Overview of Computer Graphics

Topics

- Image Representation
- The RGB Color Model
- Direct Coding
- Lookup Table
- Display Monitor
- Color Display
- Printer
- Halftone
- Halftone Approximation
- Dithering
- Error Diffusion
- Image Files
- Setting the Color Attributes of the Pixel

Raster or Matrix

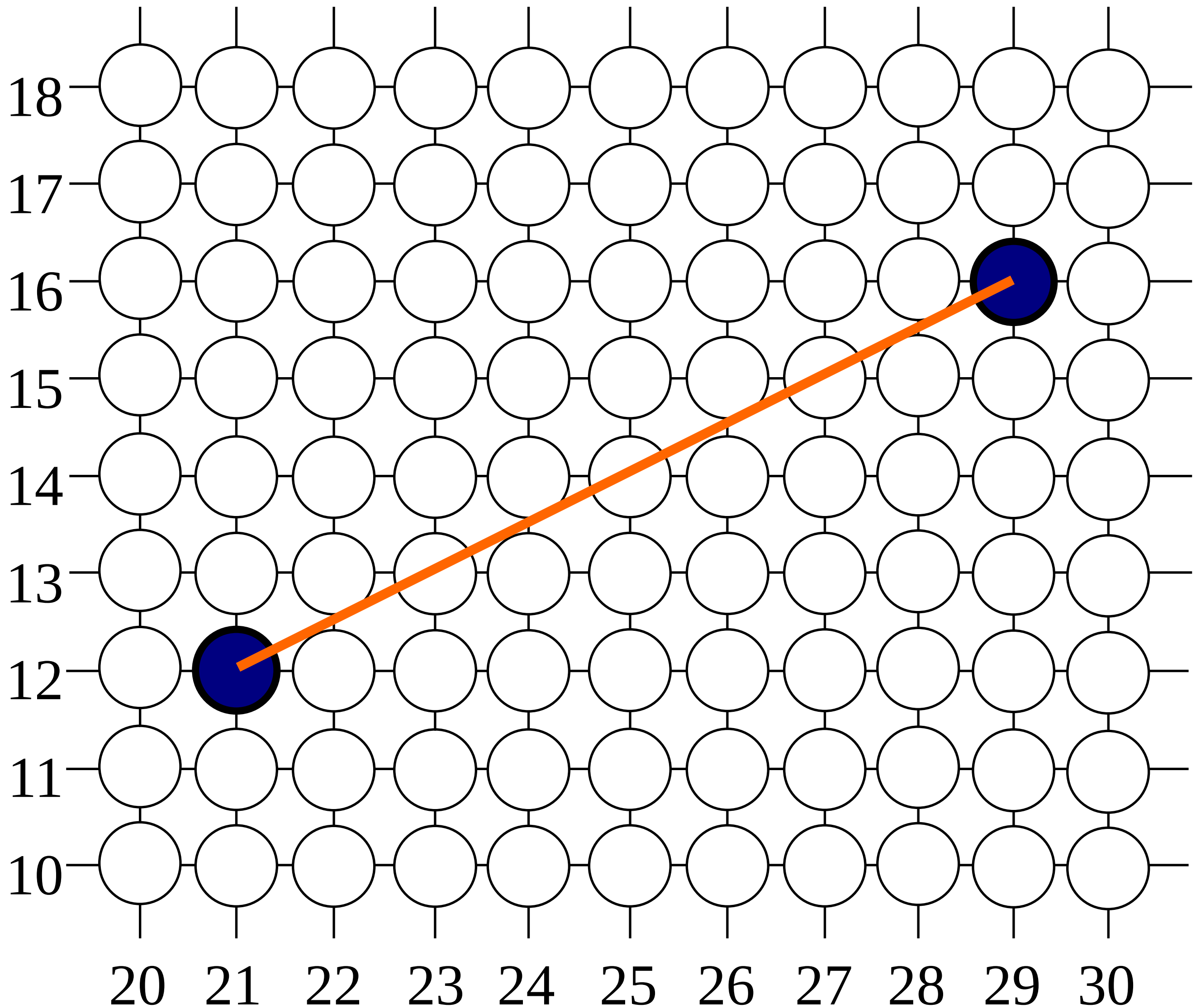


Image Representation

- A digital image is composed of discrete **pixels** or **picture elements.**
- These pixels are arranged in a **row-column** fashion to form a rectangular picture area, some times referred to **a raster.**
- Clearly the total number of the pixels in an image is a function of **the size of the image** and the number of the **pixels per unit length** (e.g. inch) in the horizontal as well as the vertical direction.
- This number of pixels per unit length is referred to as the **resolution of the image**.
- Thus a **3 x 2 inch image** at a resolution of **300 pixels per inch** would have a total of **540,000 pixels**.

Image Representation

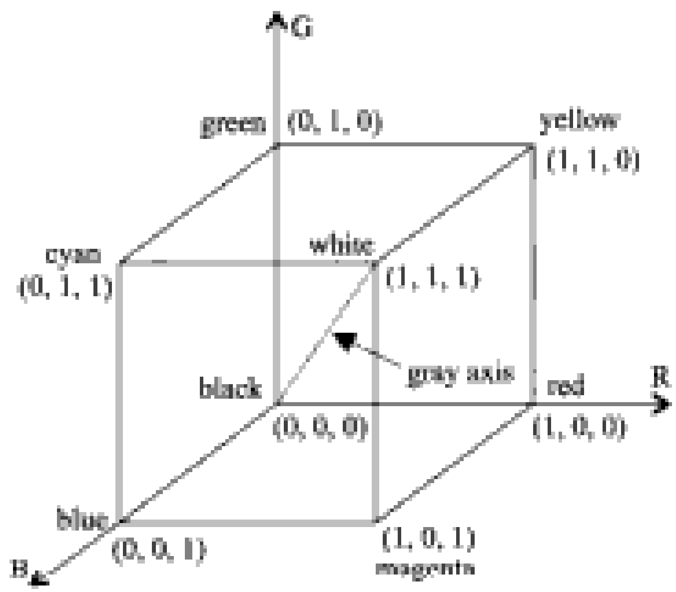
- Frequently **image size** is given as
  - the total number of pixels in the horizontal direction times the total number of pixels in the vertical direction.
- For example, **512 x 512,**
  640 x 480,
  1024 x 768.
- Although this convention makes it relatively straightforward to gauge the **total number of pixels** in an image, it does not specify the size of the image or its resolution.
- A **640 x 480 image** would measure 6 2/3 inches by 5 inches when presented (displayed or printed) at 96 pixels per inch.
