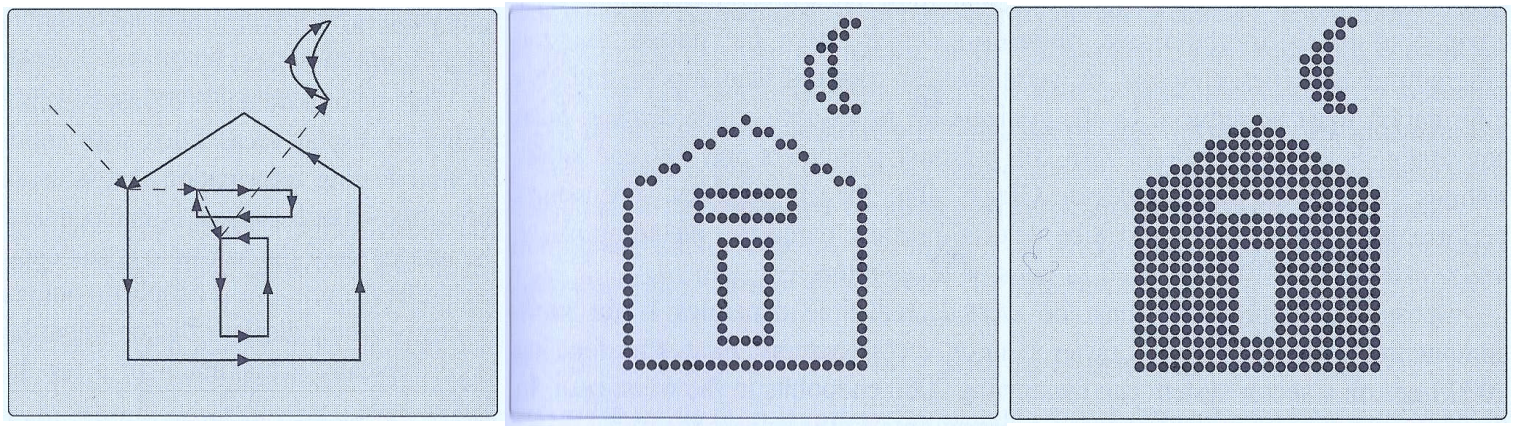
FACULTY OF ENGINEERING AND ARCHITECTURE

# E016712: Computer Graphics

## Graphics Formats



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# Overview

- Graphic formats
  - Vector graphics
  - Raster graphics
- Color perception and reproduction
  - Tristimulus theory of color perception
  - True color images
  - Indexed color images

# Graphic formats

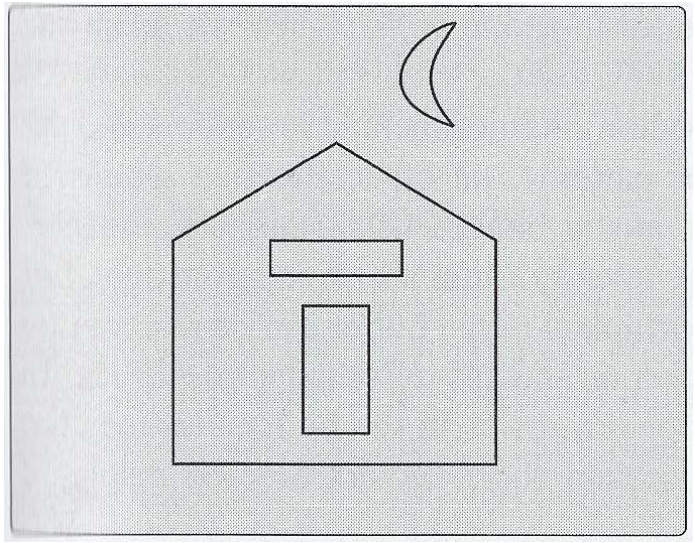
# Vector and raster graphics

Two main types of computer images

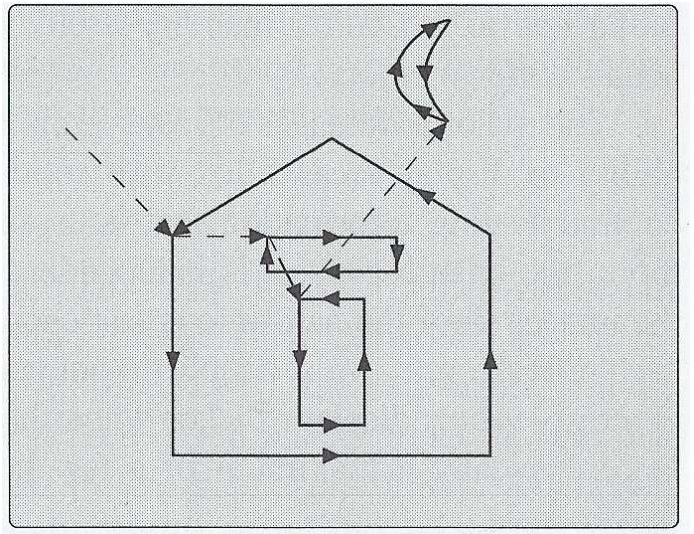
- Raster images
  - Each pixel separately stored
- Vector images
  - Image consists of objects
  - Objects are represented by their contours

# Vector graphics

- Represented in terms of vertices (points) and lines.
- Lines can be straight or curved; Generated mathematically
- Ideal for “simple” images with precise contours (cartoons, logo’s,…)
- For displaying on Cathode-Ray Tube (CRT) screen, a vector generator converts the digital coordinates to analog voltages for beam deflection



