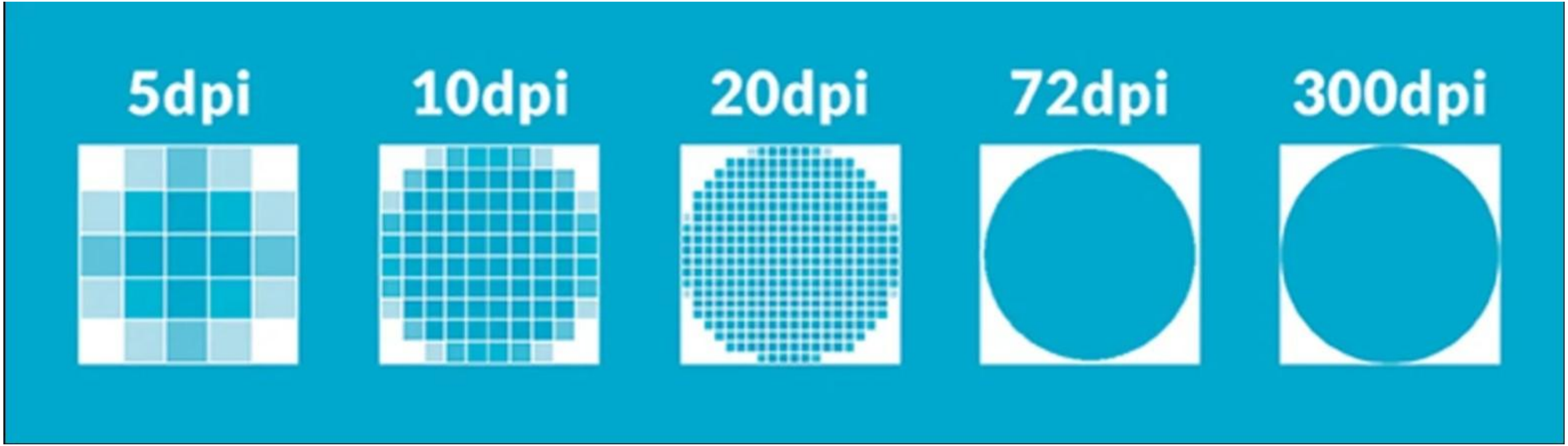
I. Introduction to Image Representation:

- Image as Data: Images are represented as arrays of pixels, where each pixel contains color information.



I. Introduction to Image Representation:

Image Resolution: Determines the clarity and detail of an image, measured in pixels per inch (PPI) or dots per inch (DPI).



I. Introduction to Image Representation:

Screen Resolution:

- Screen resolution refers to the number of pixels (individual points of color) contained on a display screen.
- It is typically represented as the number of pixels in width by the number of pixels in height, such as "1920x1080" for Full HD resolution.
- The resolution of a screen determines the level of detail that can be displayed, with higher resolutions providing sharper and more detailed images. Resolution is often cited as one of the key specifications of a display, along with factors like refresh rate and panel technology.

I. Introduction to Image Representation:

Screen Resolution:

- A higher screen resolution means that more pixels are packed into the same physical space, resulting in finer detail and smoother images.
- This is particularly noticeable when viewing text, images, or videos with intricate details.
- However, it's essential to consider that higher resolutions require more processing power from the device driving the display. For example, rendering graphics at 4K resolution demands more computational resources than at 1080p resolution.
- Additionally, higher resolutions can also affect performance in gaming, video editing, and other tasks.

I. Introduction to Image Representation:

Screen Resolution:

1. **HD (High Definition):** 1280x720 pixels, also known as 720p.