- On the other hand, it would measure 1.6 inches by 1.2 inches at 400 pixels per inch.
- The ration of an image's width to its height, measured in unit length or number of pixels, is referred to as its **aspect ratio.**

Image Representation

- Both a **2 x 2 inch image** and a **512 x 512 image** have an **aspect ratio of 1/1**, whereas both a **6 x 4 ½ inch image** and a **1024 x 768 image** have an **aspect ratio of 4/3.**
- Individual pixels in an image can be referred by their coordinates.
- Typically **the pixel at the lower left corner of an image** is considered to be at the origin (0, 0) of a pixel coordinate system.
- Thus the pixel at the **lower right corner** of a **640 x 480 image** would have coordinates **(639, 0),**
  - whereas the pixel at the upper right corner would have coordinates **(639, 479).**
- The task of composing an image on a computer is essentially a matter of setting pixel values.
- The collective effects of the pixels taking on different color attributes give us what we see as a picture.

The RGB Color Model

- Color is a **complex, interdisciplinary subject spanning from physics to psychology.**
- Here, we only introduce the basics of the most widely used color representation method in computer graphics.
  - Figure shows a color coordinate system with **three primary colors:**
    - **R (Red),**
    - **G(Green) and**
    - **B(Blue).**
  - Each primary color can take on an intensity value ranging from **0(off - lowest) to 1 (on - highest).**
  - Mixing these **three primary colors** at different intensity levels produces a variety of colors.