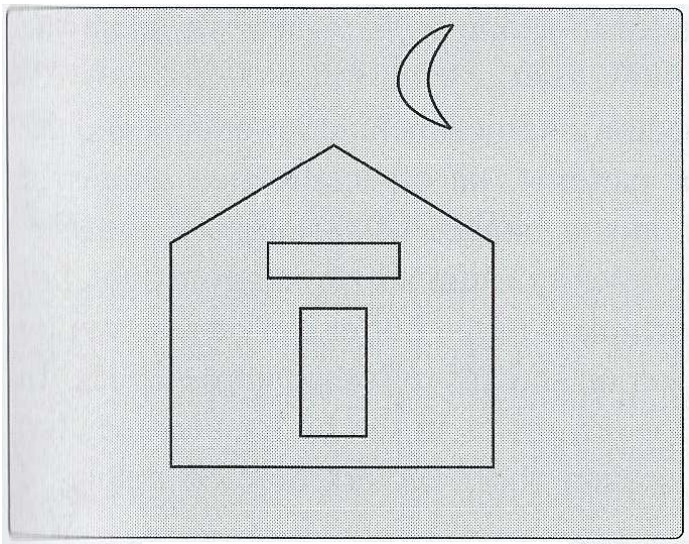
Ideal line drawing



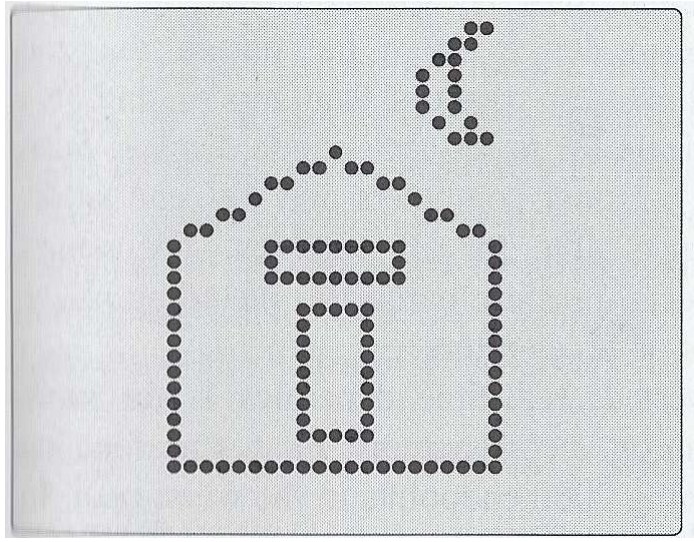
Vector scan

# Raster graphics

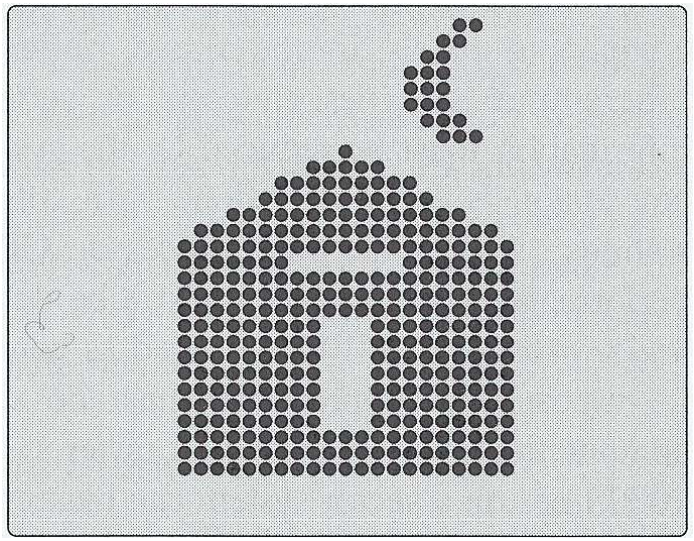
- Represented in terms of elementary picture elements: pixels
- Well suited for images with a variety of intensity levels, such as digital photographs and other “realistic” images
- Commonly referred to as bitmap (BMP) even though bitmap strictly speaking applies only to binary systems



