Color Theory

COMP575/COMP770

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Overview

- Welcome!
- Today:
  - **Color representation**
  - Video hardware
  - Gamma
  - Color theory
  - Homework

Color representation

- How to store colors in the computer?

Color representation

- Grays

How many colors are there?
How many bits are needed?

What does the stored value represent?
What if there are many more colors between these (not shown)?

Color representation

- Grays
  - Number of bits: 8, 32(int), 32(float)
  - Colors represented: 256, 2^32 (4.3 billion)
  - Meaning: radiant intensity, reflected intensity, arbitrary

Color representation

- Blues

How many bits are needed to mix blue in?
What should we call the values we are storing?
Should all values use the same number of bits?

Color representation

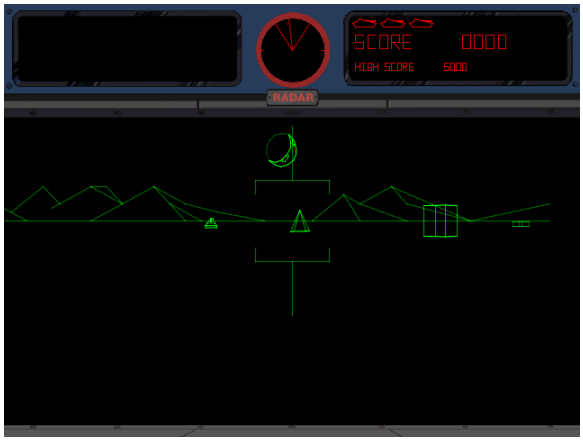
- Blues
  - Number of bits: 8, 32(int), 32(float) (per channel)
  - Channel names: brightness, lightness, blueness, blue, gray...
  - Colors represented: 256, 2^32 (4.3 billion) (per channel)
  - Meaning: radiant intensity, reflected intensity, ratio of blue, arbitrary

Color representation

- Value representation

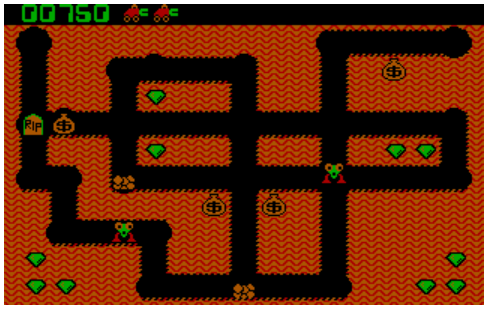
    - Bit count
    - Integer, float
- Color model
    - Red, green, blue
    - Cyan, magenta, yellow, black
    - Hue, saturation, value
    - more...
- Format details
    - Palette
    - Channel layout
    - more...
    -

Color representation

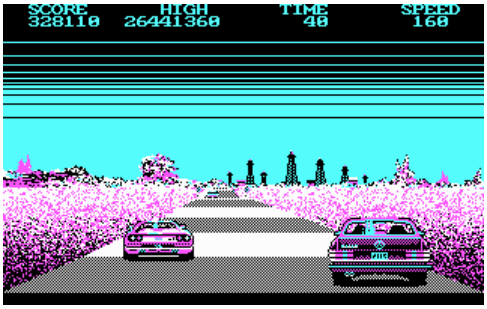


Battlezone (1980)
1 bit, colored with red and green filters.

Color representation

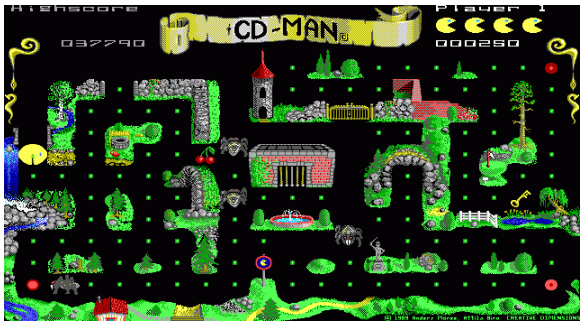


Digger (1983)
CGA 4 color mode.



Crazy Cars (1987)

Color representation



CD-Man (1992)
EGA 16 color mode.

Color representation

Jazz Jackrabbit (1994)
VGA 256 color mode.