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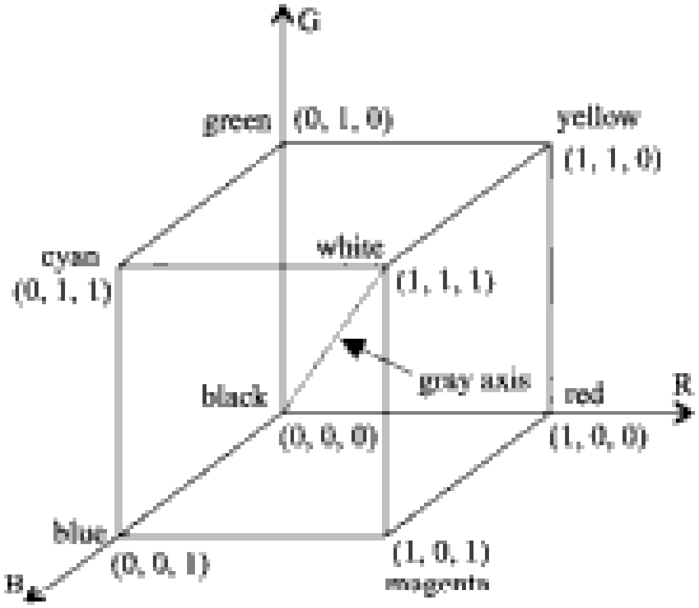
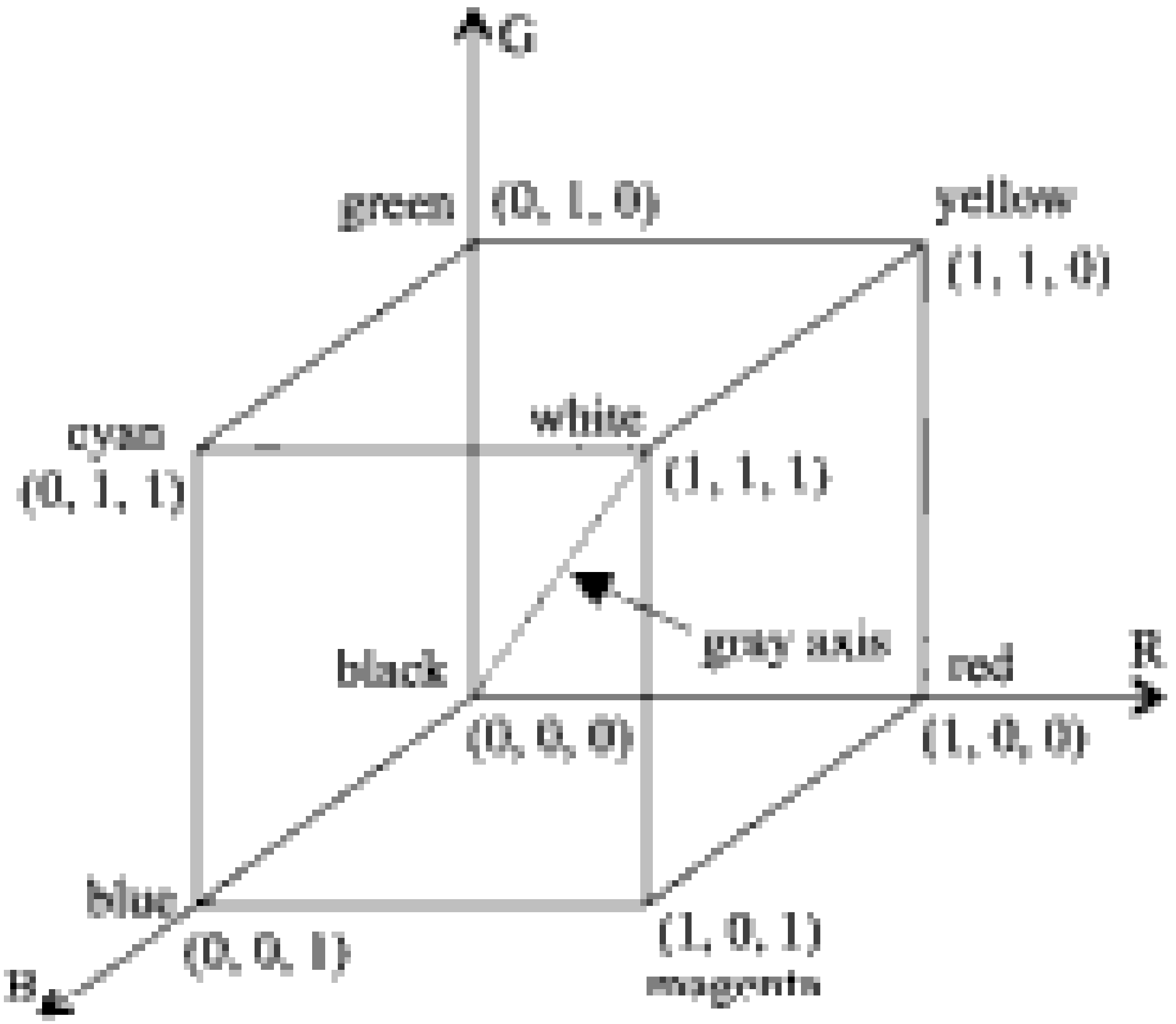