Ideal line drawing

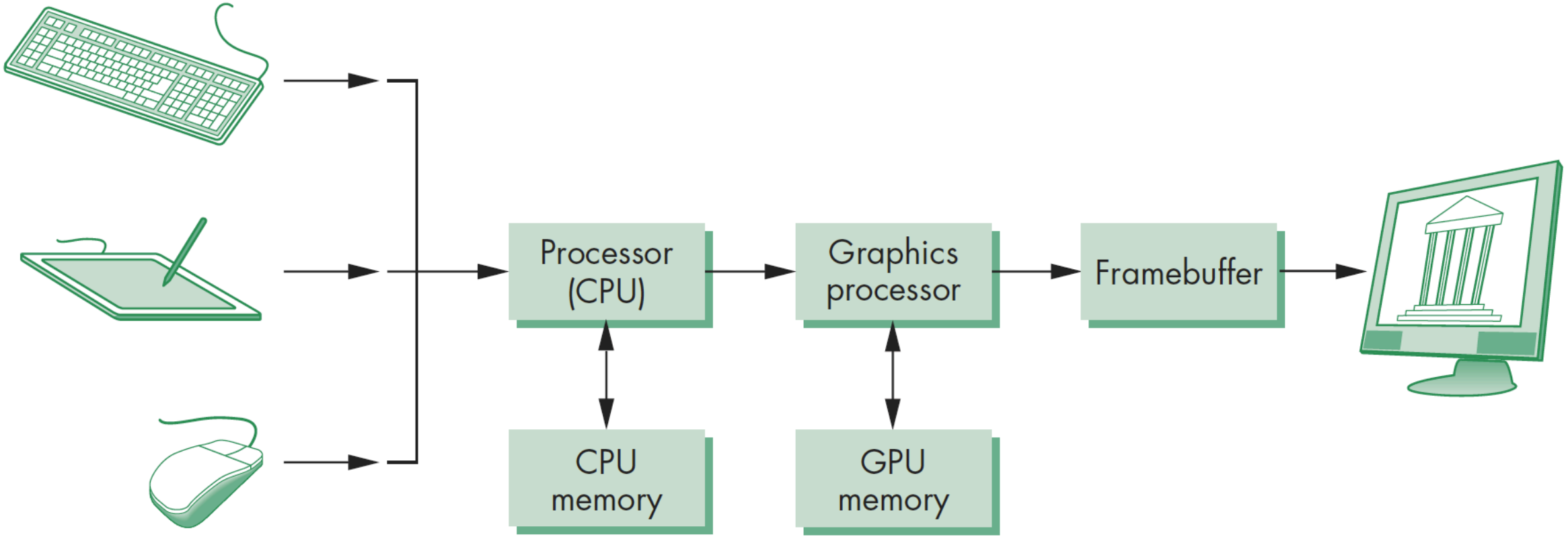


Raster outline

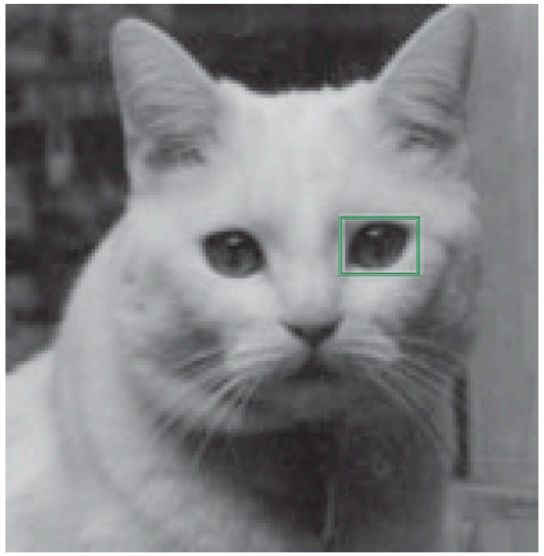


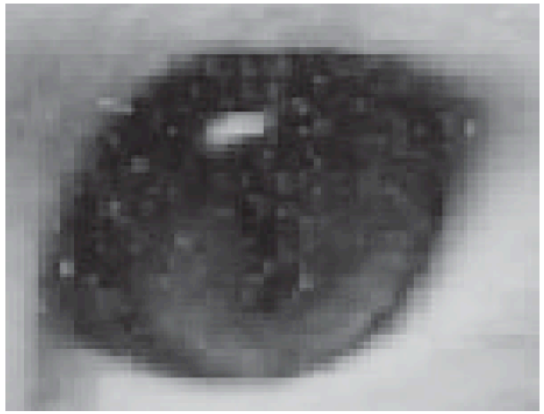
Raster scan with filled primitives

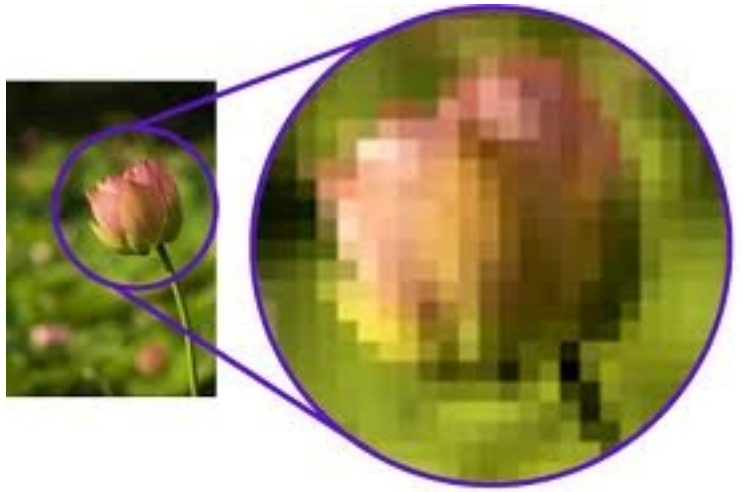
# A graphics system



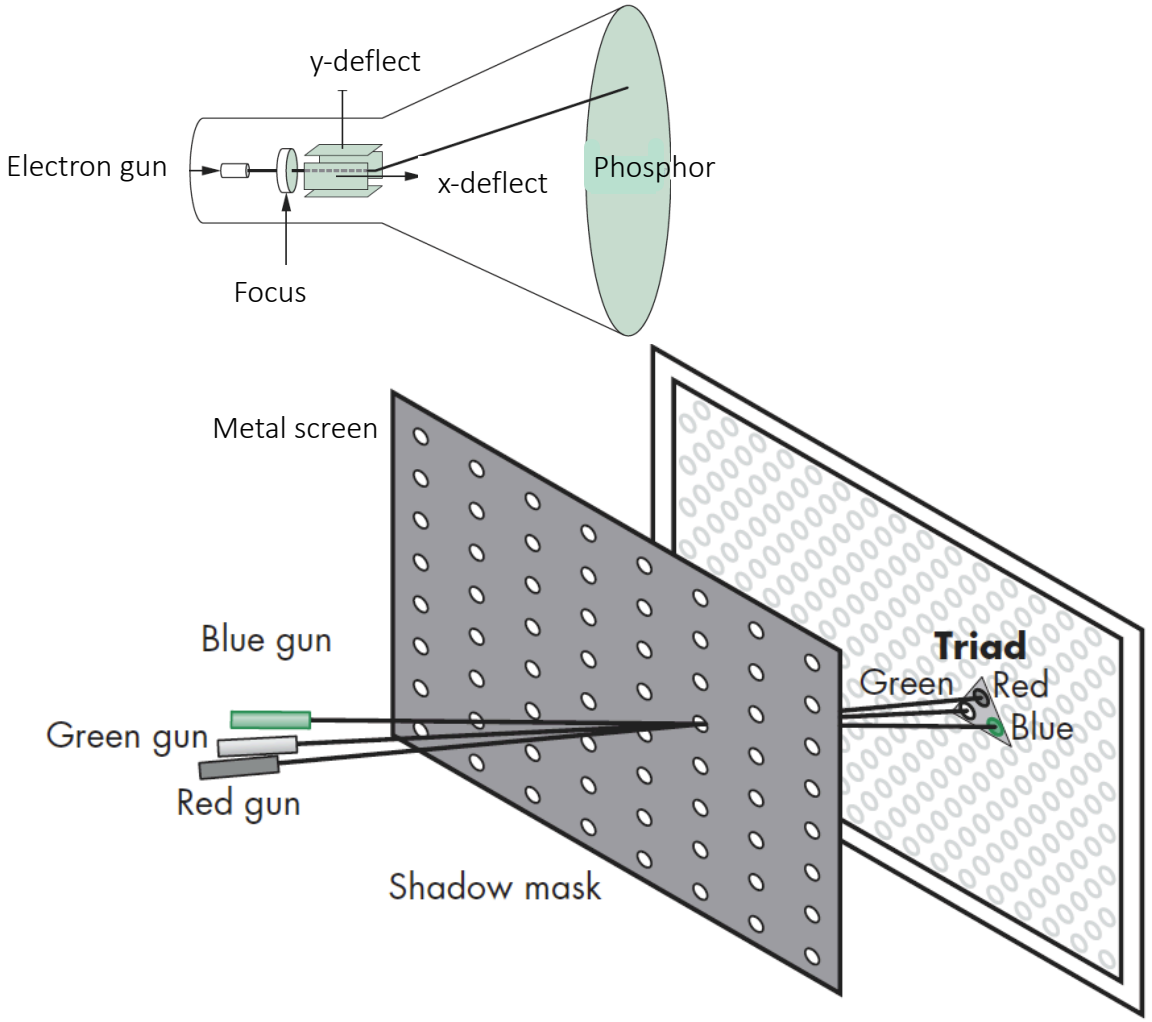
# Examples of raster images



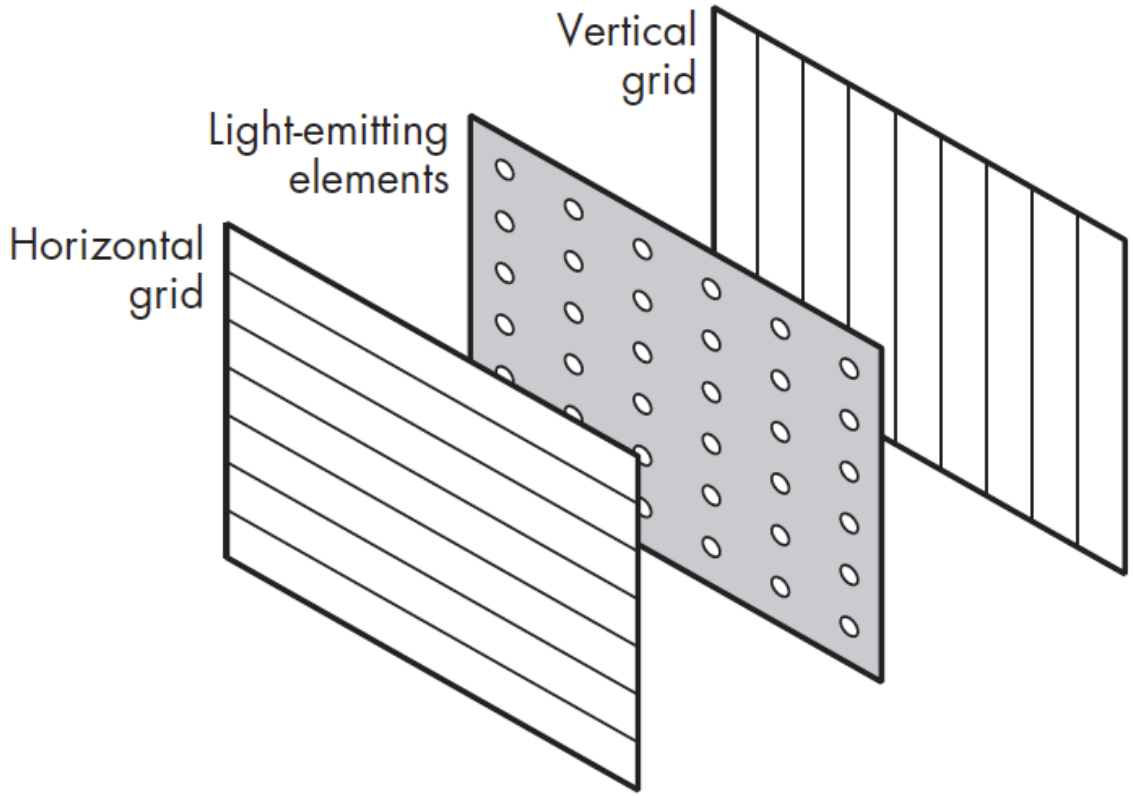




# Output devices




Shadow-mask CRT

