CSE-303: COMPUTER GRAPHICS

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BOOKS

Textbook:

- Angel and Shreiner: Interactive Computer Graphics 6E © Addison-Wesley 2012

Reference Book:

- Roy A. Plastock and Zhigang Xiang : Computer Graphics 2/E Book © Schaum's Outline Series

OBJECTIVES

- Fundamental imaging notions
- Physical basis for image formation
  - Light
  - Color
  - Perception
- Synthetic camera model
- Other models

WHAT IS AN IMAGE?

- Composed of discrete pixels or picture elements.
- Rectangular grid of pixels - 5x5 grid
- What is a pixel?
  - Point/cell in the image that contains color data
  - Each pixel is made up of *bits*
- Resolution: details contained in an image
  - Defined by the number of pixels

[0,0]	[0,1]	[0,2]	[0,3]	[0,4]
[1,0]	[1,1]	[1,2]	[1,3]	[1,4]
[2,0]	[2,1]	[2,2]	[2,3]	[2,4]
[3,0]	[3,1]	[3,2]	[3,3]	[3,4]
[4,0]	[4,1]	[4,2]	[4,3]	[4,4]

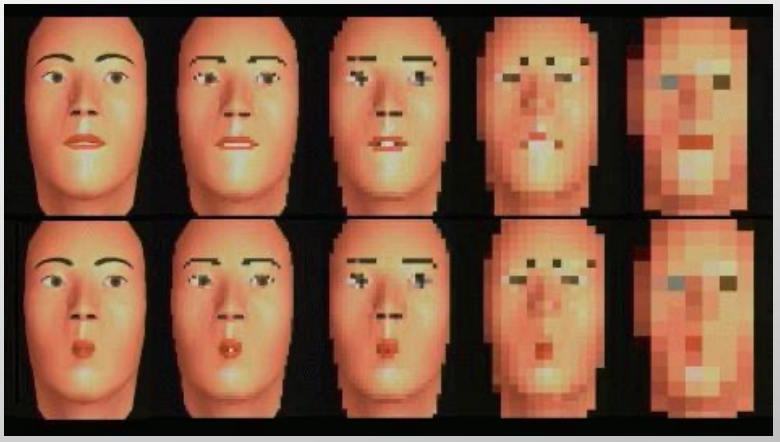
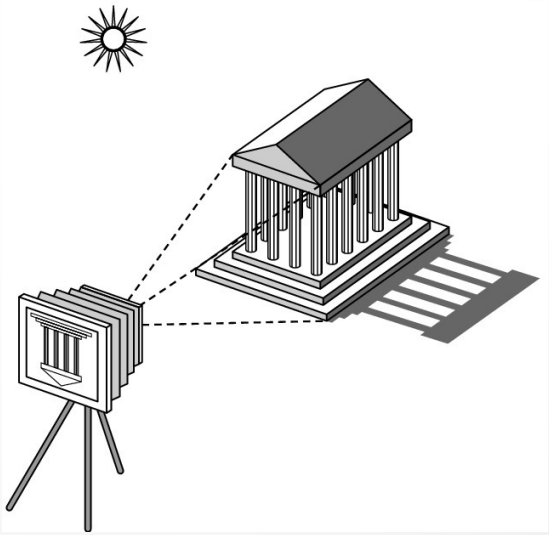


IMAGE FORMATION

- In computer graphics, we form images which are generally two dimensional using a process analogous to how images are formed by physical imaging systems
  - Cameras
  - Microscopes
  - Telescopes
  - Human visual system