The RGB Color Model

- White = R + G + B
- R = Red
- G = Green
- B = Blue



The RGB Color Model

- In the CMY model, we begin with **white** and **take away the appropriate primary components** to yield a desired color.
- For example, if we **subtract red from white**, what remains consists of **green and blue**, which is **cyan.**

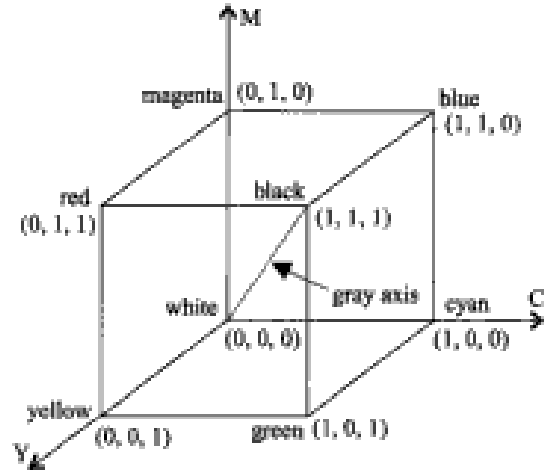


Fig. 2-2 The CMY color space.

- Looking at this from another perspective,
  - we can use the amount of cyan, the complementary **color of red**, to control the amount of red, which is equal to **one minus the amount of cyan**.
- Figure shows a coordinate system using the three primaries' complementary colors: **C (cyan)**, **M (magenta)**, and **Y (yellow)**.