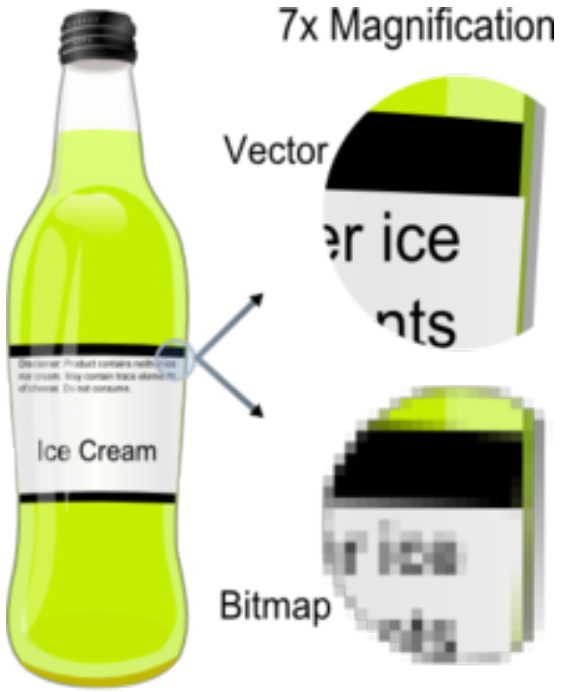



Generic flat-panel display (LED, LCD or plasma)

# Vector versus raster systems

- Advantages of raster systems
  - Richer textural and pattern representation
  - Cheaper (repetitive regular scanning compared to complex random scan of vector systems)

- Advantage of vector systems
  - No jaggies
  - Scales up arbitrarily retaining perfectly smooth lines
  - Easier real-time manipulation