ELEMENTS OF IMAGE FORMATION

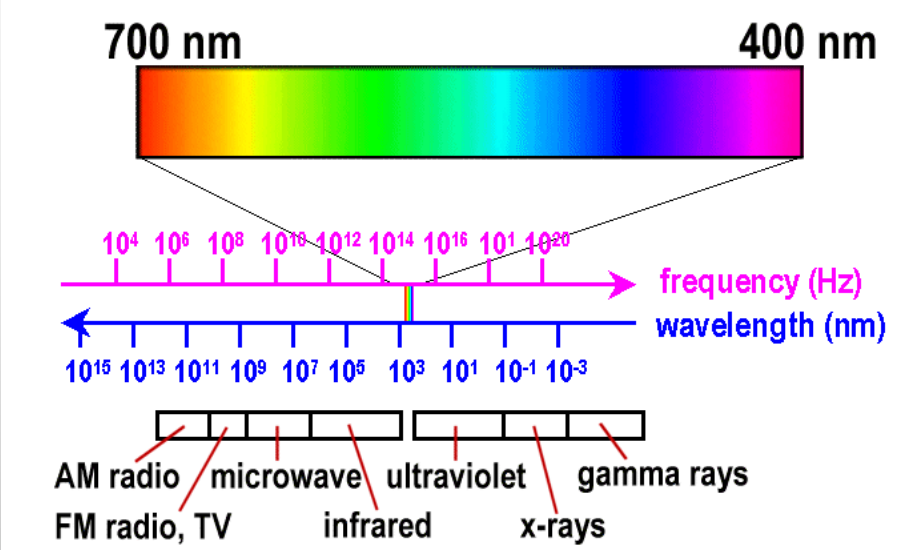
- Objects
- Viewer
- Light source(s)



- Attributes that govern how light interacts with the materials in the scene
- Note the independence of the objects, the viewer, and the light source(s)

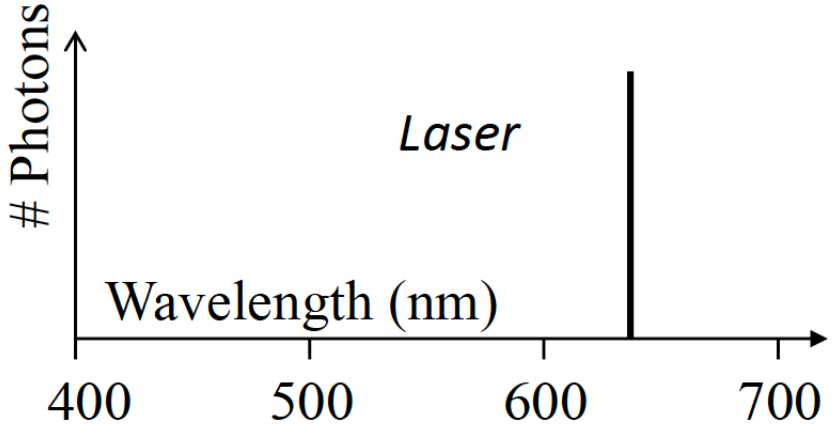
LIGHT

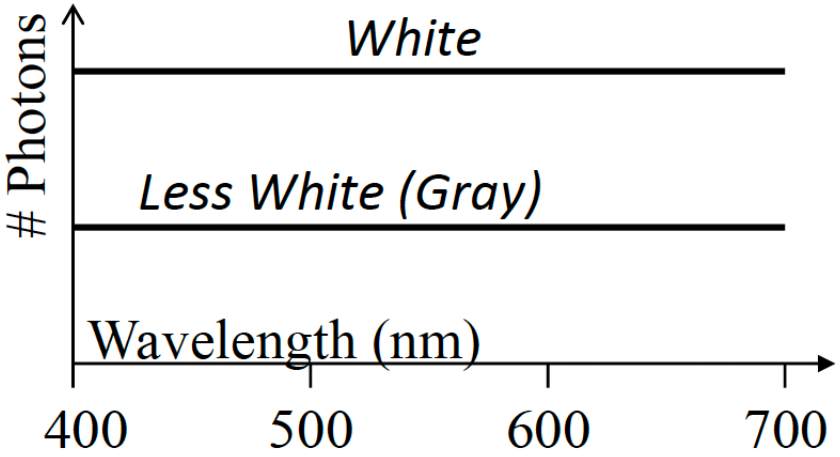
- Light is the part of the electromagnetic spectrum that causes a reaction in our visual systems
- Generally these are wavelengths in the range of about 350-750 nm (nanometers)
- Long wavelengths appear as reds and short wavelengths as blues