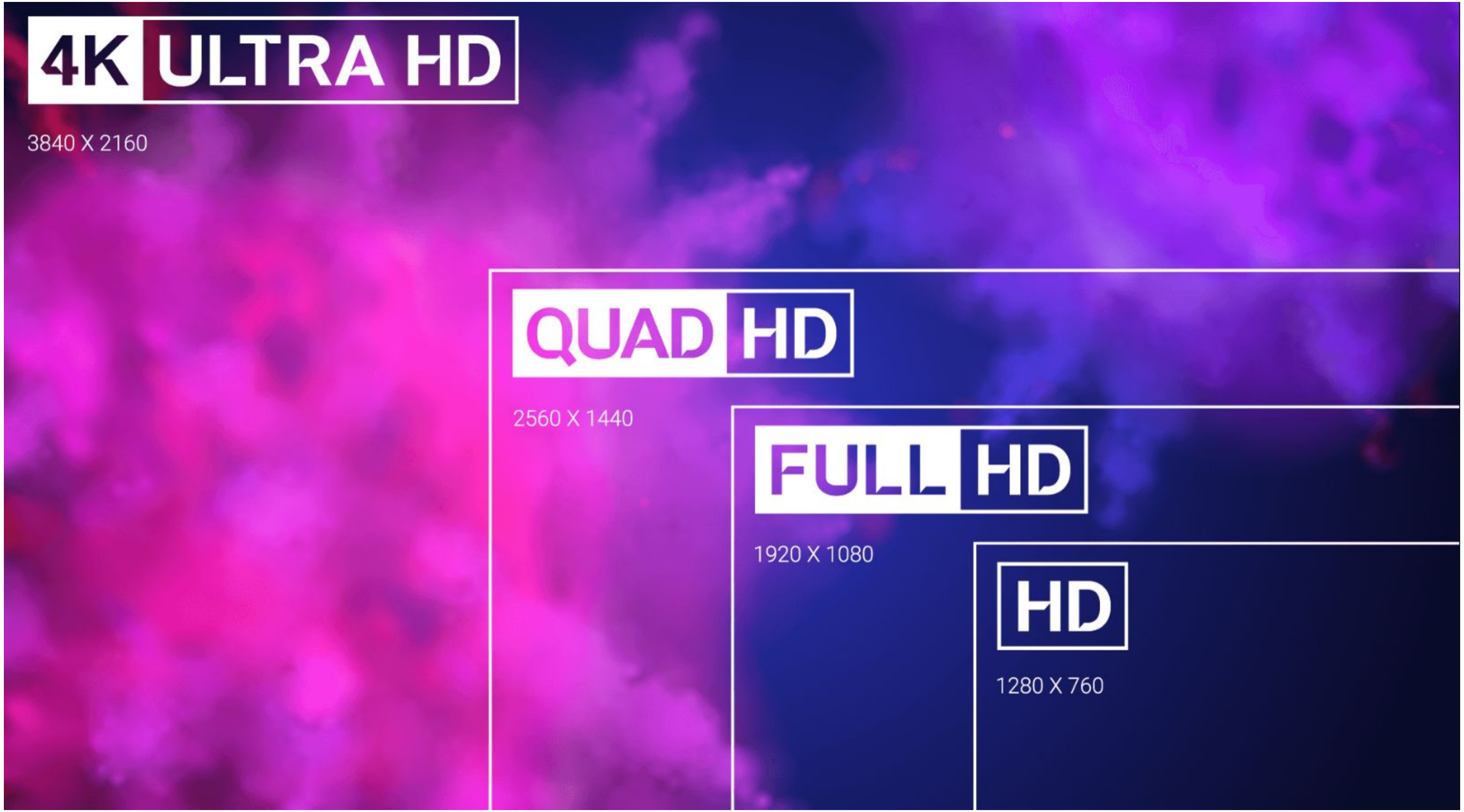
2. **Full HD**: 1920x1080 pixels, also known as 1080p.

3. **Quad HD (QHD)**: 2560x1440 pixels, also known as 1440p.

4. **4K Ultra HD**: 3840x2160 pixels, also known as 2160p or simply 4K.

5. **8K Ultra HD:** 7680x4320 pixels, providing even higher detail and clarity than 4K.

I. Introduction to Image Representation:



II. Digital Color Representation

Screen Resolution:

1. **HD (High Definition):** 1280x720 pixels, also known as 720p.

2. **Full HD**: 1920x1080 pixels, also known as 1080p.

3. **Quad HD (QHD)**: 2560x1440 pixels, also known as 1440p.

4. **4K Ultra HD**: 3840x2160 pixels, also known as 2160p or simply 4K.

5. **8K Ultra HD:** 7680x4320 pixels, providing even higher detail and clarity than 4K.

II. Digital Color Representation

A. RGB Color Model:

- Definition: Represents colors using combinations of Red, Green, and Blue channels.

- Additive Color: Mixing different intensities of RGB channels produces a wide range of colors.

- Applications: Commonly used in digital displays, cameras, and computer graphics.