- **C = Cyan,**
- **M = Magenta** and
- **Y = Yellow**
- **C+M+Y = Black**

The RGB Color Model

- **CMY Model**

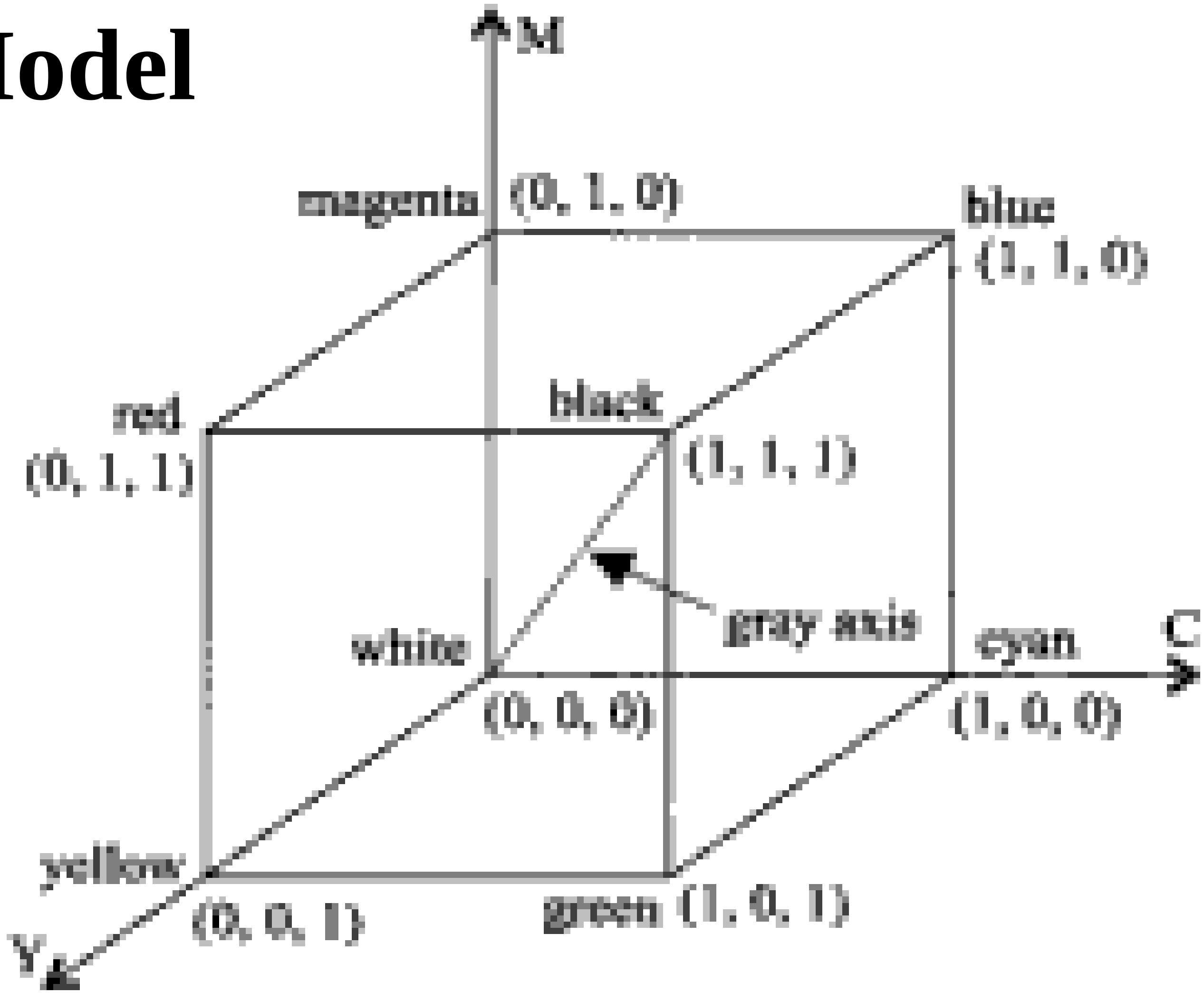


Fig. 2-2 The CMY color space.

The RGB Color Model

- The corner of the **CMY color cube** that is at
  - (0,0,0) corresponds to white, whereas
  - the corner of the cube that is (1,1,1) represents black
  - **Black means (no red, no green, no blue).**
- The following formula summaries the conversion between the two color models:

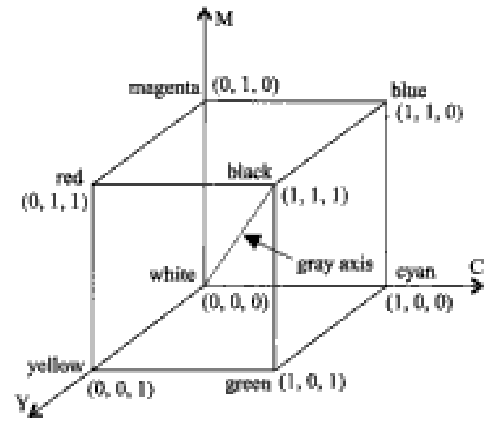


Fig. 2-2 The CMY color space.