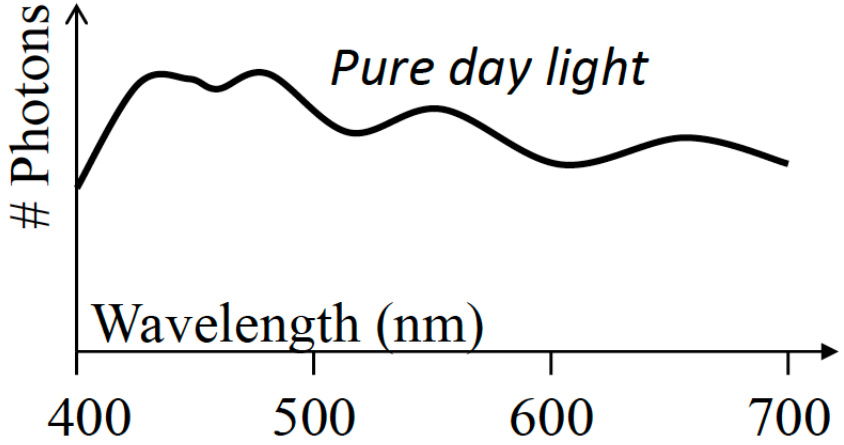


SPECTRAL ENERGY DISTRIBUTIONS

Violet	388-440nm
Blue	440-490nm
Green	490-565nm
Yellow	565-590nm
Orange	590-630nm
Red	630-780nm





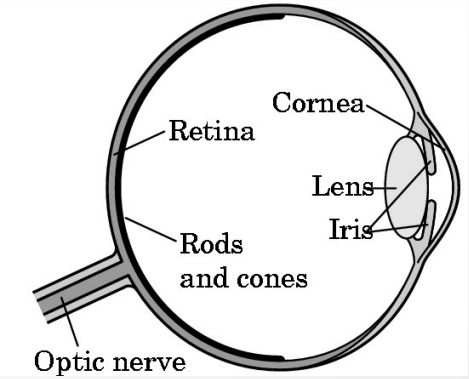


LUMINANCE AND COLOR IMAGES

- Luminance image
  - Monochromatic
  - Values are gray levels
  - Analogous to working with black and white film or television
- Color image
  - Has perceptional attributes of hue, saturation, and lightness

THREE-COLOR THEORY

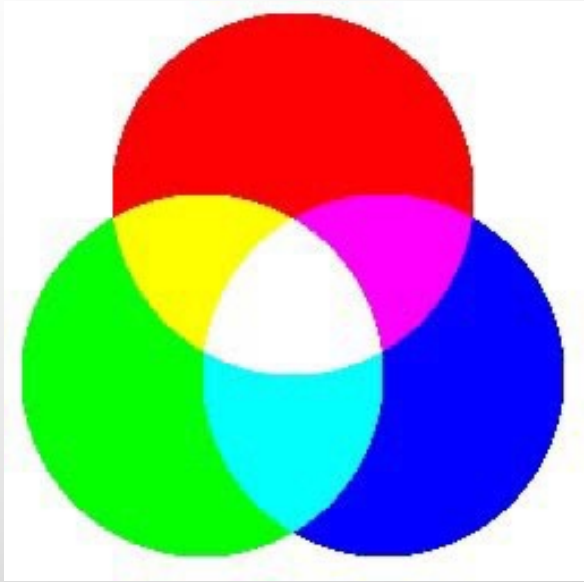
- Human visual system has two types of sensors
  - Rods: monochromatic, night vision
  - Cones
    - Color sensitive
    - Three types of cones
      - Only three values (the tristimulus values) are sent to the brain



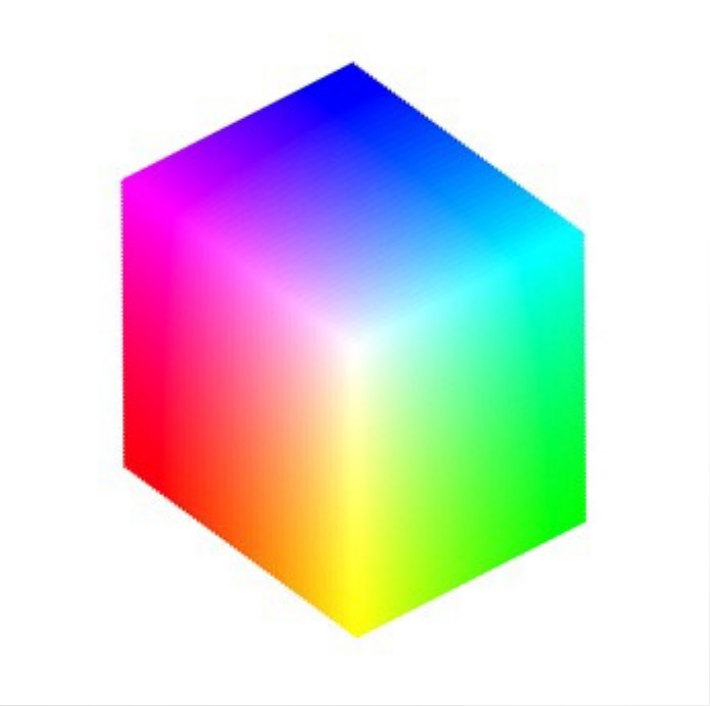
- Need only match these three values
  - Need only three primary colors