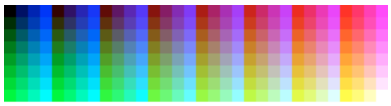
Descent (1994)

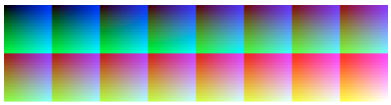
Color representation

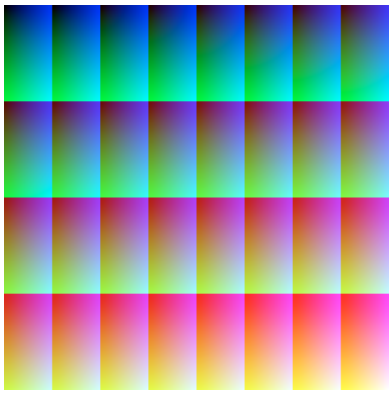
Diablo (1997)

256 colors.

Color representation







Palettes for 16 colors, 256 colors, 4096 colors, and 65536 colors.

Color representation

24 bit

Color representation

16 bit

Color representation

12 bit

Color representation

8 bit

Color representation

4 bit

Color representation

2 bit

Color representation

1 bit

Overview

- Color representation
- **Video hardware**
- Gamma
- Color theory
- Homework

Video hardware

- Cathode Ray Tube (CRT)
- Liquid Crystal Display (LCD)
- Others...

Other output include hard copies, like printouts.

Video hardware

- Cathode Ray Tube (CRT)

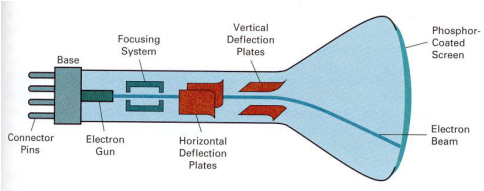


Fig 2.4, H&B

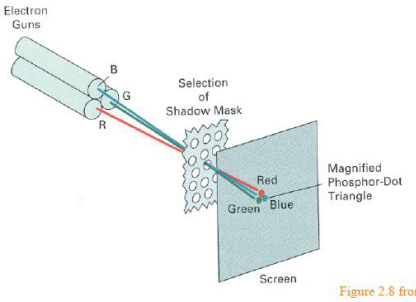
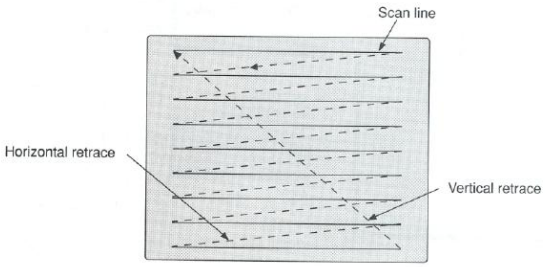


Figure 2.8 from H&B

Video hardware

- Cathode Ray Tube (CRT)

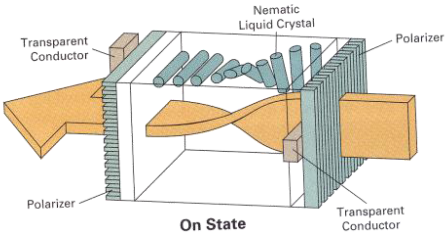


Refresh rate is usually 60-120 Hz

Figure 1.3 from FvDFH

Video hardware

- Liquid Crystal Display (LCD)



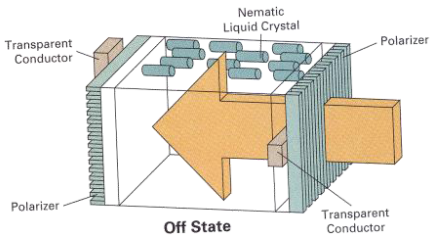


Fig 2.4, H&B

Overview

- Color representation
- Video hardware
- **Gamma**
- Color theory
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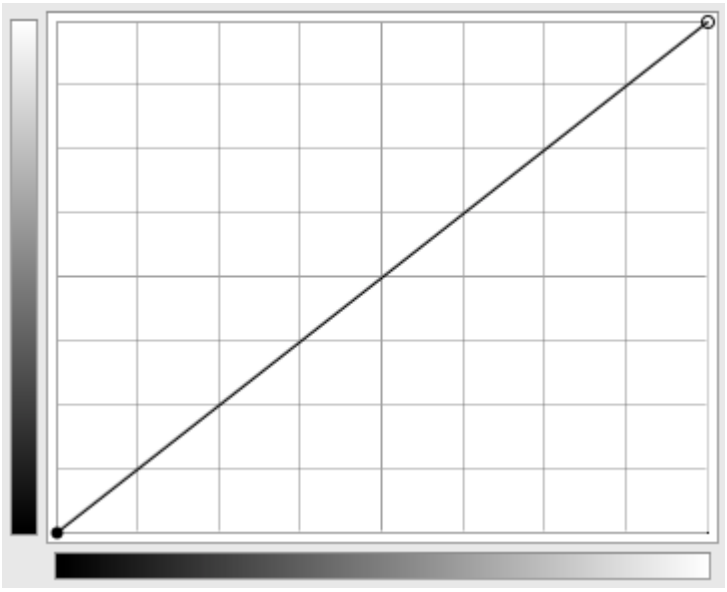
Gamma correction