II. Digital Color Representation

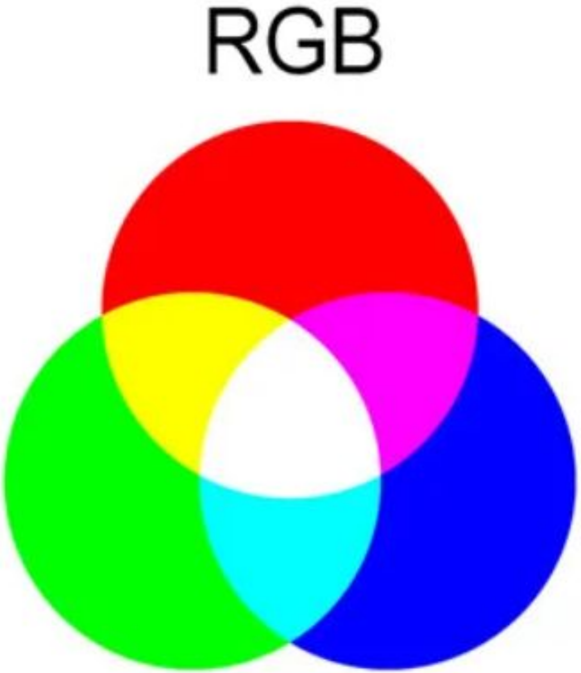
B. CMYK Color Model:

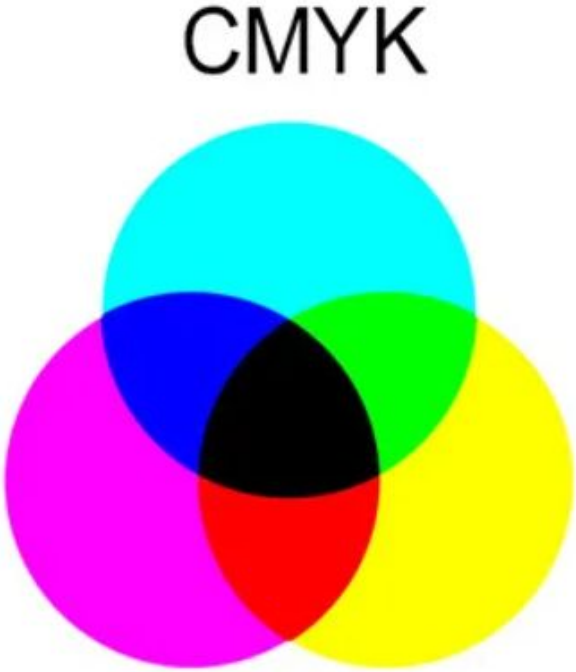
- **Definition:** Used in color printing, comprises Cyan, Magenta, Yellow, and Key (black) channels.

- **Subtractive Color**: Colors are created by subtracting light from white.

- **Applications**: Primarily used in printing industry for producing color prints.

II. Digital Color Representation





II. Digital Color Representation

C. HSL and HSV Color Models:

- HSL (Hue, Saturation, Lightness):

- Represents colors based on hue (type of color), saturation (intensity of color), and lightness (brightness).

- Intuitive for color selection and manipulation in graphic design applications.