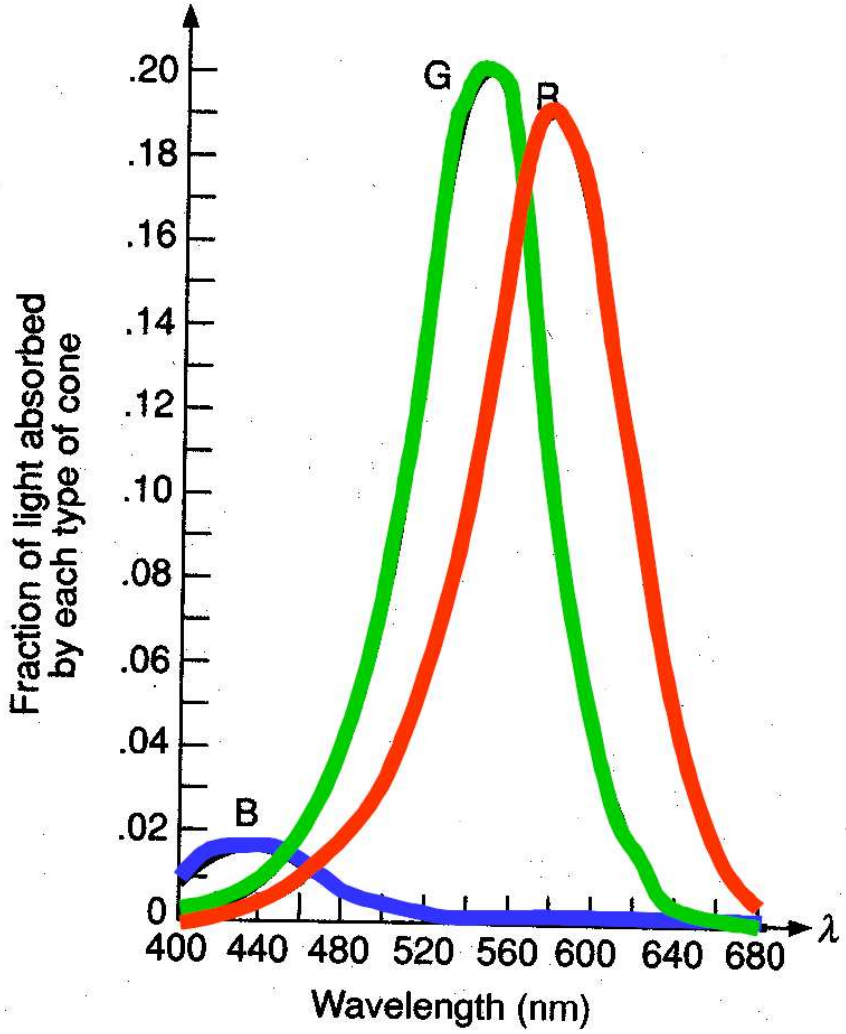


# Graphic formats

# Color perception

- Color as such does not exist in nature!
  - (Colored) light consists of electromagnetic waves of different frequencies (or wavelengths)
- Color perception is three-dimensional (3D)
  - We have three types of “sensors” in the eye, which are sensitive to different parts of the spectrum (Tristimulus theory of color)
- All color representations are hence 3D
  - Additive (RGB) ; red-green-blue
  - Subtractive (CMY) ; cyan-magenta-yellow
  - Other (HSV, Luv, Lab)
- We limit ourselves to RGB representation

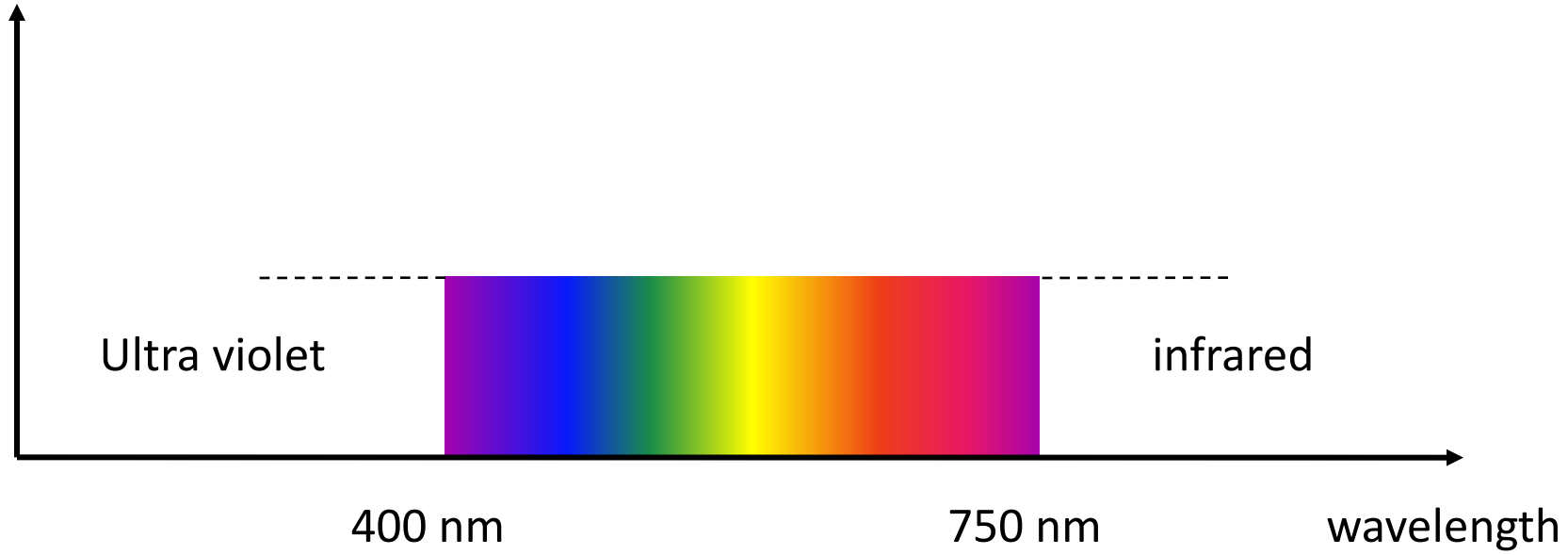
# Color perception




Spectral-response functions of the three types of cones in the human retina.

# Color perception

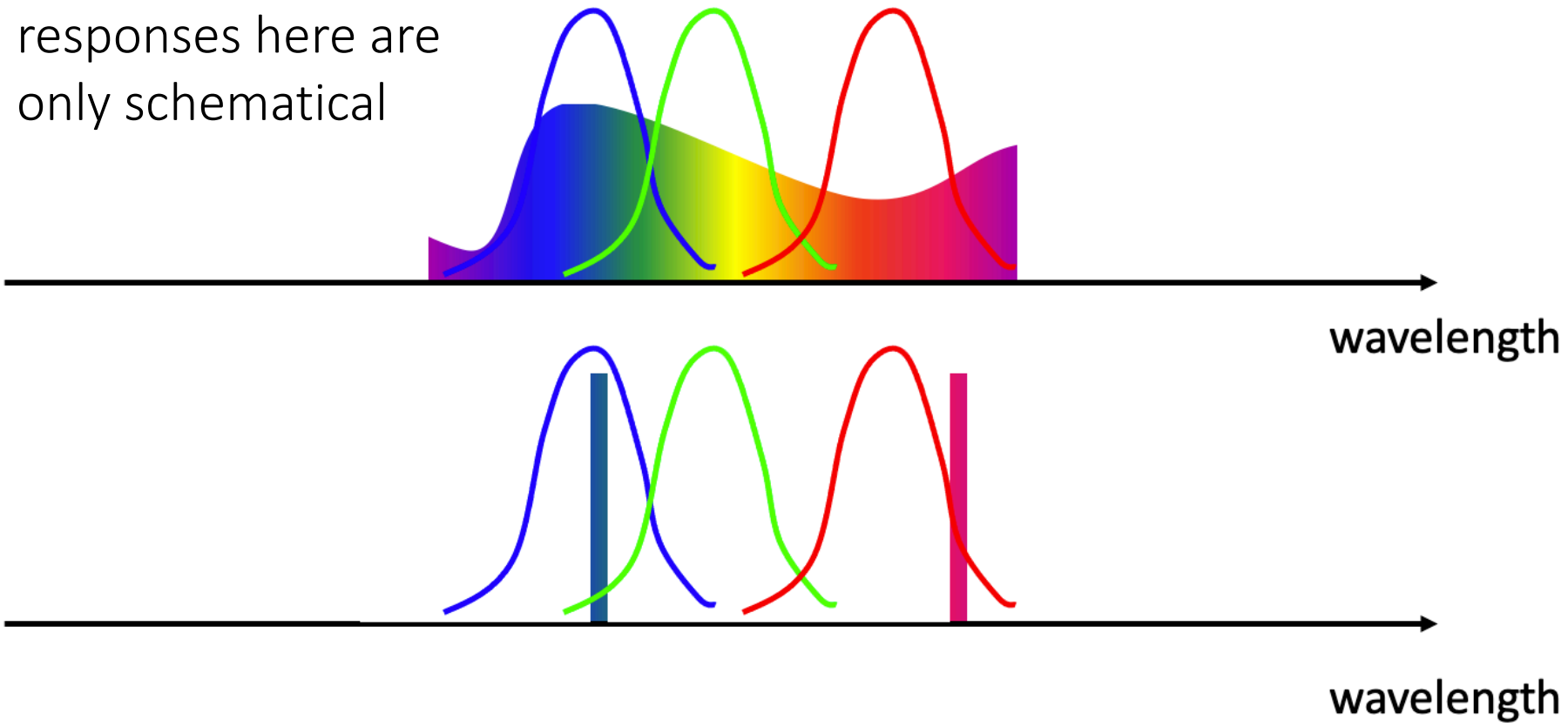
Natural white light consists of an continuous and uniform spectrum of EM waves, visible from violet to red (rainbouw)