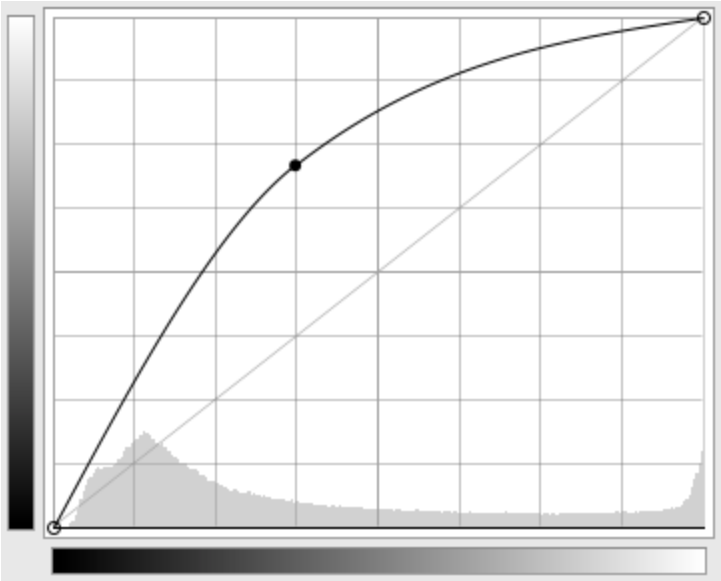
- Response curve



Bottom: input, left side: output

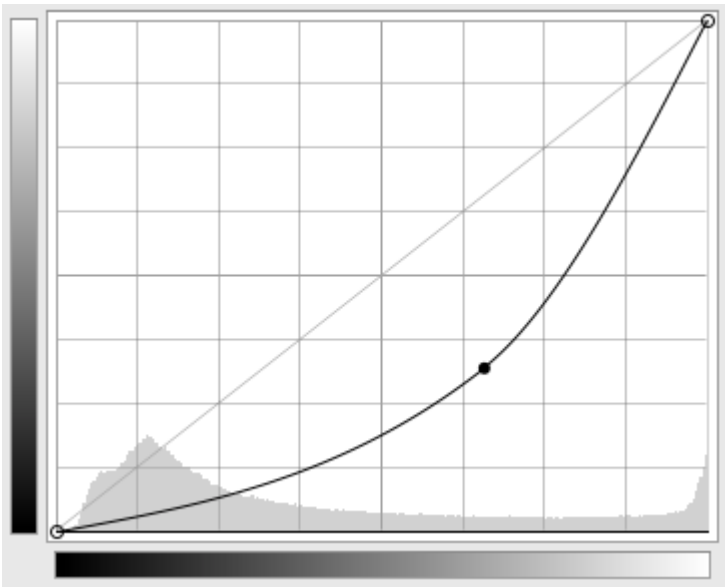
Gamma correction

- Response curve



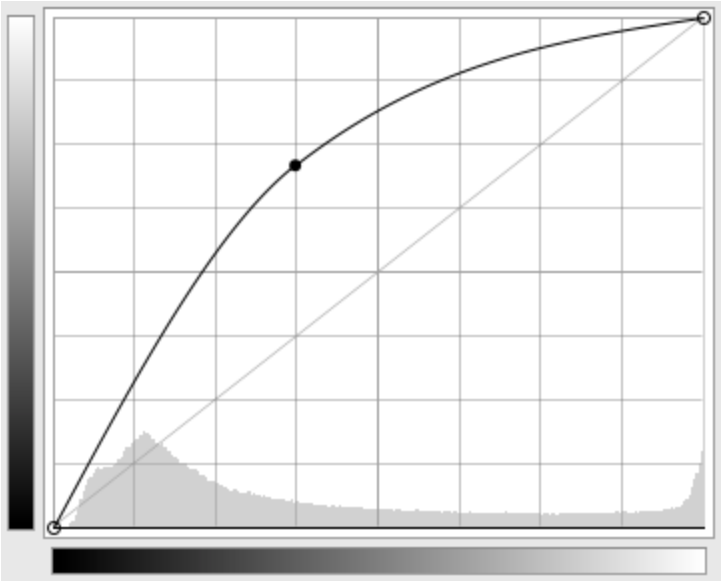
Gamma correction

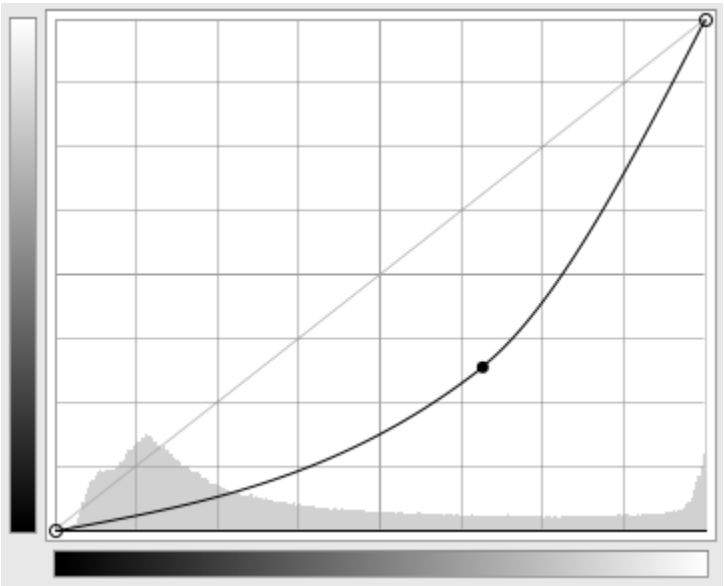
- Response curve



Gamma correction

- What functions do these curves look like?





They are similar to sqrt(x) and x^2.

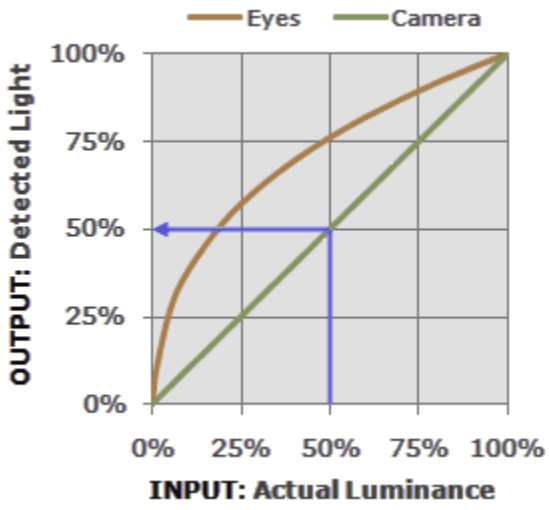
Gamma correction

- Humans perception is not always linear