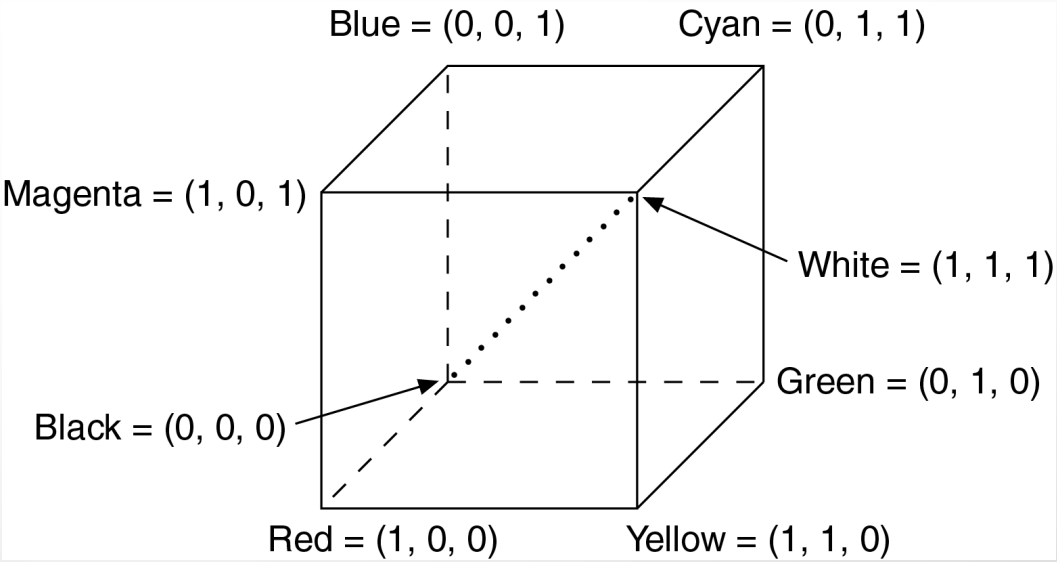
ADDITIVE AND SUBTRACTIVE COLOR

- Additive color
  - Form a color by adding amounts of three primaries
    - CRTs, projection systems, positive film
- Primaries are
  - Red (R), Green (G), Blue (B)



RGB COLOR CUBE





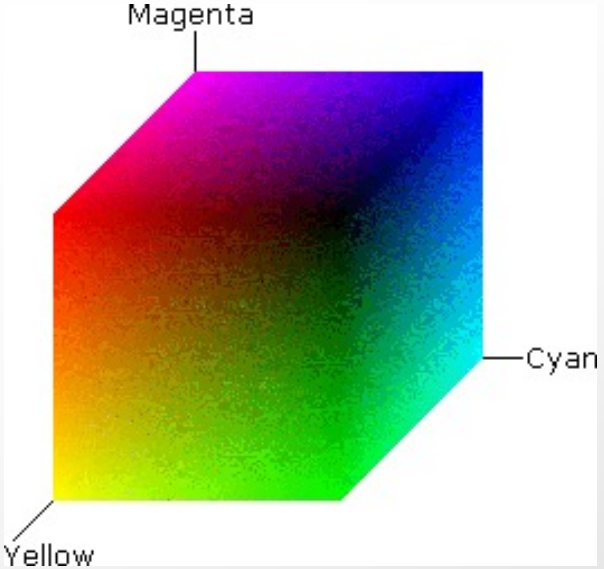
- RGB used in monitors and other light emitting devices
- TV uses YIQ encoding which is somewhat similar to RGB

ADDITIVE AND SUBTRACTIVE COLOR

- Subtractive Color
  - Form a color by filtering white light with Cyan (C), Magenta (M), and Yellow (Y) filters
    - Light-material interactions
    - Printing
    - Negative film