II. Digital Color Representation

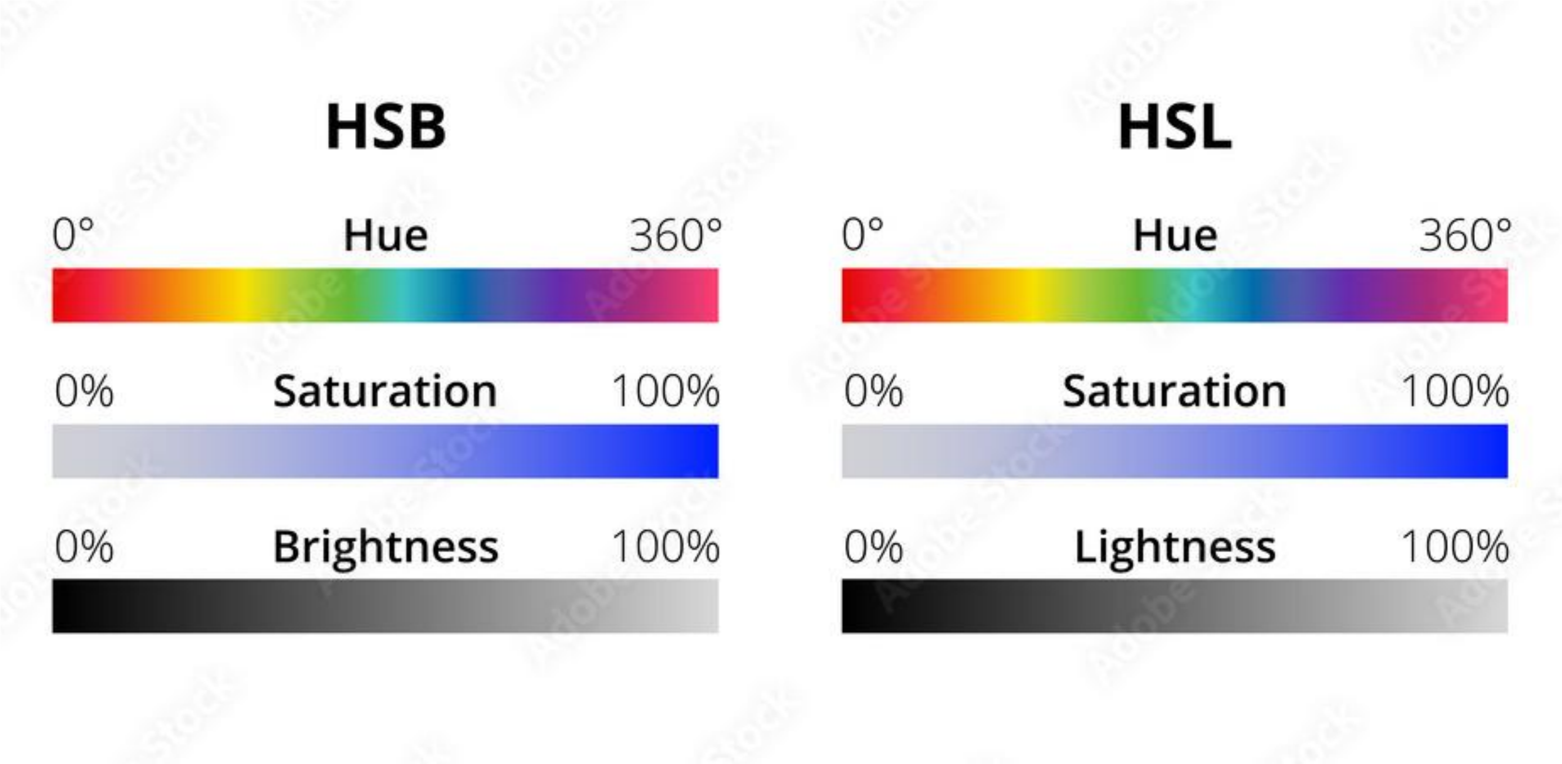
C. HSL and HSV Color Models:

- HSV (Hue, Saturation, Value):

- Similar to HSL, but replaces lightness with value, which represents the brightness of a color.

- Widely used in color manipulation operations such as color correction and adjustment.

II. Digital Color Representation

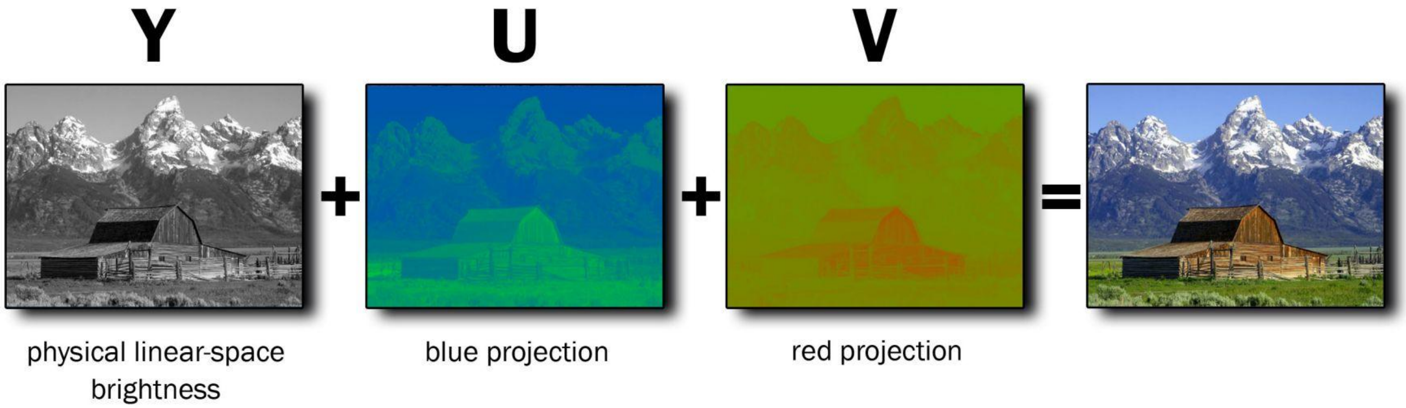


II. Digital Color Representation

YUV Color Model

- The YUV color space is what is primarily used on an analog television.
- YUV color space was particularly useful when color was first introduced to television as it could decode and display both color and black and white.
- Like all color spaces, YUV is just an abbreviated term for ‘luma’, ‘red projection’ and ‘blue projection’.
- Essentially, a YUV system is a mathematical encoding system like any other, but incorporates both brightness and color.
- YUV is most useful for producing grayscale images, because all the user has to do is get rid of the U and V elements of the equation.