  - Sound volume
  - Weight
  - Brightness
  - Weber's law

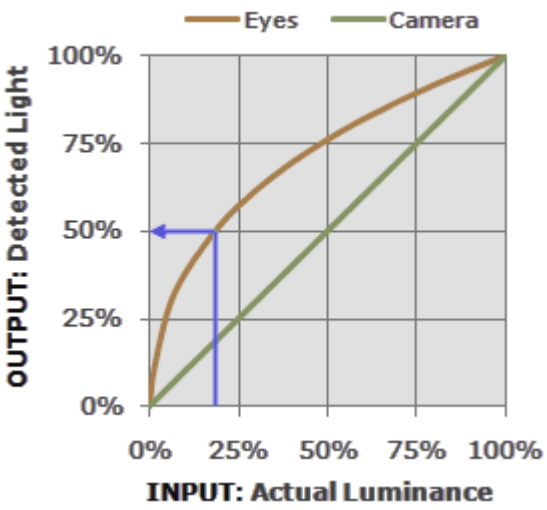
  Human perception changes with intensity.

Gamma correction

- Devices and programs use linear data
- Humans perceive logarithm data

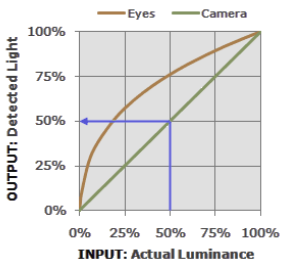


Camera
Sean McHugh - Cambridge in Colour



Eyes

Gamma correction

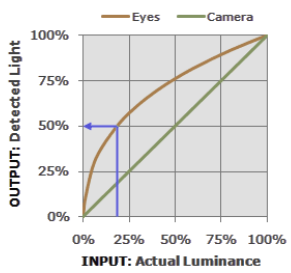


Camera

Full gray gradiant:

Linear gradiant:

Gamma correction



Full gray gradiant:

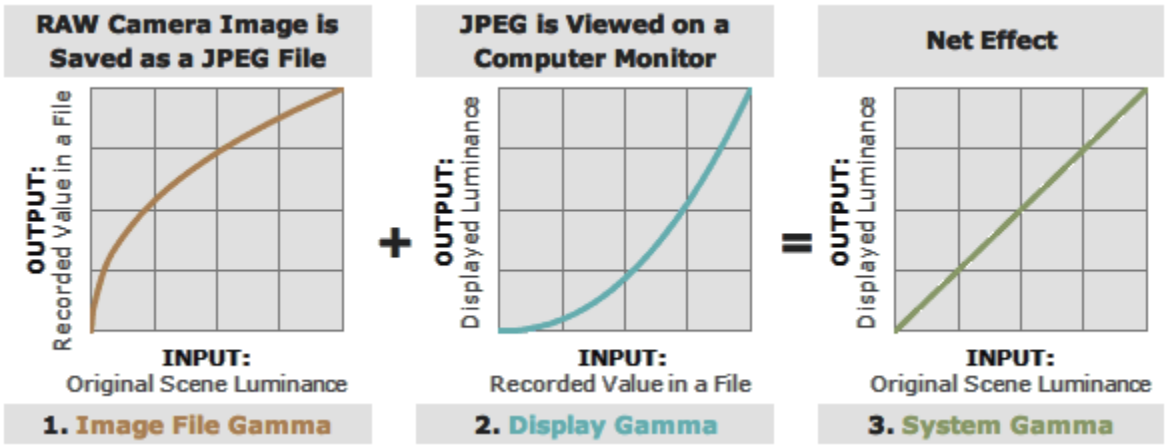
Eyes

Gamma gradiant:

Sean McHugh - Cambridge in Colour

Gamma correction

- Output devices have their own gamma curve!
- Normalizes image gamma back to linear luminance



Sean McHugh - Cambridge in Colour

Gamma correction

- Gamma encoding
  - Applied when creating image

    - $V_{out} = AV_{in}^{\frac{1}{\gamma}}$
- Gamma decoding
    - Applied at output
    - $V_{out} = AV_{in}^{\gamma}$

Overview

- Color representation
- Video hardware
- Gamma
- **Color theory**
- Homework

Color Theory

- Mixing modes
- Light
- Color spaces

Color Theory

- Mixing modes
    - Subtractive
    - Mixes reflective materials
    - Removes light (absorption)

Color Theory

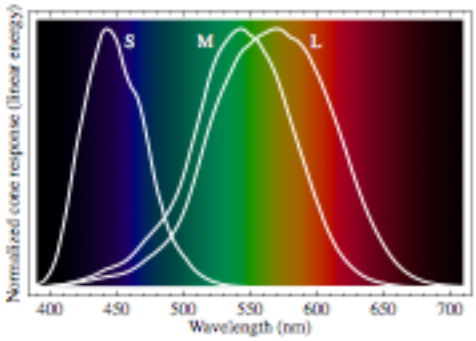
- Mixing modes
  - Additive
  - Mixes emmissive materials
  - Adds light

Color Theory

- Light
  - We only care about tiny visible portion

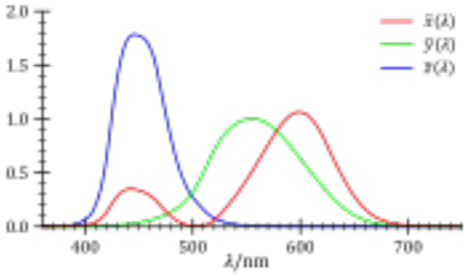
Color Theory

- Human eyes have 2 types of sensors
  - Rods - very sensitive, no color
  - Cones - color



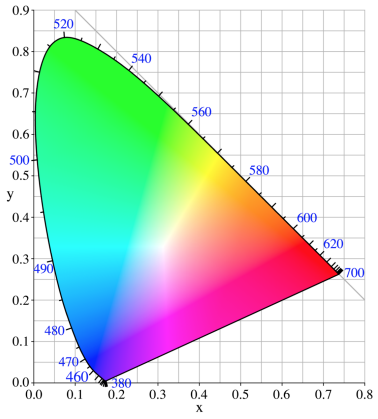
Color Theory

- CIE 1931 standard



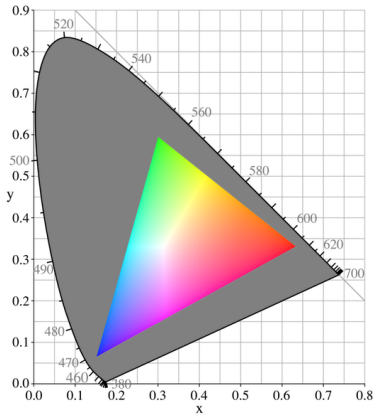
Color Theory

- CIE 1931 gamut



Color Theory

- Modern sRGB gamut



Overview

- Color representation
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- **Homework**

Homework

- Questions?