COLOR MODELS CMY

- Describes hardcopy color output
- We see colors of reflected light



- Cyan ink absorbs red light and reflects green and blue
- To make blue, use Cyan ink (to absorb red), and Magenta ink (to absorb green)

CONVERSION

- $W = (0, 0, 0)$ $B = (1, 1, 1)$
- Conversion from RGB to CMY

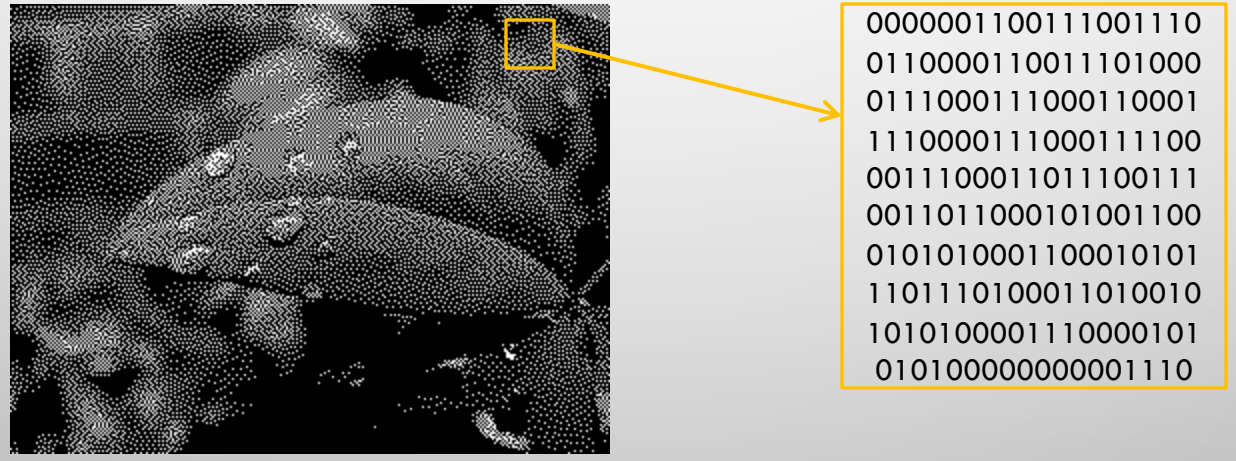
$$\begin{bmatrix} C \\ M \\ Y \end{bmatrix} = 1 - \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

- Conversion from CMY to RGB

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

BINARY IMAGES

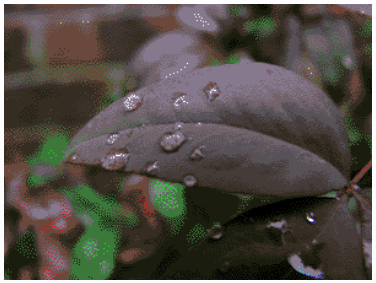
- Remember, everything on a computer is stored as 0s and 1s.
- Thus, we must *interpret* these numbers as different forms of data.
- One bit (binary digit) can be either a 0 or a 1.
  - Therefore, it can only represent two possibilities: hot or cold, black or white, on or off, etc…



BIT COLOR DEPTH


1 bit


2 bits


4 bits


8 bits


24 bits

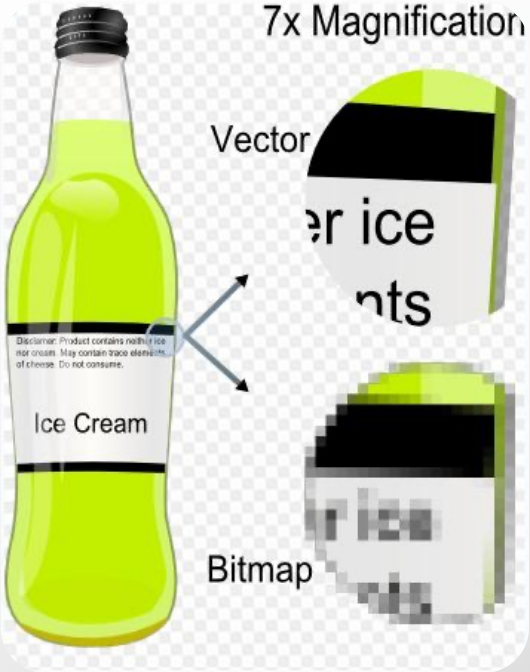
1= ON 0
=OFF

00 01 10 11
Different shades of gray

24 bit *TrueColor* can represent more than 16.7 million unique colors. More colors than the human eye can distinguish!