# Color perception

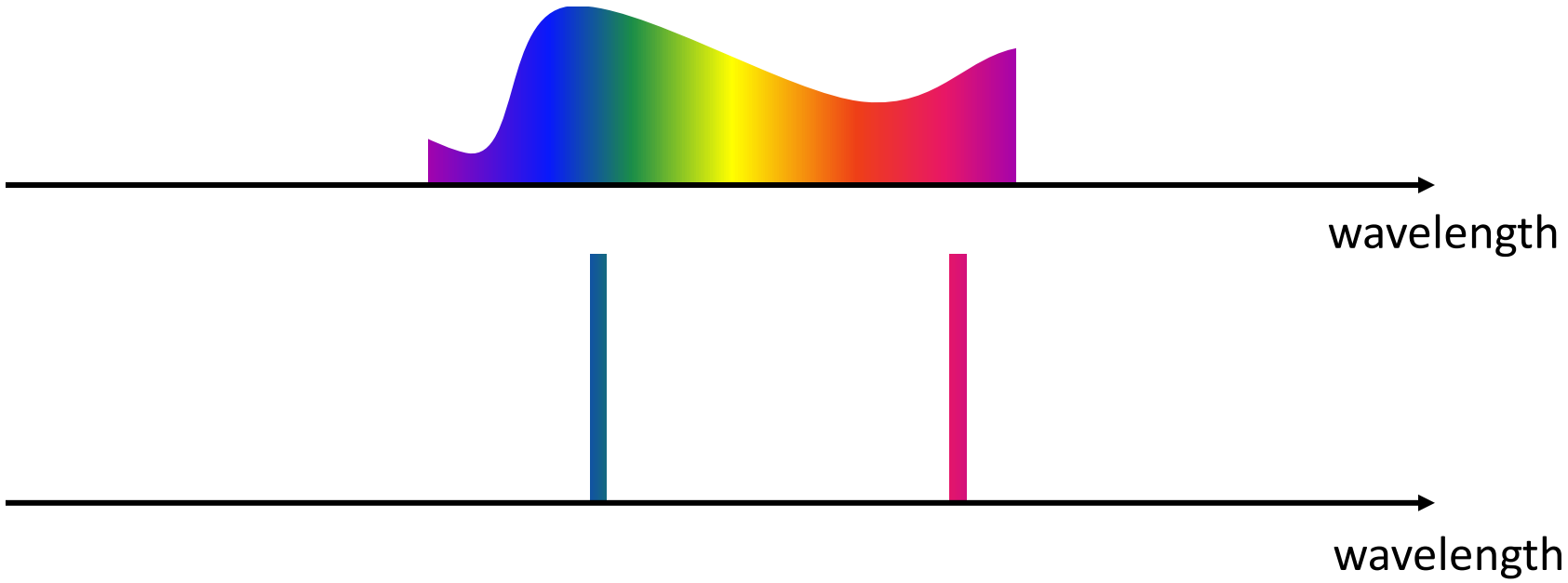
Color perception depends only on how the light activated each of the three sensors (Red, Green and Blue)

Note: Spectral responses here are only schematical



# Color perception

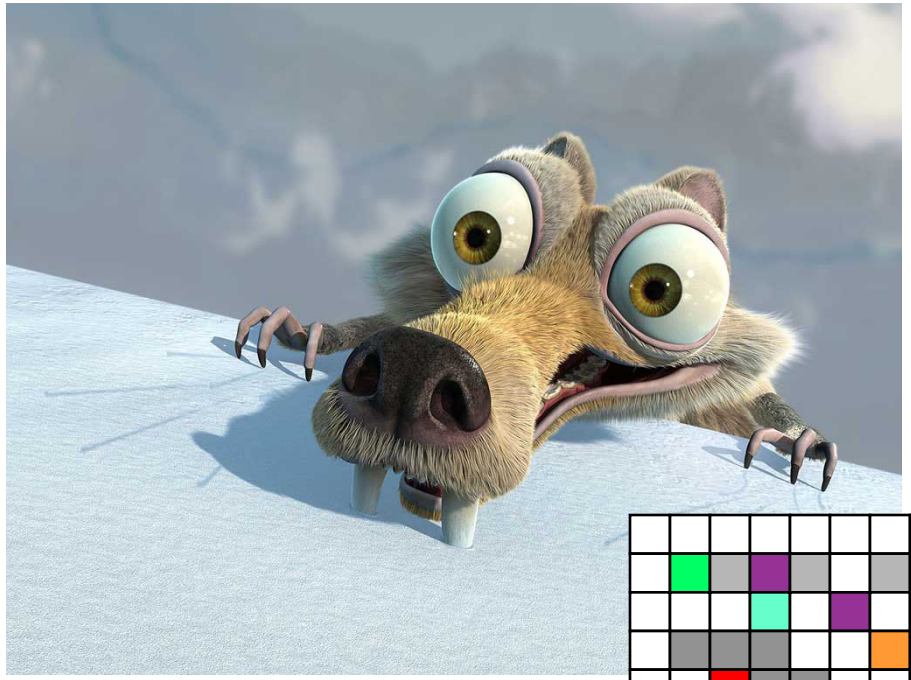
Two totally different spectra can be perceived as the same color