II. Digital Color Representation



Color Depth

A. Color Depth:

- Definition: Color depth refers to the number of bits used to represent the color of each pixel in an image. It determines the range of colors that can be displayed in an image.

Color Depth

A. Color Depth:

- Common Depths:

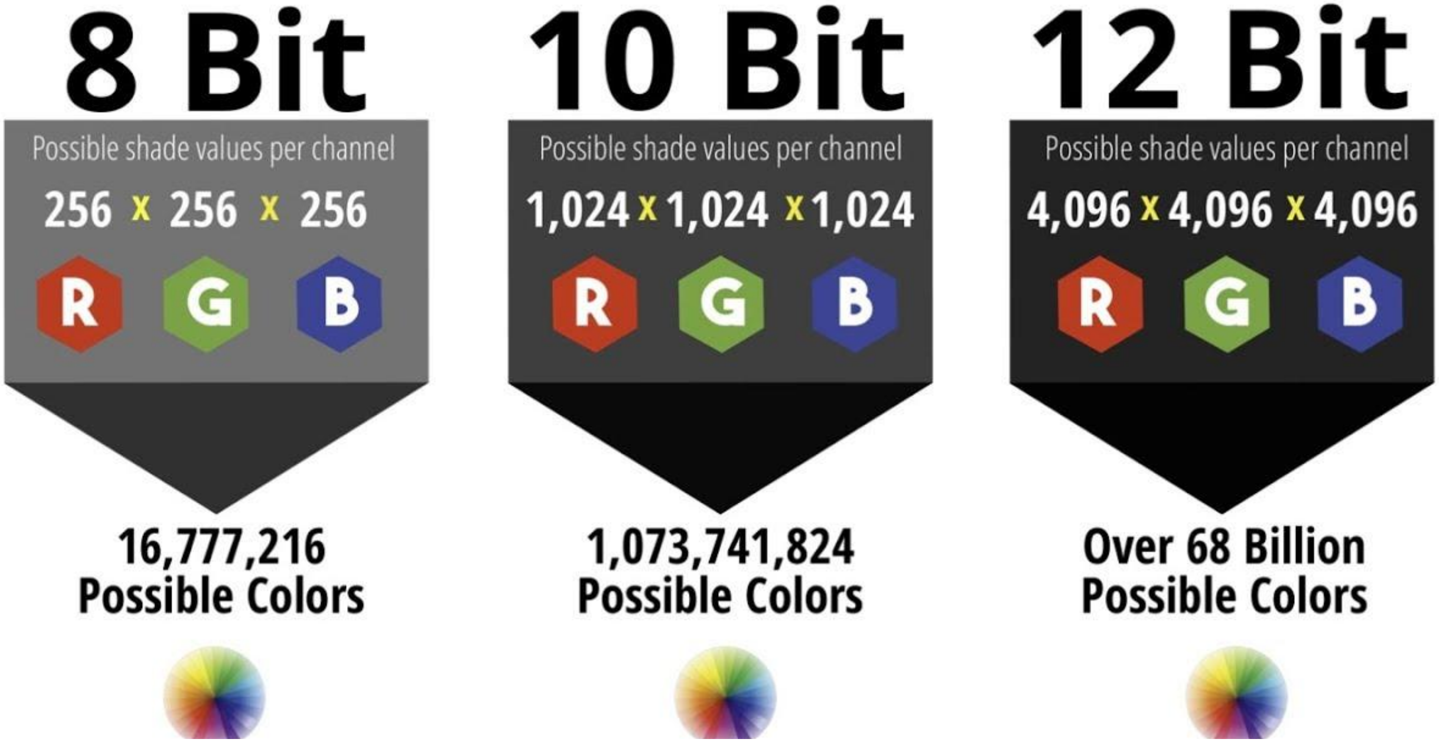
- 8-bit (256 colors): Each pixel is represented by 8 bits, allowing for 256 different color variations.
- 16-bit: Each pixel is represented by 16 bits, enabling 65,536 color variations.
- 24-bit: Each pixel is represented by 24 bits, providing over 16 million color variations.
- 32-bit: Similar to 24-bit, but includes an additional 8 bits for an alpha channel (transparency).