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

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.**
- 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.**

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

Fig. 2-3 Direct coding of colors using 3 bits.

Direct Coding

- A widely accepted industry standard uses **3 bytes, or 24 bits, per pixel, with one byte for each primary color.**
- This way we allow each primary color to have **256 different intensity levels**,
  - **corresponding to binary values from 00000000 to 11111111.**
- Thus a pixel can take on **a color from 256 x 256 x 256** or
  - **16.7 million possible choices.**
- The 24-bit format is commonly referred to as **the true color** representation, for the difference between two colors that **differ by one intensity level** in one or more of the primaries is virtually **undetectable** under normal viewing conditions.
- Hence a more precise representation involving more bits is of little use in terms of perceived color accuracy.

Direct Coding

- A notable special case of direct coding is the representation of
  - **black-and-white (bilevel)** and
  - **gray-scale images**, where the **three primaries** have the same value and hence need not be coded separately.
- A **black-and-white** image requires only **one bit per pixel**, with bit value **0 representing black** and **1 representing white.**
- A **gray-scale image** is typically coded with **8 bits per pixel** to allow **a total 256 intensity** or **gray levels.**
- Although this direct coding method features simplicity and has supported a variety of applications, we can see a relatively high demand for storage space when it comes to the **24-bit standard**.
- For example, **a 1000 x 1000 true color image** would take up **three million bytes.**
- Furthermore, even if every pixel in that image had a different color, there would only be **one million colors** in the image.
- In many applications the number of colors that appear in any one particular image is much less.
- Therefore the **24-bit representation's ability** to have **16.7 million different colors** appear simultaneously in a single image seems to be somewhat overkill.

Lookup Table

- Image representation using a lookup table can be viewed as a compromise between our desire to have a lower storage requirement and our need to support a reasonably sufficient number of simultaneous colors.
- In this approach **pixel values** do not code colors directly.
- Instead, they are addresses or indices into a **table of color values.**
- The color of a particular pixel is determined by the color value in the table entry that the value of the pixel references.

- Figure shows a lookup table with **256 entries.**
- The entries have addresses **0 through 255.**
- Each entry contains a **24-bit RGB color value.**
- Pixel values are now **1-byte**, or **8-bit**, quantities.

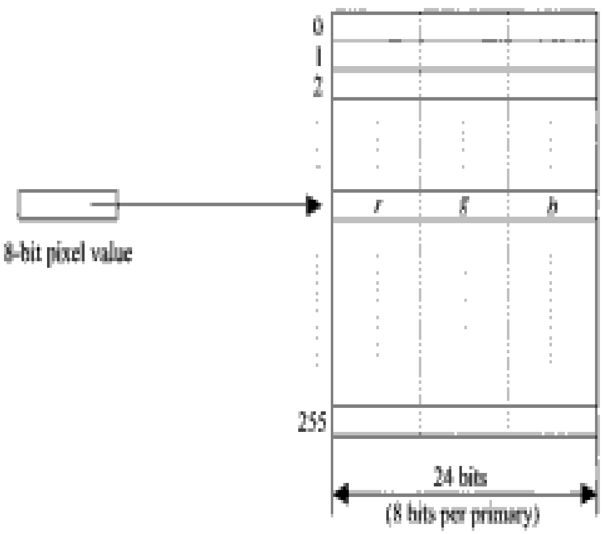


Fig. 2-4 A 24-bit 256-entry lookup table.

Lookup Table

- The color of a pixel whose value is i, where **0<=i<=255**, is determined by
  - the color value in the table entry whose address is i.
- This **24-bit 256-entry look up table** representation is often referred to as the **8-bit format**.
- It reduces the storage requirement of a **1000 x 1000 image** to one million bytes plus 768 bytes for the color values in the lookup table.
- It allows **256 simultaneous colors** that are chosen from 16.7 million possible colors.
- It is important to remember that,
  - using the lookup table representation,
  - an image is defined not only by its pixel values but also
  - by the color values in the corresponding lookup table.
- **Those color values from a color map for the image.**

That's All