RASTER VS VECTOR GRAPHICS

- Raster graphics: made up of pixels
  - Resolution dependent
  - Cannot be scaled without losing quality
  - Can represent photo realistic elements better than vector graphics
- Vector graphics: geometric primitives, composed of paths
  - Mathematical equations
  - Resolution independent
  - Can be scaled to any size without losing quality
  - Best for cartoon-like images
  - 3D modeling



RASTER VS VECTOR GRAPHICS…

- Raster graphics - image formats:
  - BMP
  - GIF
  - JPEG
  - PNG
- Vector graphics - image formats:
  - FLASH
  - SCALABLE VECTOR GRAPHICS (SVG)
  - CDR (CORELDRAW)
  - AI (ADOBE ILLUSTRATOR)

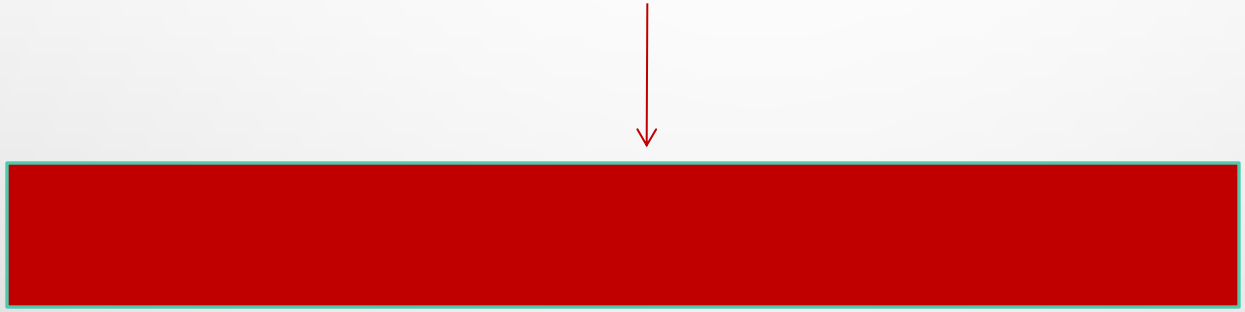
RASTER GRAPHICS

- BMP (Bitmaps)
  - Simple structure
  - Pixel color values *left to right, top to bottom*
  - Can be compressed using run-length encoding
- GIF (Graphics Interchange Format)
  - 8-bit palette (any 256 colors)
  - Small size
  - Simple images: line art, shapes, logos
  - Lossless compression: covering areas with single color
- JPEG (Joint Photographic Experts Group)
  - Is a *compression method* stored in JFIF (JPEG file interchange format)
  - Lossy compression: averages color hues over short distances
    - Taking advantage of limitations of our visual system, discarding invisible information
  - Compression ratio is usually 0.1
  - Structure: sequence of segments. Marker followed by a definition of the marker

VECTOR GRAPHICS

- SVG (Scalable Vector Graphics)
  - Text based scripts

```
<rect class="redbox" x="10" y="0" width="460"
  height="50"/>
```



  - Text compression
  - Compression ratio can be as small as 0.2
  - Great for web-based imaging

DIRECT CODING

- Image representation is essentially the representation of pixel colors.
- Using direct coding we allocate a certain amount of storage space for each pixel to code its color.
- For example, we may allocate 3 bits for each pixel, with one bit for each primary color.

bit 1: r	bit 2: g	bit 3: b	Color name
0	0	0	black
0	0	1	blue
0	1	0	green
0	1	1	cyan
1	0	0	red
1	0	1	magenta
1	1	0	yellow
1	1	1	white

- This 3-bit representation allows each primary to vary independently between two intensity levels:
  - 0 (off) or 1 (on).
- Hence each pixel can take on one of the eight colors that correspond to the corners of the RGB color cube.

LOOKUP TABLE

A lookup table (LUT) maps input values to corresponding output colors, allowing a limited number of input colors to be displayed with a larger number of output colors. These tables are used to reduce memory usage and improve performance.