Color Depth

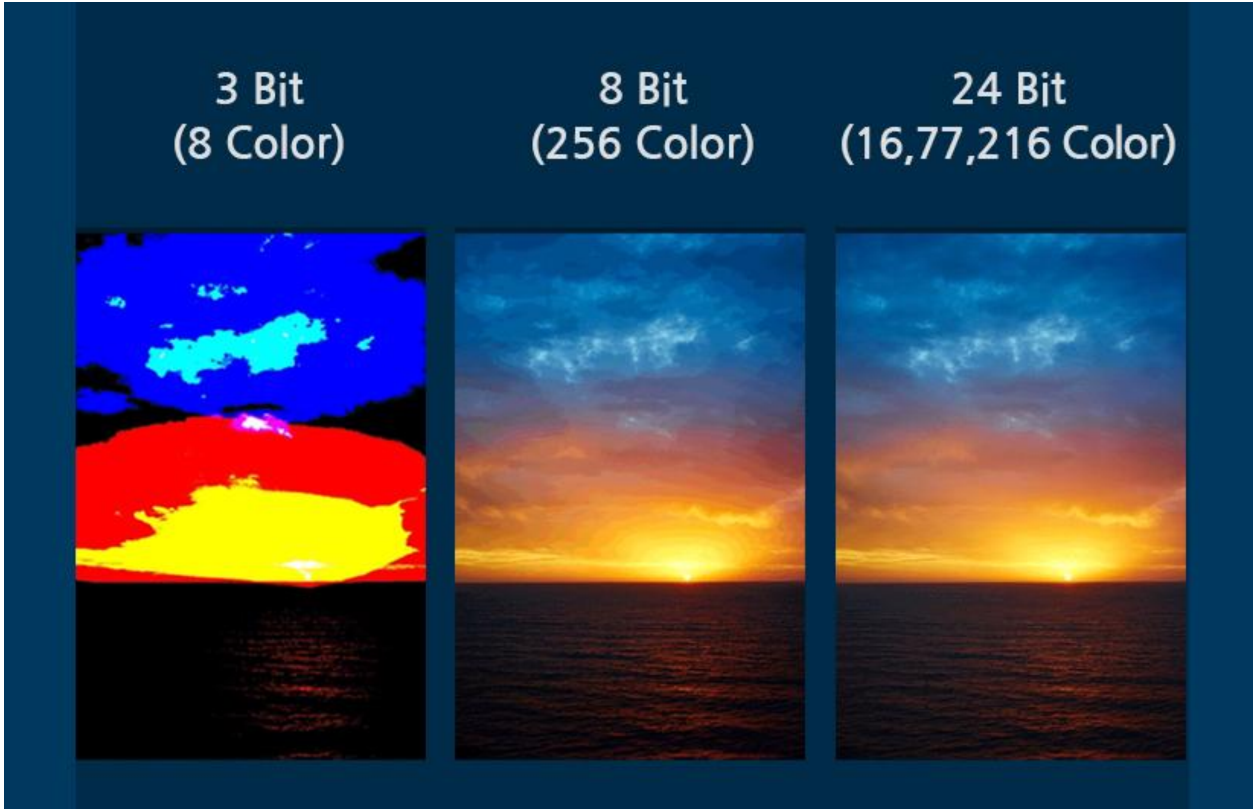
A. Color Depth:

- Higher Color Depth: Higher color depth allows for a wider range of colors to be accurately represented in an image. This results in smoother gradients, more subtle color variations, and better color accuracy.
- Impact on Image Quality: Images with higher color depth tend to have higher quality and more realistic color representation.
- However, they also tend to have larger file sizes due to the increased amount of data required to store the additional color information.

II. Digital Color Representation



II. Digital Color Representation



III : Basic Image Processing Algorithms:

A. Grayscale Conversion:

- **Description:** Grayscale conversion transforms a color image into a grayscale image by removing color information, leaving only shades of gray.

GrayScale Conversion

1. Weighted Average Method:

- Description: This method calculates the luminance value of each pixel by taking a weighted average of its red, green, and blue color components. **(the intensity of light emitted from a surface per unit area)**

- Algorithm:

- Let R, G, and B represent the red, green, and blue color components of a pixel, respectively.
- The luminance value Y for each pixel is computed as follows:

$$Y = 0.299R + 0.587G + 0.114B$$

- This formula is based on the relative sensitivity of the human eye to different colors, with green having the highest sensitivity, followed by red and blue.