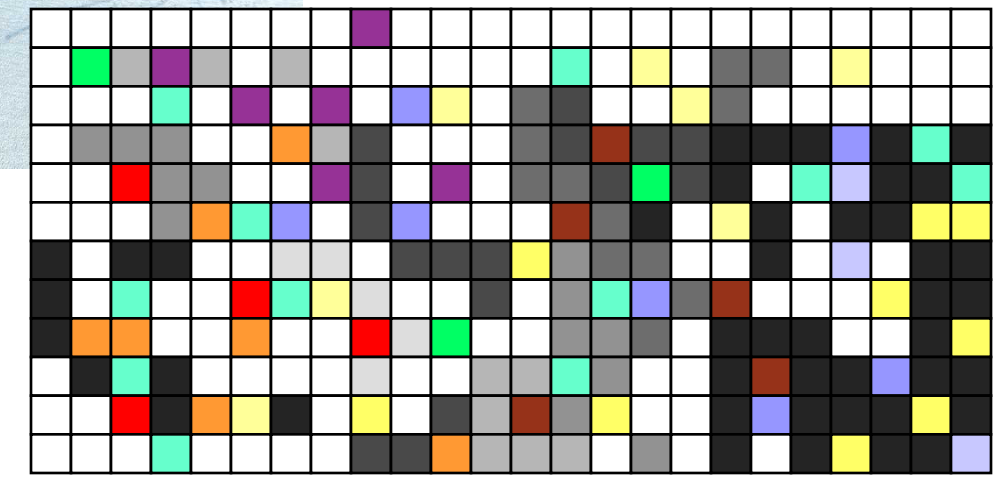


# Color perception

- Two totally different spectra can be perceived as the same color
- To reproduce artificially (the impression of) a color, it is sufficient to generate the same sensor stimuli
- This is best done with light sources with wavelengths that are close to the maximum sensitivity of the sensors, hence Red, Green, Blue → called R, G, B primaries
- This process is called additive color synthesis
  - By mixing R, G, B primaries in the right proportions, we can create impressions of all colors

# Color images





# Color images

One bit per color (0/1) – 3 bits/pixel

| R | G | B | Color |
|---|---|---|---|
| | | | |
| 0 | 0 | 0 | Black |
| 1 | 0 | 0 | Red |
| 0 | 1 | 0 | Green |
| 0 | 0 | 1 | Blue |
| 0 | 1 | 1 | Cyan |
| 1 | 0 | 1 | Magenta |
| 1 | 1 | 0 | Yellow |
| 1 | 1 | 1 | White |

# Color images

- With 8 bits per color channel → 24 bits per pixel
- In this way we can theoretically represent 16.777.216 different colors
- Human eye can differentiate “only” several hundreds of thousands of colors
- The 24-bit representation is in principle inefficient
- However, much simpler than the “optimal” one

# Color images

Eight bits per color (0-255). 24 bits/pixel

| R | G | B | Color |
|---|---|---|---|
| | | | |
| 0 | 0 | 0 | Black |
| 255 | 255 | 255 | White |
| 50 | 100 | 0 | |
| 100 | 100 | 150 | |
| 20 | 60 | 40 | |
| 0 | 255 | 100 | |
| 150 | 50 | 150 | |
| 150 | 50 | 25 | |
| 100 | 0 | 0 | |
| 200 | 200 | 255 | |

# Indexed color images

24 bits is too much for some applications

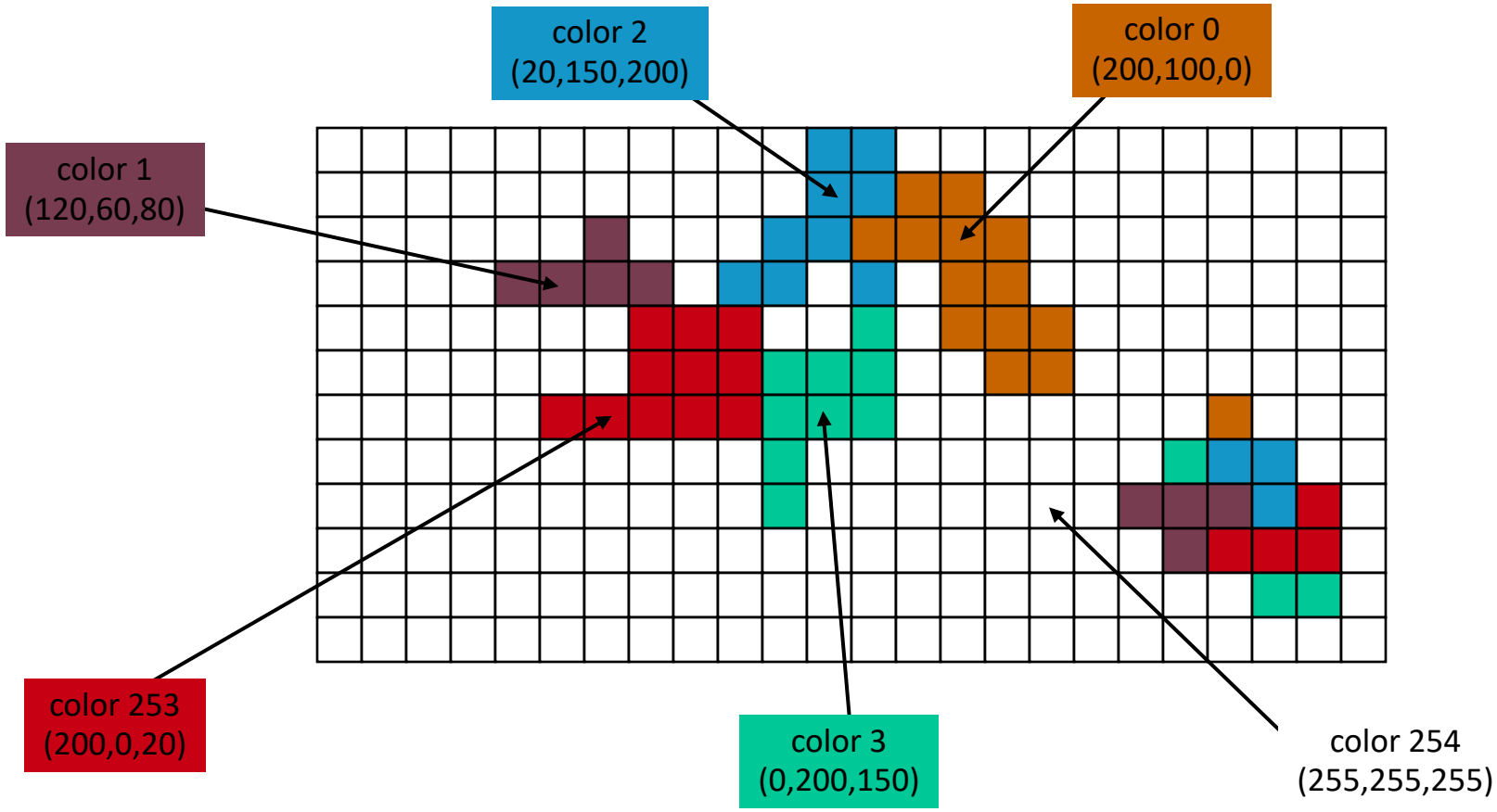
- Especially when the image contains only a limited number of colors (e.g., cartoon or logo)

Solution: instead of representing a color with 24 bits give as input the color “index”, i.e., the number of this color

- How many colors need to be displayed at a time? $N$
- How many bits are needed to represent this number? $n = \log_2(N)$
- For $N$=256, $n$=8

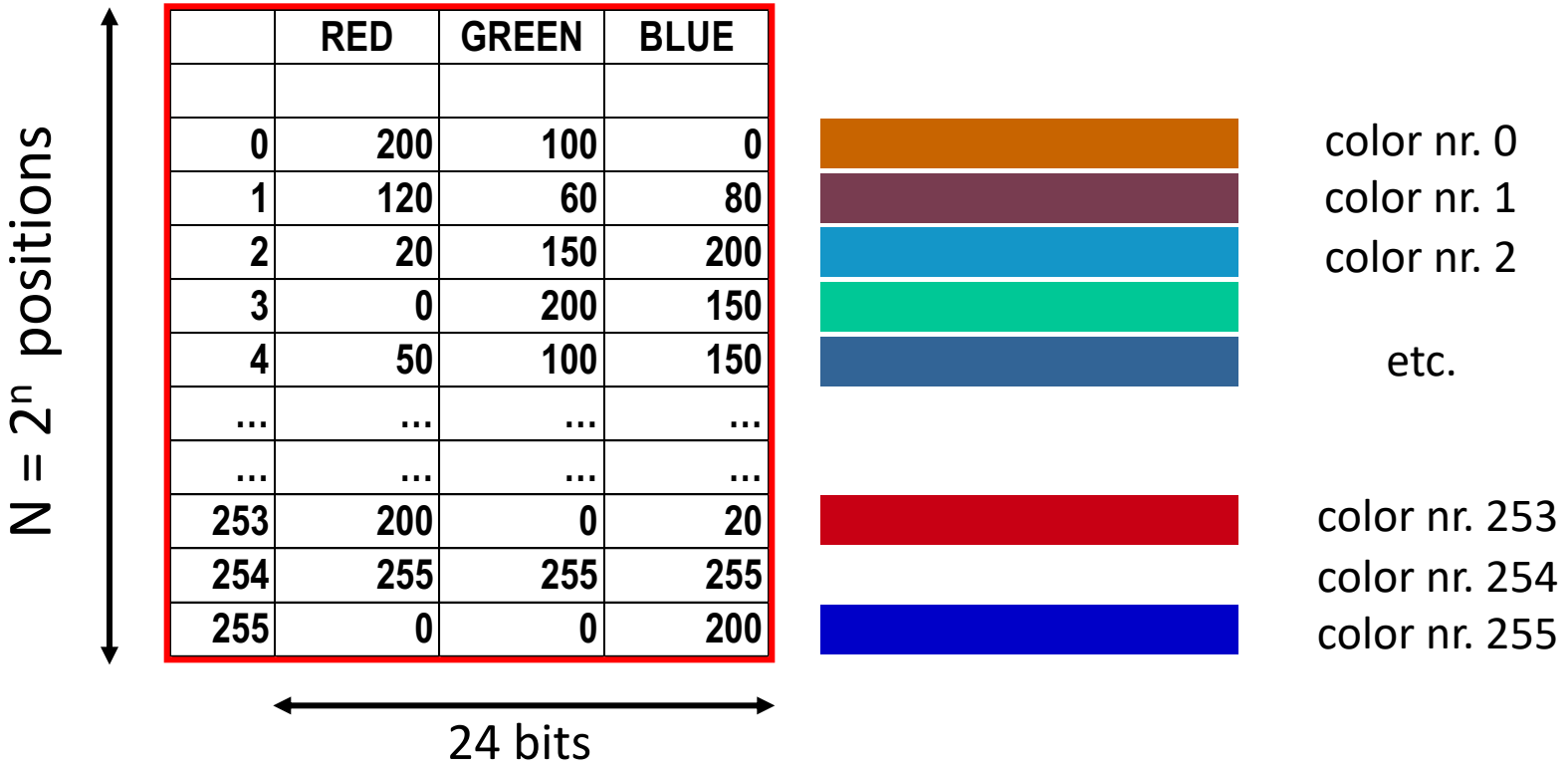
Most common are color palletes with 4, 16 and 256 colors. The color index of each pixel is then represented with 2, 4 and 8 bits, respectively.

# Indexed color images



# Indexed color images

Color-look-up (CLT) table gives the relationschip between the color index and the true color



# Problems with CLT

- It can be difficult to exchange raw image data and/or color map tables between different image files (intermediate mapping needed).

- If the original color palette for a given indexed image is lost, it can be nearly impossible to restore it.

A typical indexed 256-color image and a result of restoring it with a wrong color palette
[http://en.wikipedia.org/wiki/Indexed_color]

# Summary

- Vector and raster graphics have each their advantages in certain applications.
- By mixing R, G and B primaries in the right proportions all colors can be reproduced.
- Indexed color palettes interesting in many practical applications, especially for ‘cartoon-like’ images (with piece-wise uniform colors) and logos.