GrayScale Conversion

2. Luminance Method:

- Description: This method directly extracts the luminance value from a color space that separates brightness from color information, such as the Y component in the YUV color space.

- Algorithm:

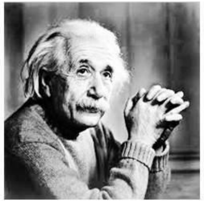
- Convert the RGB color space to the YUV color space.
- Use the luminance component (Y) as the grayscale intensity value for each pixel.
- This approach separates color information from brightness, resulting in more accurate grayscale conversion.

III : Basic Image Processing Algorithms:

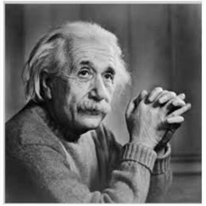
B. Histogram Equalization:

- Description: Histogram equalization is a technique used to enhance the contrast and improve the overall brightness distribution of an image by redistributing pixel intensities.

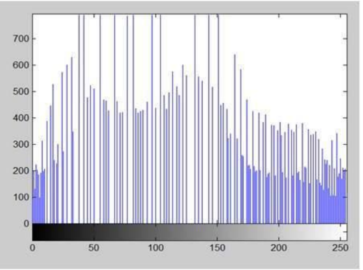
New Image



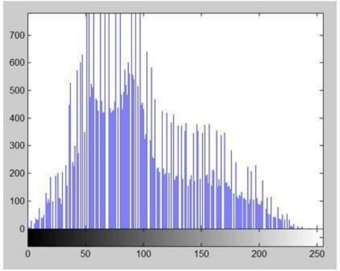
Old image



New Histogram



Old Histogram



III : Basic Image Processing Algorithms:

B. Histogram Equalization:

- How It Works:

- Histogram equalization works by computing the histogram of pixel intensities in the input image, which represents the frequency distribution of brightness levels.

- Next, the cumulative distribution function (CDF) of the histogram is computed, which represents the cumulative probability of each intensity value occurring.

- The CDF is then normalized to map the pixel intensities to new values that are spread out more evenly across the entire dynamic range.

- Finally, the pixel values in the original image are replaced with their corresponding values in the normalized CDF, resulting in an image with improved contrast.

III : Basic Image Processing Algorithms:

B. Histogram Equalization:

- How It Works:

- Histogram equalization works by computing the histogram of pixel intensities in the input image, which represents the frequency distribution of brightness levels.

- Next, the cumulative distribution function (CDF) of the histogram is computed, which represents the cumulative probability of each intensity value occurring.

- The CDF is then normalized to map the pixel intensities to new values that are spread out more evenly across the entire dynamic range.

- Finally, the pixel values in the original image are replaced with their corresponding values in the normalized CDF, resulting in an image with improved contrast.

III : Basic Image Processing Algorithms:

III : Basic Image Processing Algorithms:

III : Basic Image Processing Algorithms:

C. Image Smoothing (Blur):

- Description: Image smoothing, also known as blurring, reduces noise and sharpens edges by applying a smoothing filter to the image.

- Common Techniques:

- Gaussian blur: Applies a Gaussian filter to the image, which convolves the image with a Gaussian function, resulting in a smooth and visually pleasing blur.

- Median blur: Replaces each pixel's value with the median value of its neighboring pixels, effectively reducing noise while preserving edges.

- Bilateral filtering: A more advanced technique that smooths images while preserving edges by considering both spatial and intensity differences between pixels.

III : Basic Image Processing Algorithms:

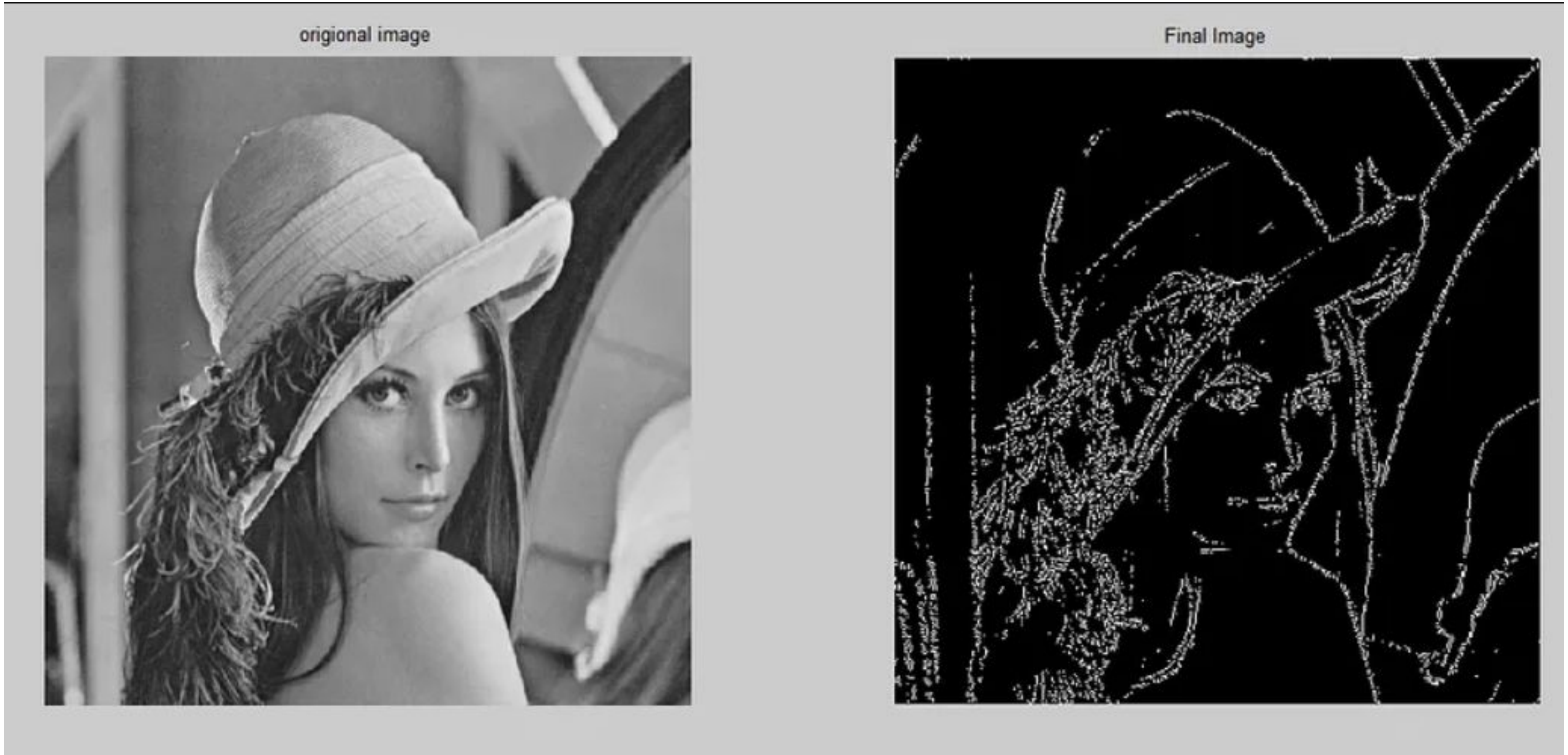
Gaussian Blur

III : Basic Image Processing Algorithms:

D. Edge Detection:

- **Description:** Edge detection algorithms identify edges and boundaries between objects in an image, which are areas of rapid intensity change.
- **Common Algorithms:**
  - **Sobel operator:** Applies convolution masks to detect horizontal and vertical edges separately, which are then combined to form the final edge image.
  - **Prewitt operator:** Similar to the Sobel operator but uses slightly different convolution masks.
  - **Canny edge detection:** A multi-stage algorithm that involves edge detection, noise reduction, and edge tracking by hysteresis, resulting in accurate edge detection with minimal noise.

III : Basic Image Processing Algorithms:



III : Basic Image Processing Algorithms:

E. Image Resizing:

- **Description:** Image resizing changes the dimensions of an image while preserving its aspect ratio.
- **Interpolation Techniques:**
    - **Bilinear interpolation:** Computes the new pixel values by taking a weighted average of the nearest four pixels in the original image, resulting in smoother resizing.
    - **Bicubic interpolation:** A more sophisticated technique that considers 16 neighboring pixels to compute the new pixel values, resulting in higher quality resizing with less aliasing artifacts.

III : Basic Image Processing Algorithms:

- Understanding these basic image processing algorithms is essential for various applications, including **image editing**, **computer vision**, and **digital photography.**
- They form the building blocks for more advanced image processing techniques and algorithms used in real-world scenarios.

III : Basic Image Processing Algorithms: