CSC 133

Object-Oriented Computer Graphics Programming

Basic Graphics

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SACRAMENTO STATE

Display

Problem?

[redacted]

★☆☆☆☆ **Only 21 inch not 24 inch**

Reviewed in [redacted] on 29 January 2021

Verified Purchase

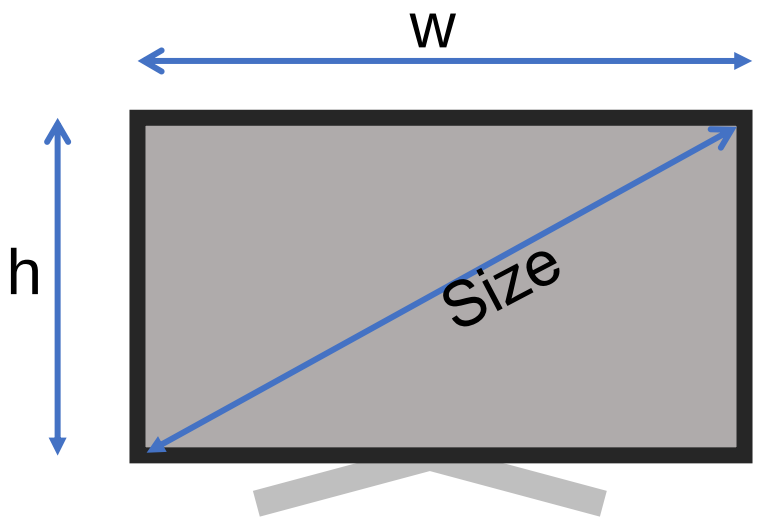
I have not used it so far but I am giving rating just because it's not 24 inch. It is 21 inch monitor to which company is claiming of 24 inch.

Helpful Report

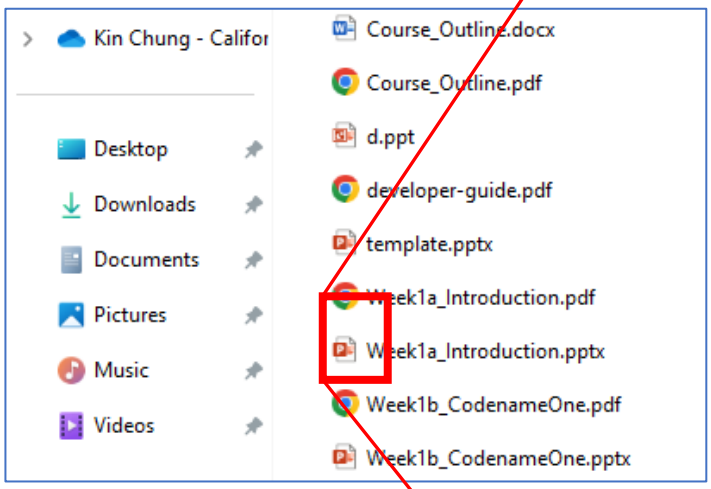
Monitor Size and Resolution

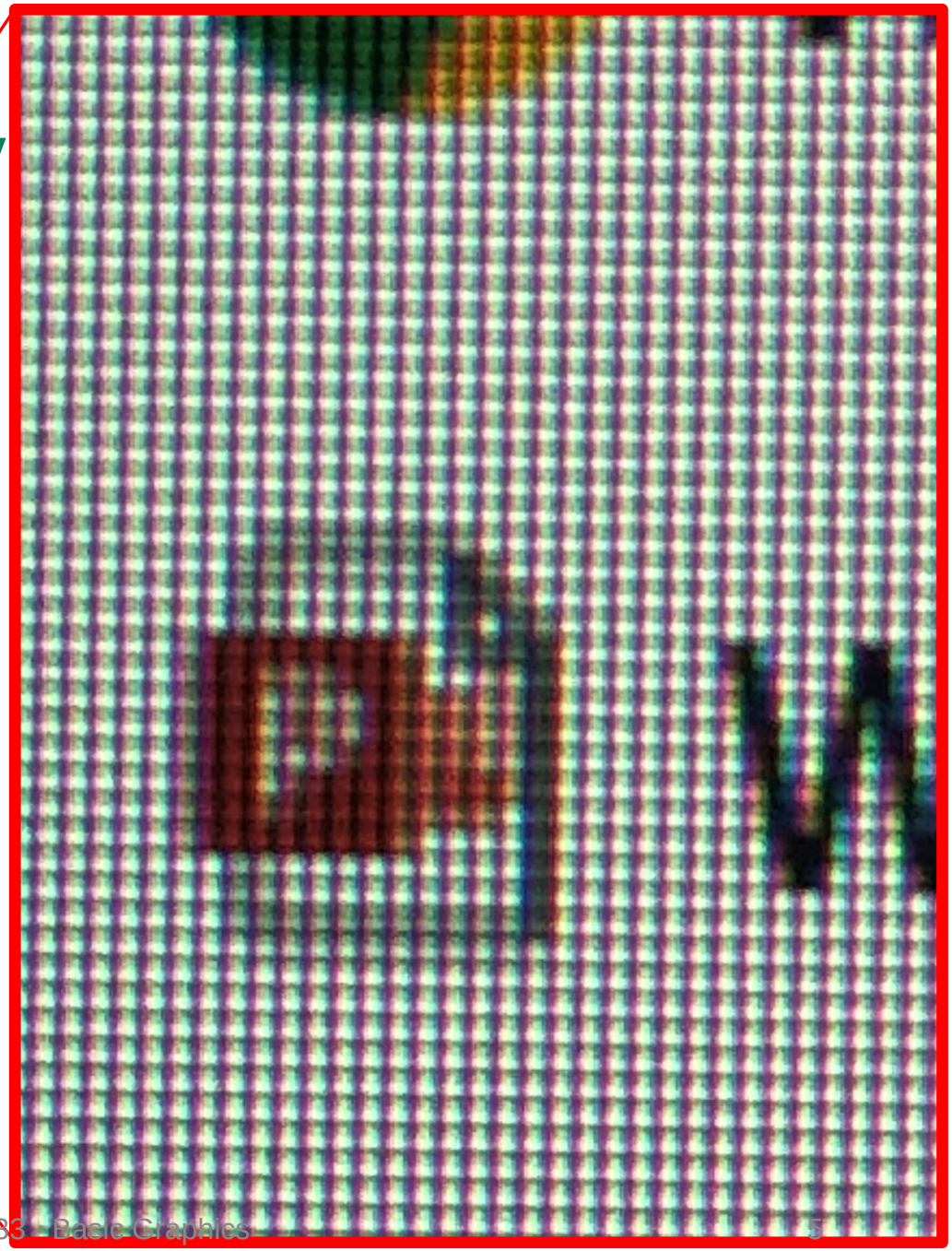
Resolution

- 720p/i (HD): h = 720
- 1080p/i (FHD): h = 1080
- 2k: w ~ 2000
- 4k: w ~ 4000
- 8k: w ~ 8000



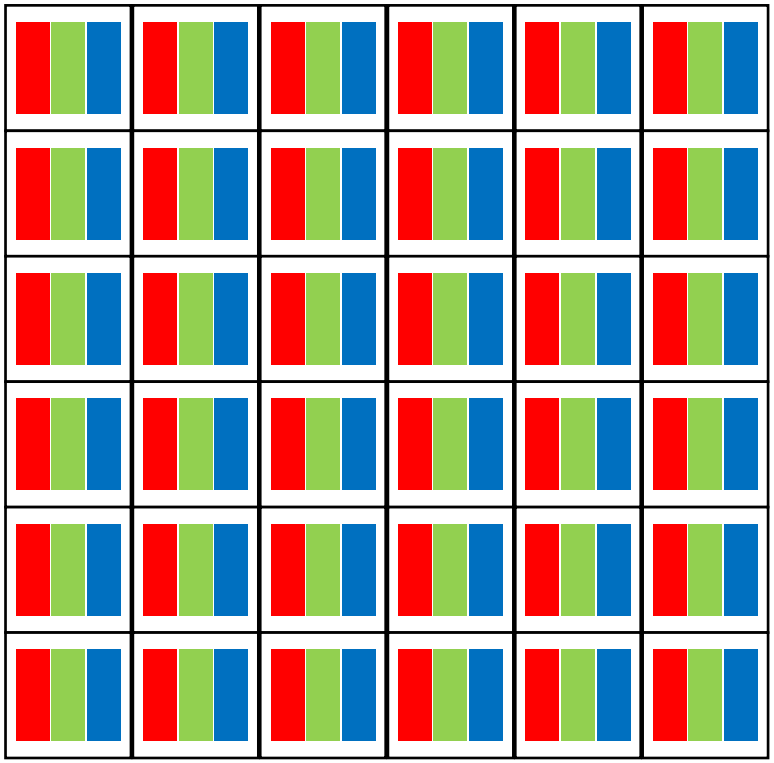
Look Closely





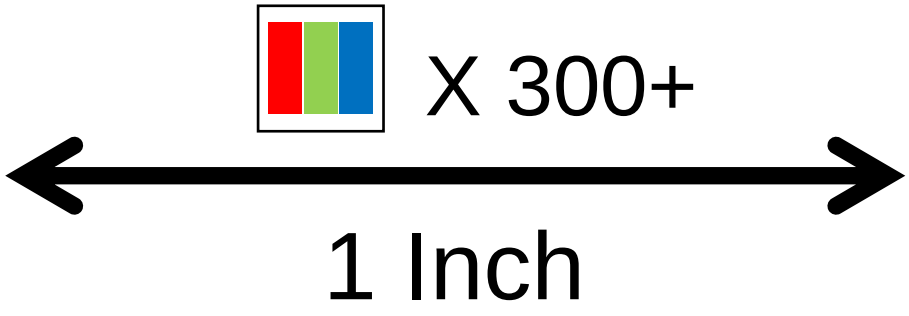
Pixels

- A 2D array of display units
- Usually, 3 colors
  - Red
  - Green
  - Blue
- Different lightness for different color



Retina Display

- Introduced by Apple
- About 300 Pixel-Per-Inch (PPI)
  - for 10 to 12 inches viewing distance
- Human cannot notice the pixel in such density



Type of Display

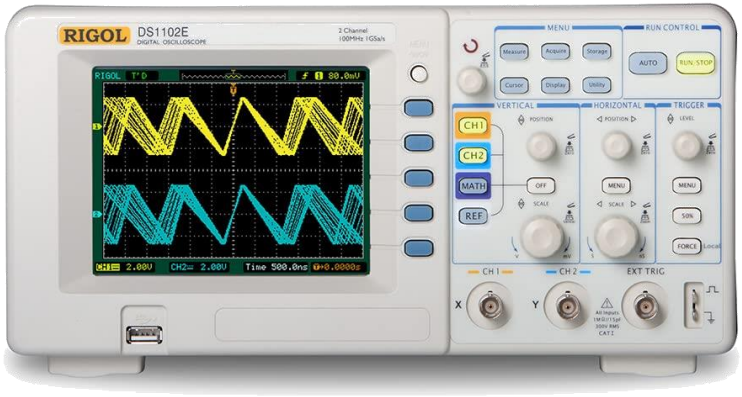
- Two types by their drawing properties

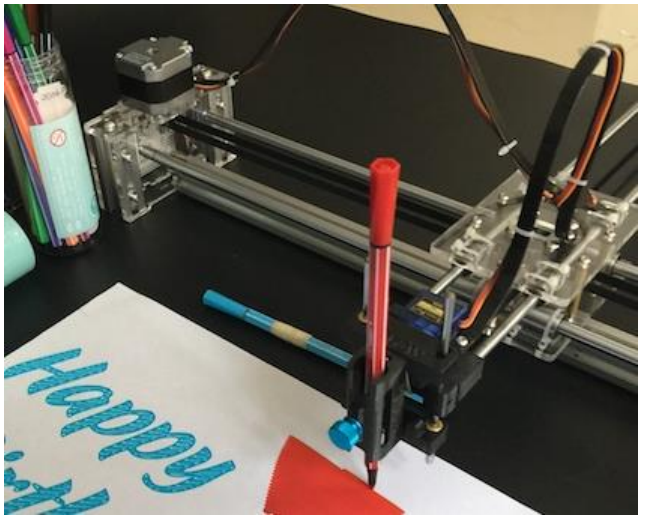
1. Random Scan Devices

2. Raster Scan Devices

Random Scan Devices

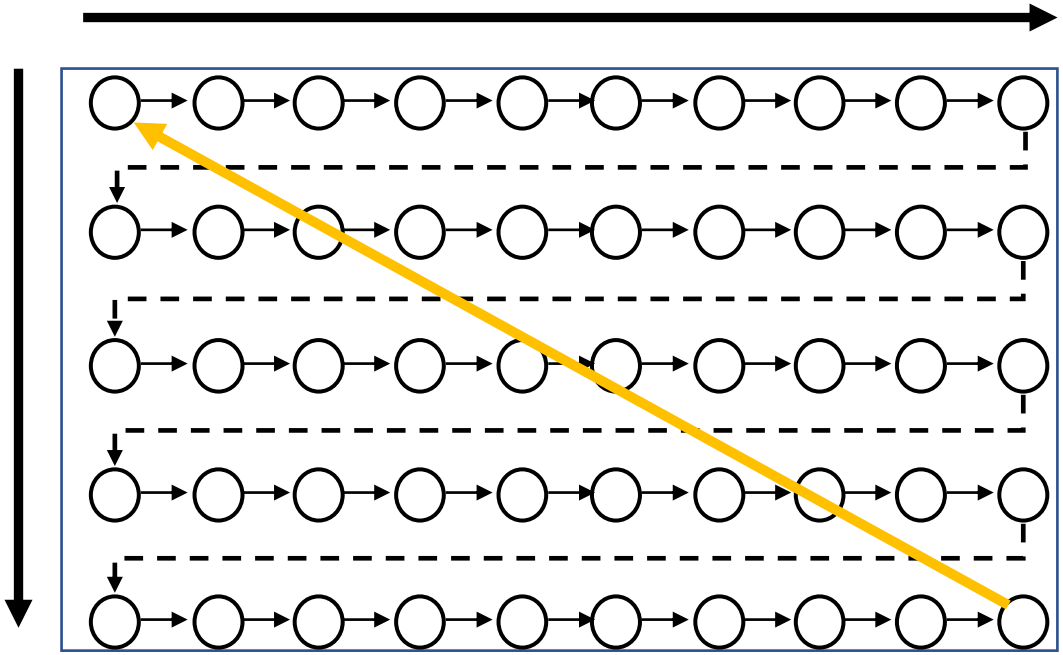
- Arbitrary movement
  - Draw any place that they want
- Example:
  - Oscilloscopes, pen-plotters, searchlights, laser light shows





Raster Scan Device

- Fixed (“raster”) pattern
  - From left to right, and then top to bottom
  - OLEDs, Plasma panels, LCDs, CRTs



Cathode Ray Tube

CRT Monitor

- Shoot a color ray onto the screen

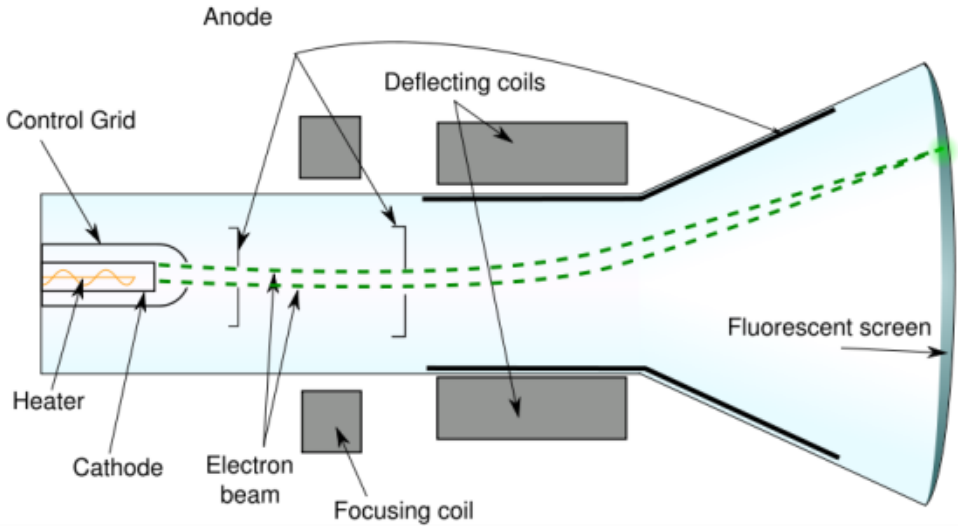
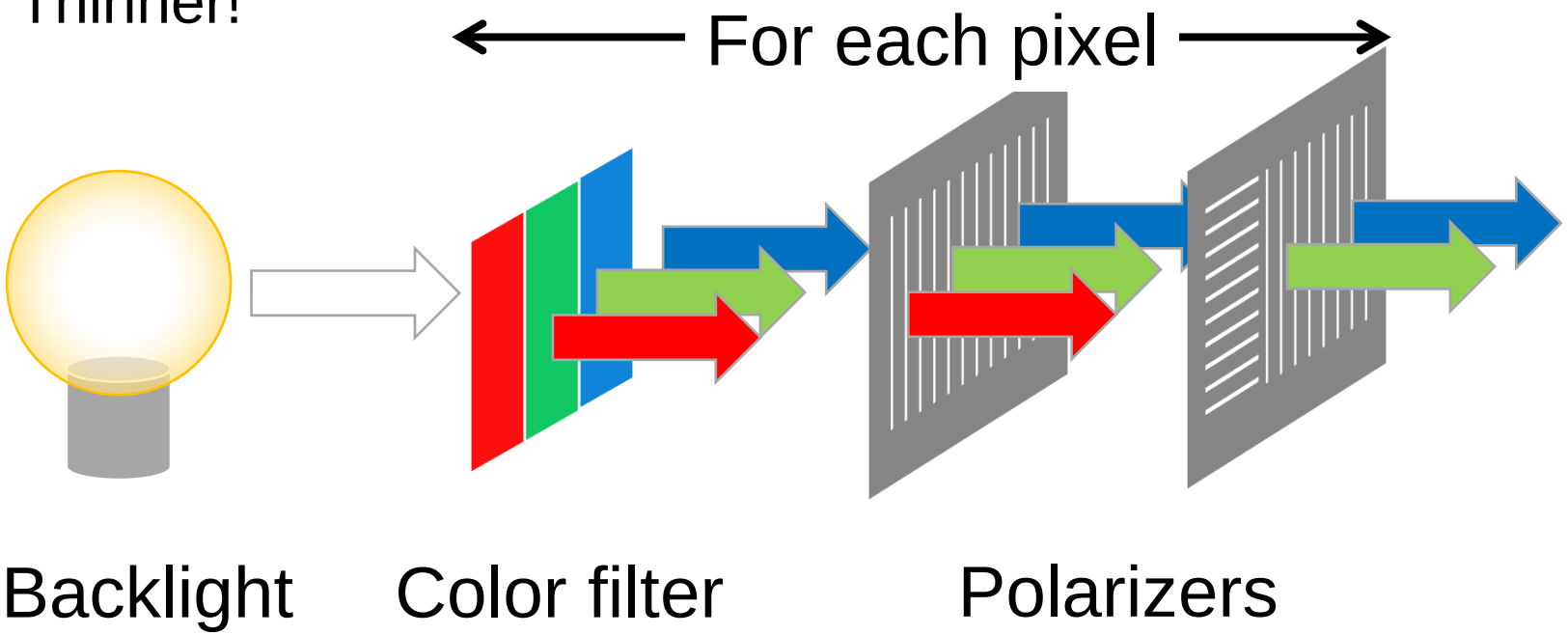


Image credits: Wikimedia Commons (http://commons.wikimedia.org); http://www.pctechguide.com/07panels.htm

Liquid Crystal Display

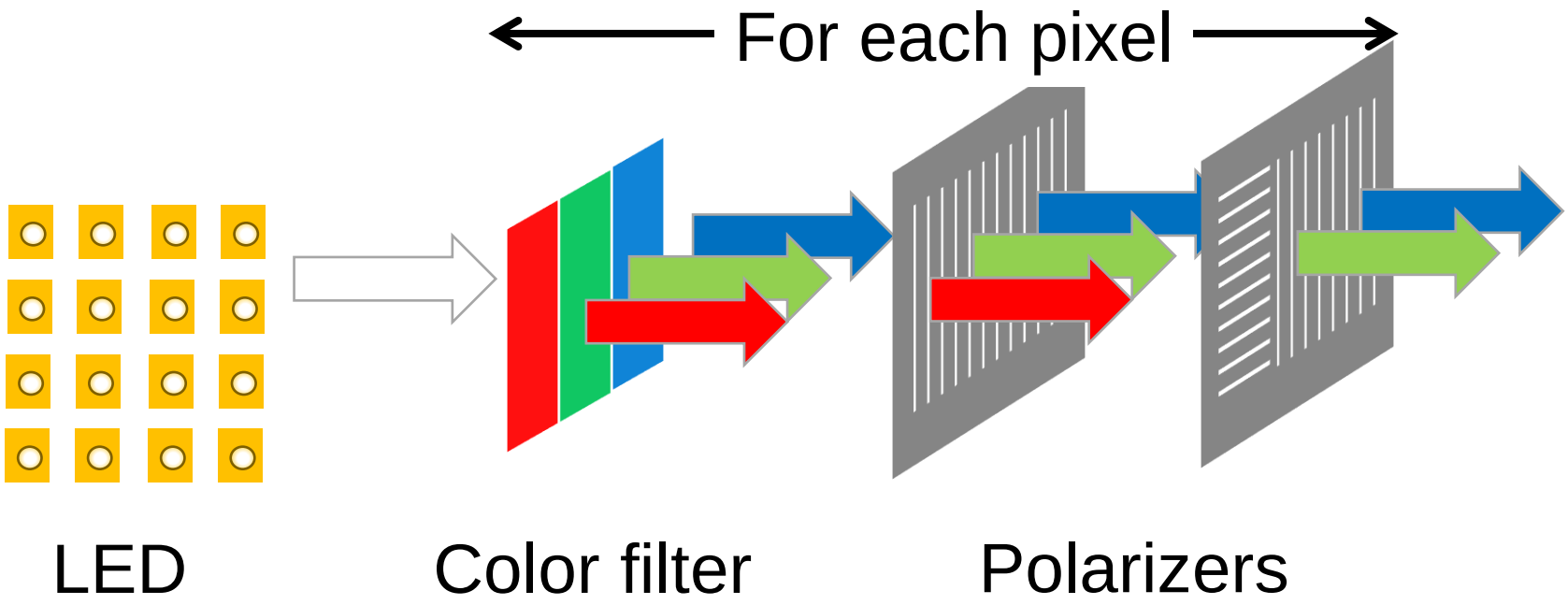
LCD Monitor

- Each pixel has a light blocker to block the backlight
- Thinner!



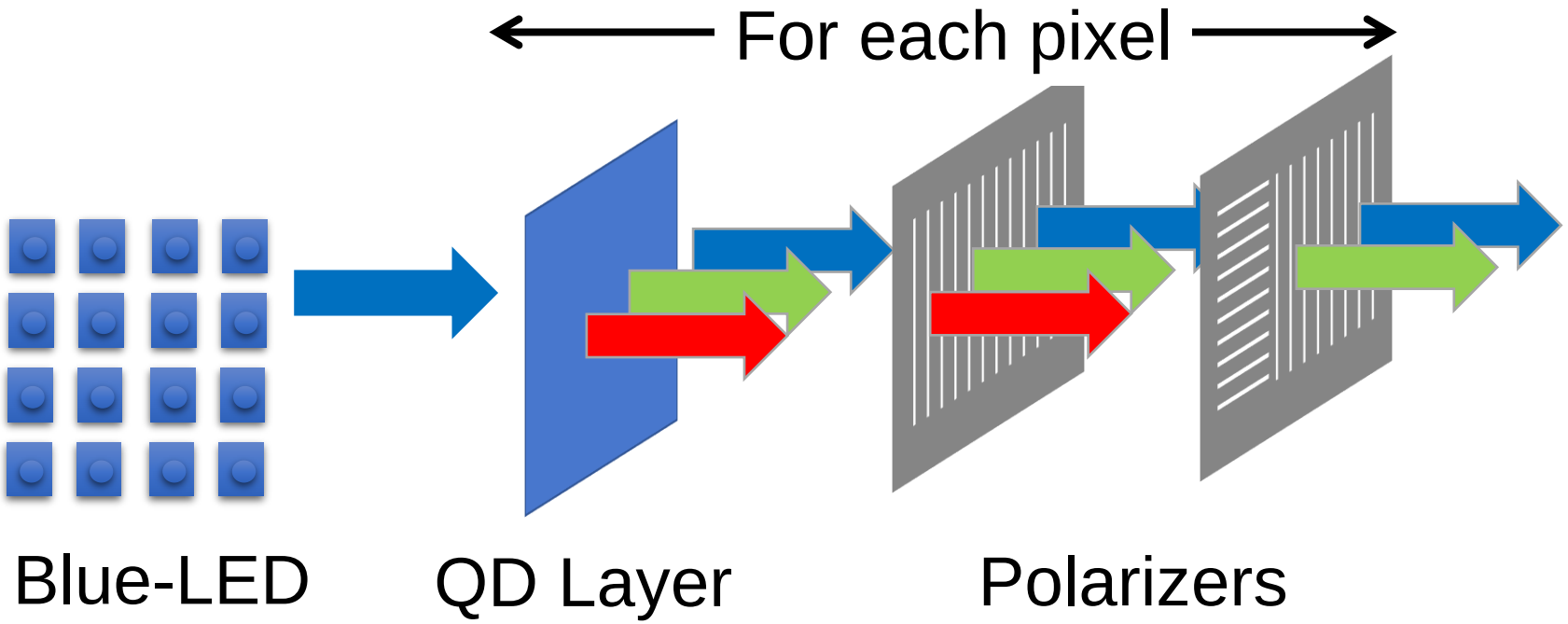
Light Emitting Diode

- LED Monitor
  - Replace the backlight by LED
  - Less power consumption



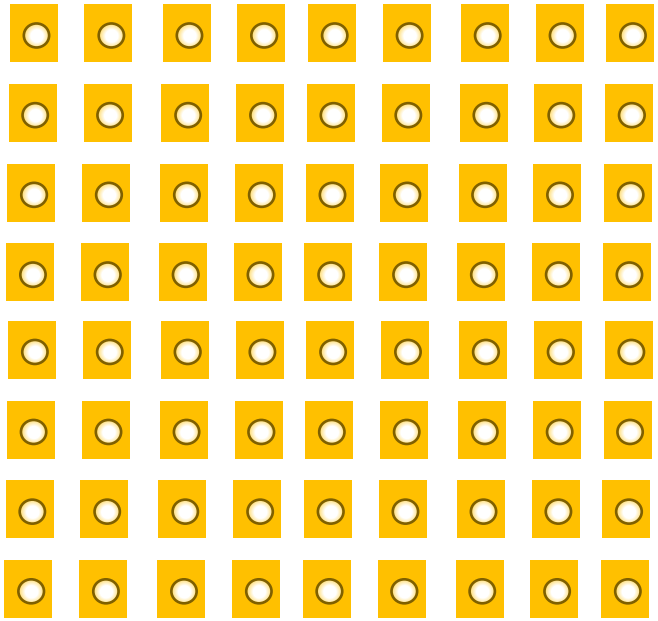
Quantum Dot LED

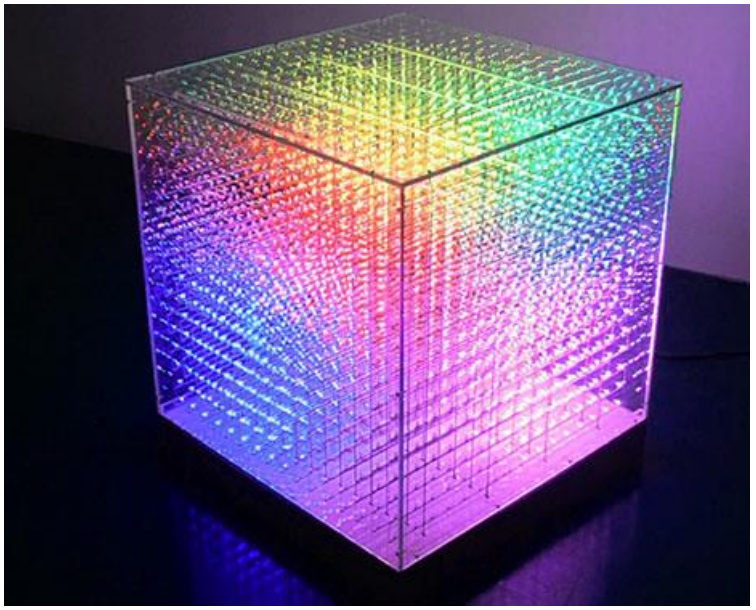
- QLED Monitor
  - Replace the color filter and use colored LED
  - Less color loss



LED Matrix

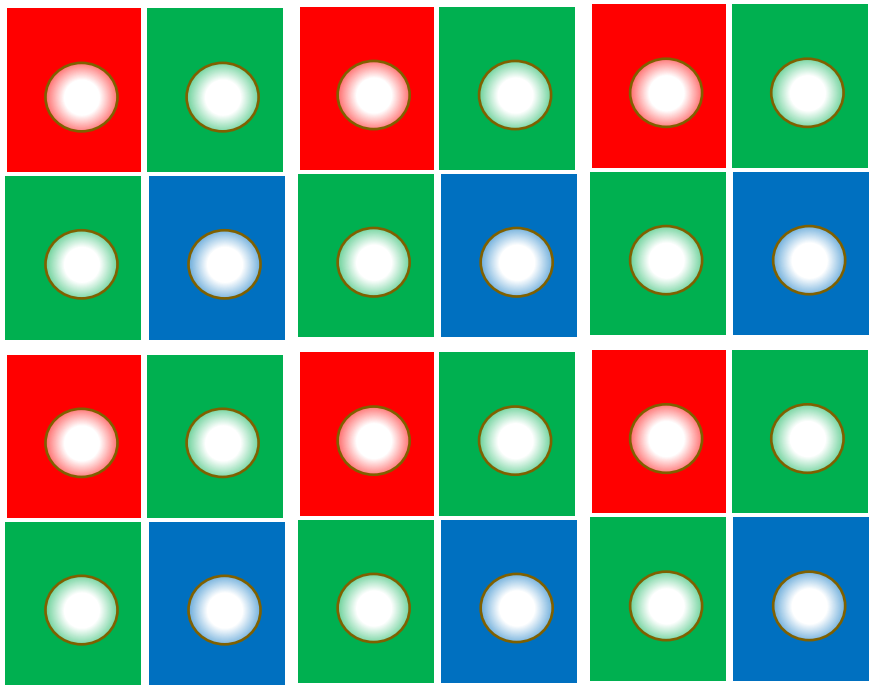
- Full of LEDs on a Grid
  - E.g., drone matrix, 3D display





Organic LED

- OLED Monitor
  - Small LED
- With RGBG
  - Bayer filter
  - Human is sensitive to green
- No backlight is needed
  - Can be very dark



Other Displays

Projector

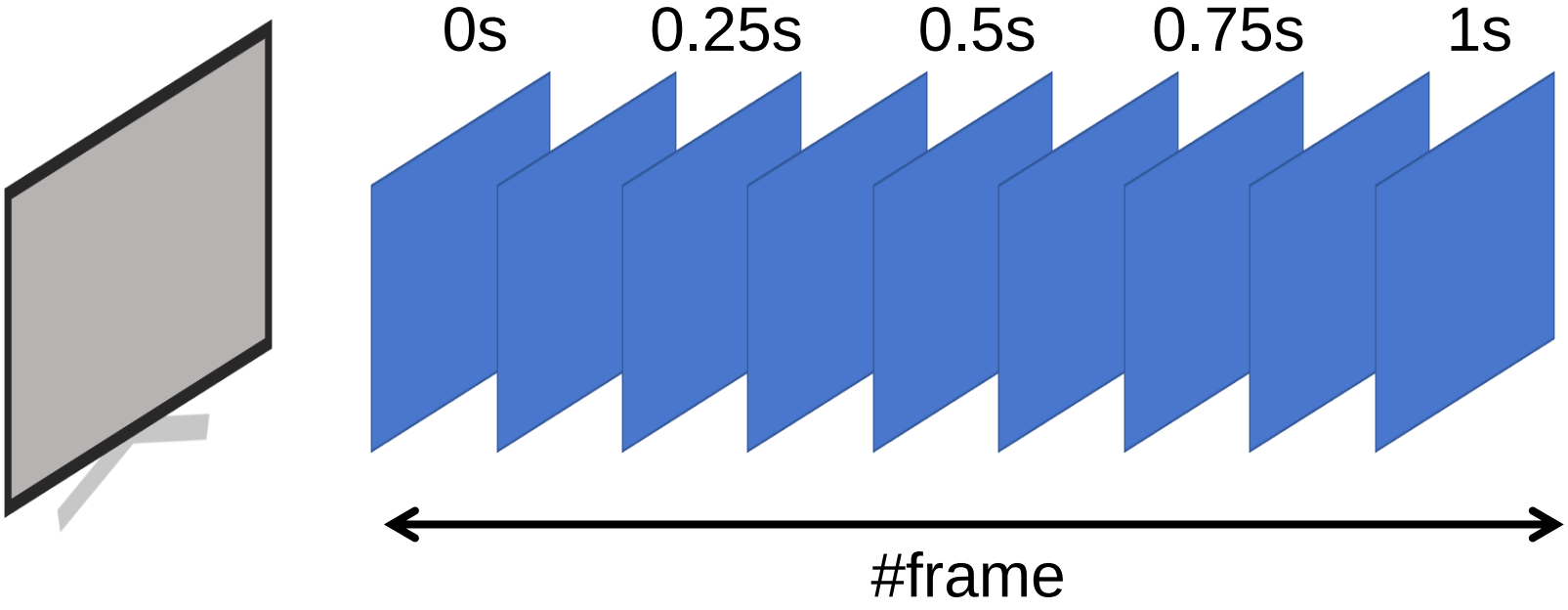
HMD

Cave

Powerwall

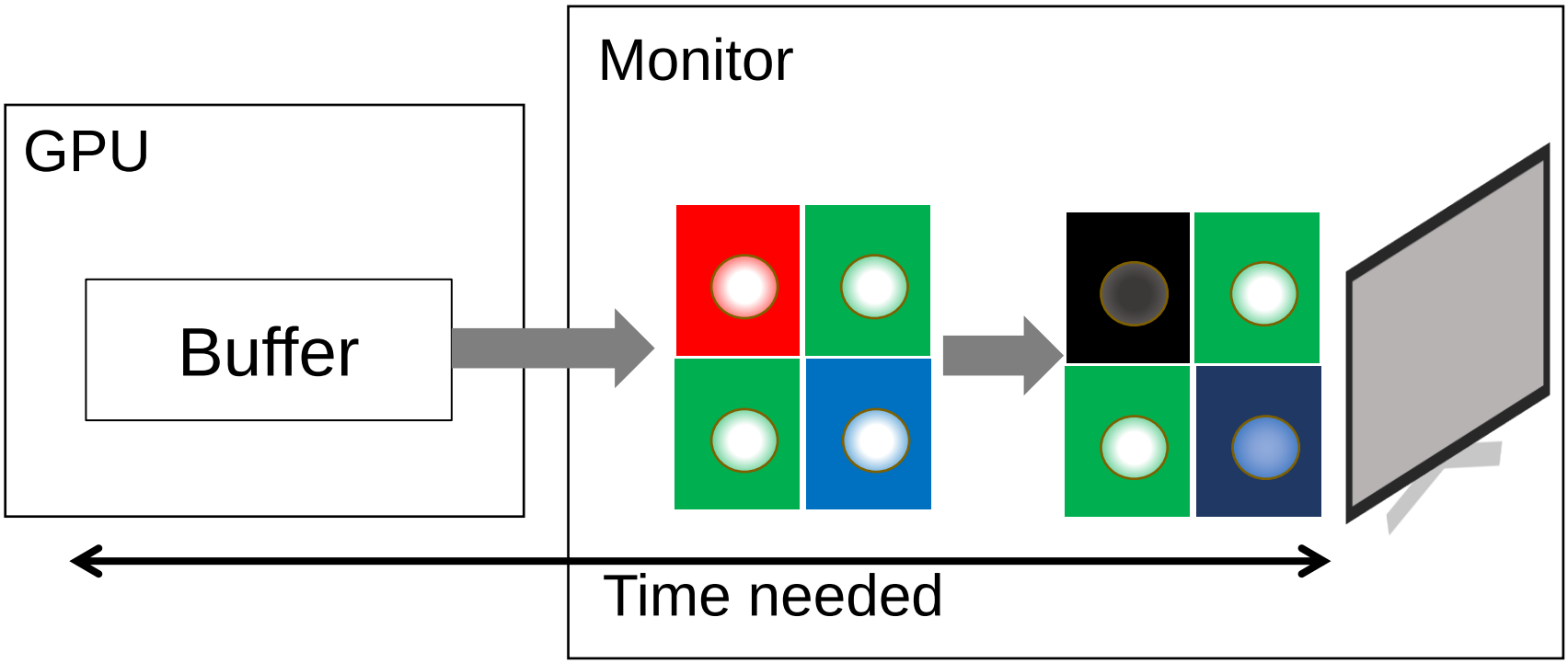
Refresh rate

- Maximum frame per second (FPS)
  - Number of picture (frame) displayed per second



Response Time

- How many time it needs to draw one image.
  - i.e., time needed to change a color



Color

RGB

- Values represent intensity of light
  - 0 to 255

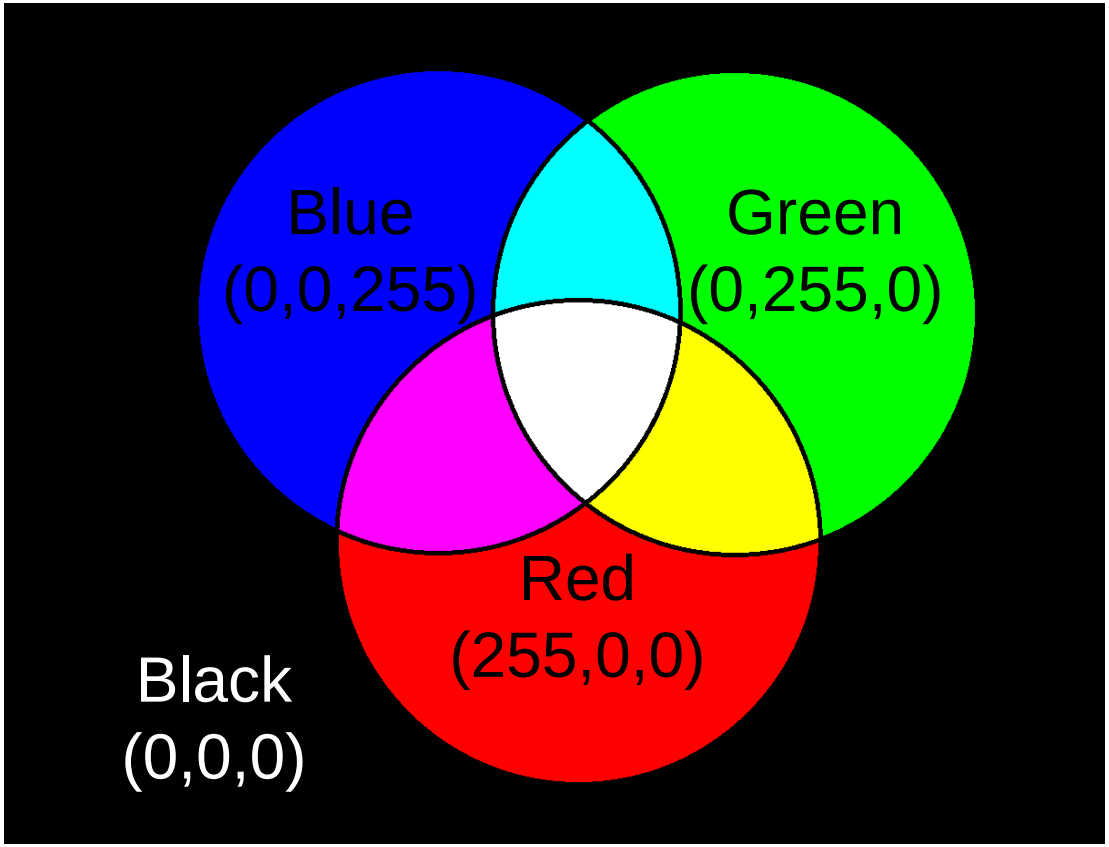
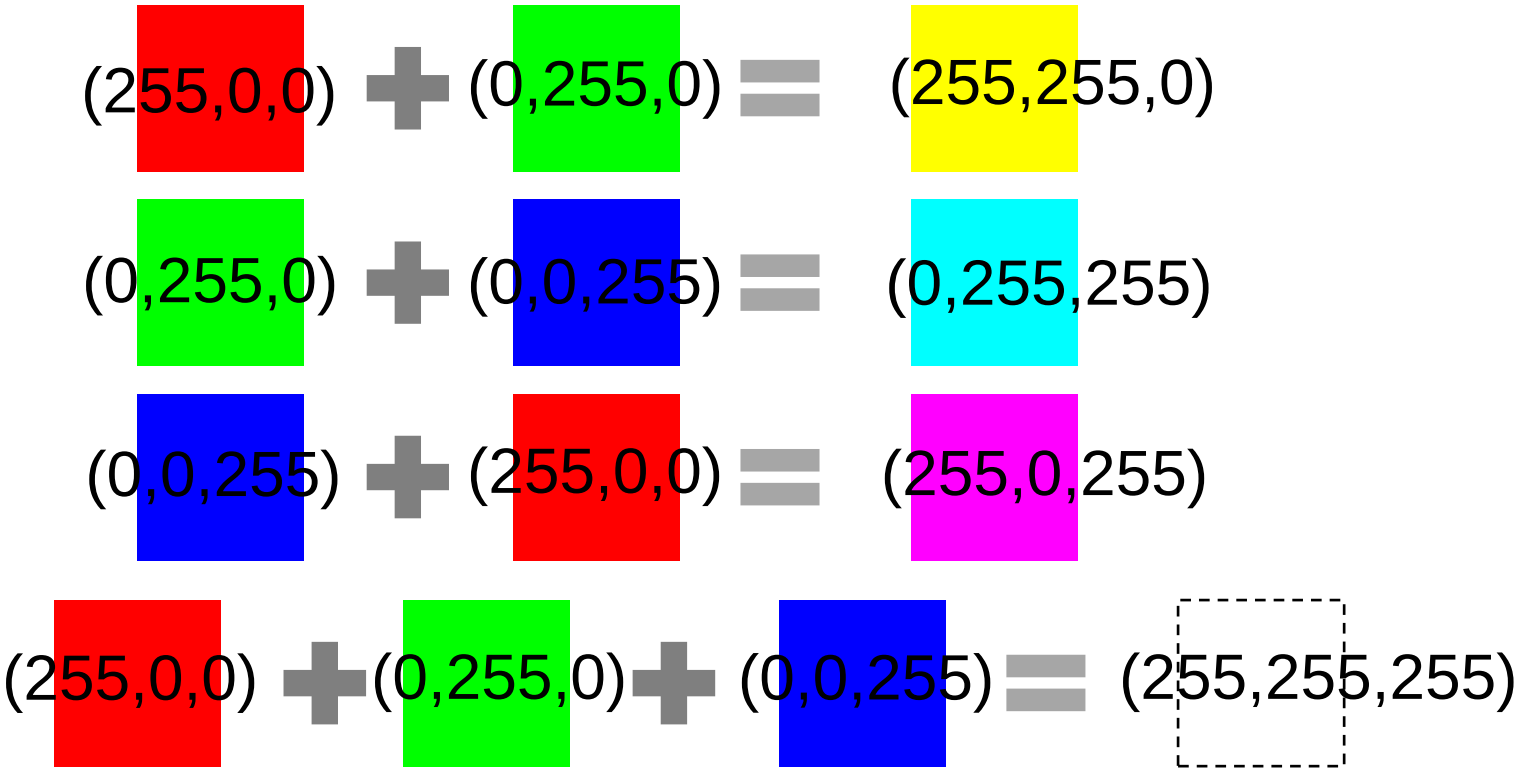


Image credit: http://en.wikipedia.org/wiki/RGB_color_model

Additive Color Model

- RGB is additive: more color = lighter



Color Representation

RGB representation never equal to actual color representation!

Actual Color

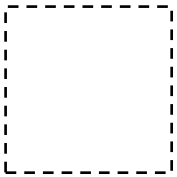
- From vision
- Natural

RGB

- Digital representation
- Human defined
- Try to approximate the actual color by mapping

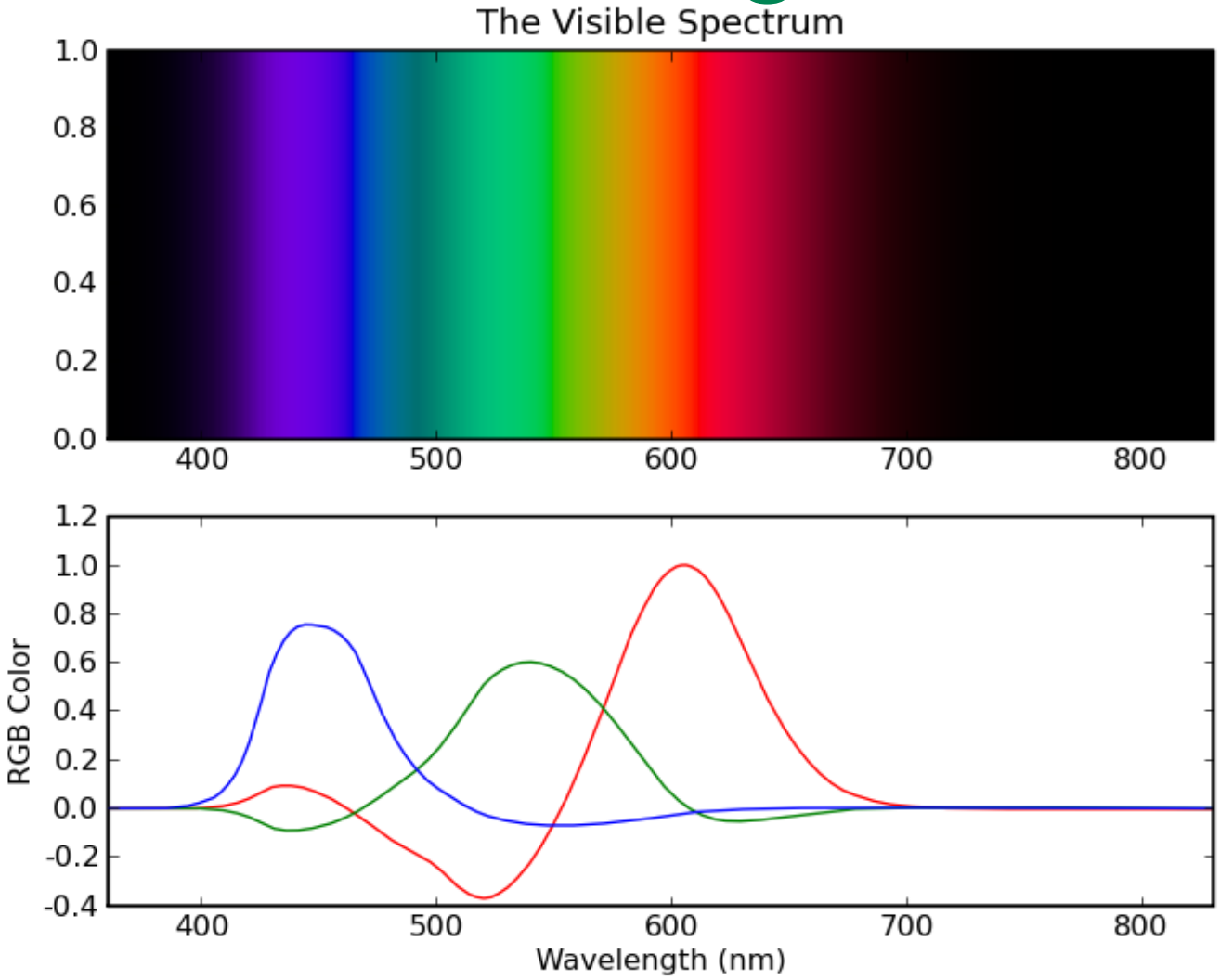
Same Color?

- (255,255,255)
  - Always white?



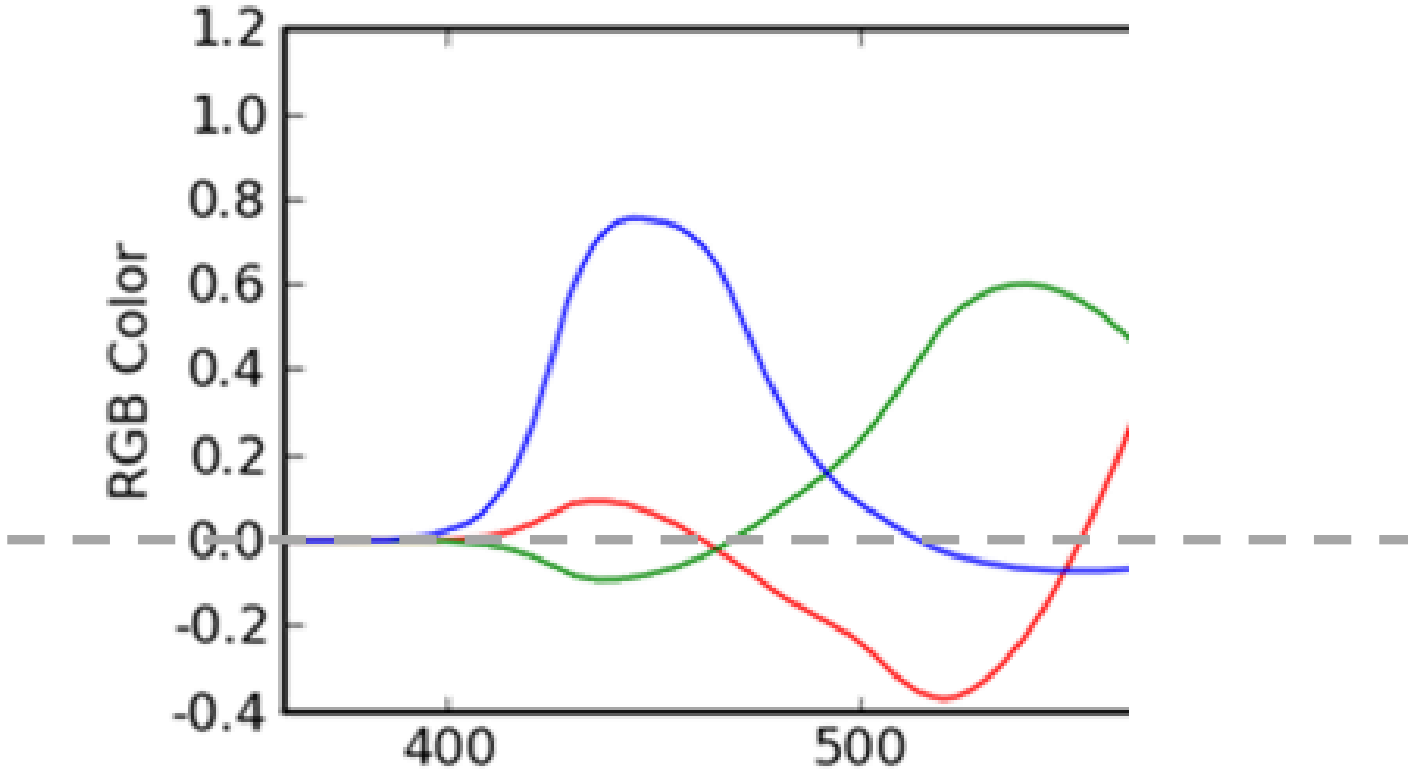
- No
  - The actual color output depends on your software, system, monitor

RGB to Wavelength Example



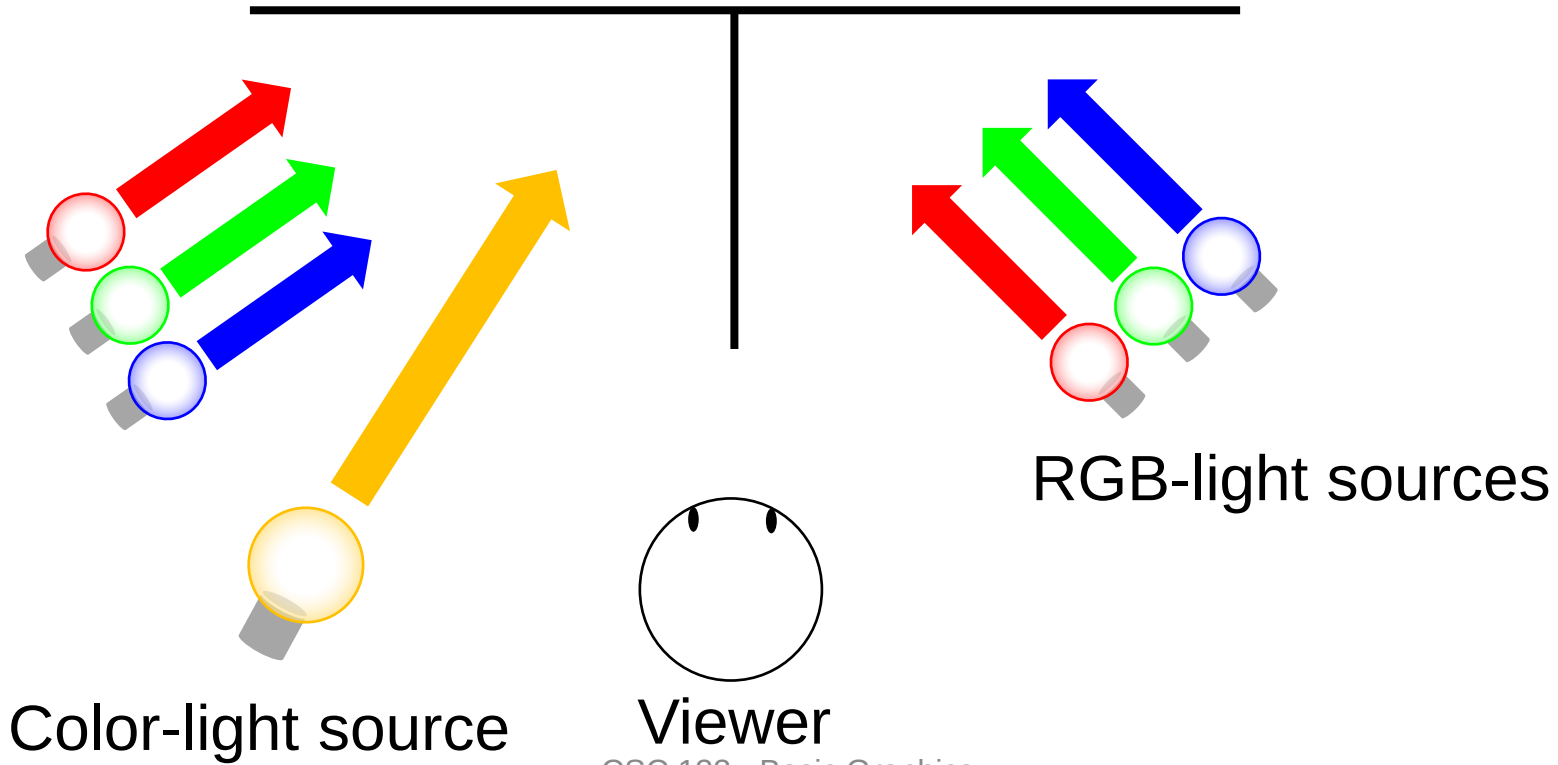
Negative Number

Why there is negative number in the graph?



Maxwell Color Matching

- 1850 by James Clerk Maxwell
  - Viewer control the RGB to match left and right



Negative Number

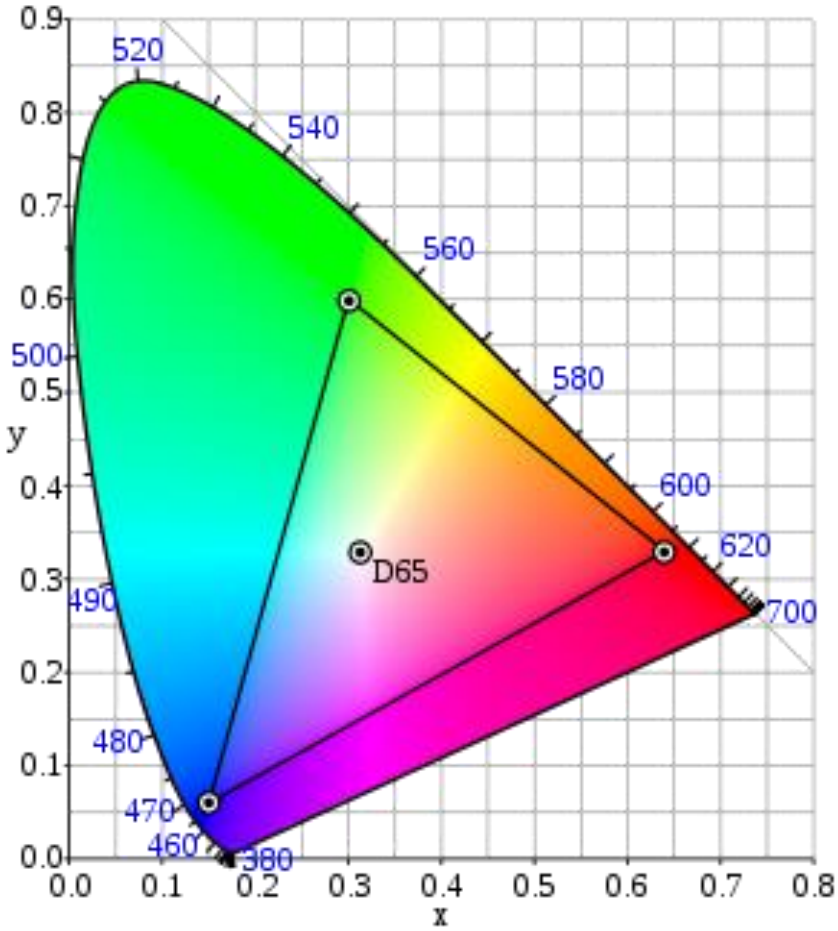
- Why there is negative number in the graph?

- RGB: 612nm, 525nm, and 445nm
  - Cannot reproduce every color

- Solution?
  - Add more color light sources
  - Or ignore it.

Need Every Color?

- Not necessary
- Only represent a subset of colors
  - Gamut

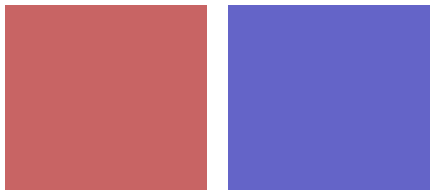


Color Distance

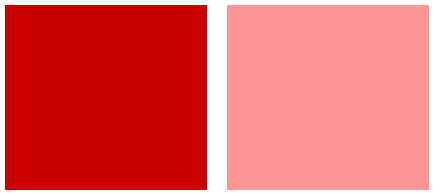
- The similarity of color, smaller = similar
  - Norm-2 distance

$$d = \sqrt{(R_1 - R_2)^2 + (G_1 - G_2)^2 + (B_1 - B_2)^2}$$

- Works but not fit to human perception



d = 141.42



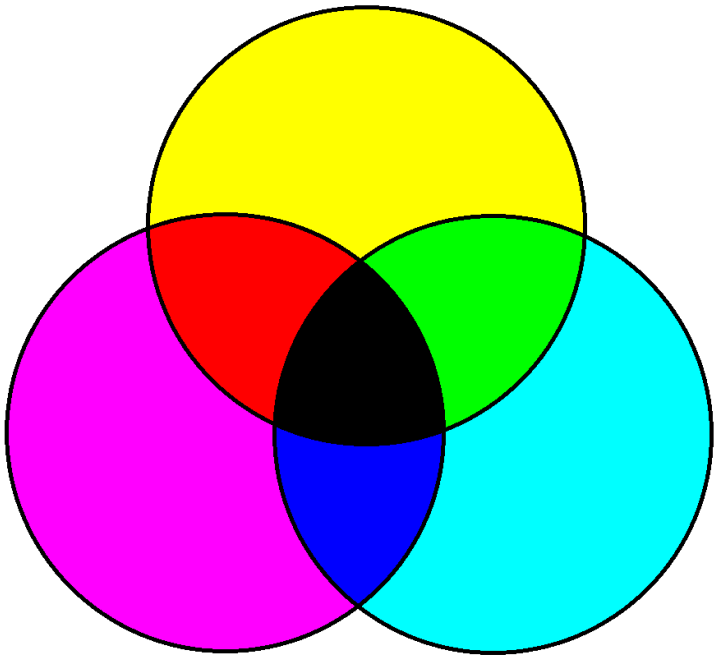
d = 219.17

Different Color space

- There are different color space.
  - CMYK
  - HSL/ HSV
  - Lab
  - XYZ
  - sRGB
  - Etc.

CMYK

- Subtractive Color Model
  - Putting more color = darker
  - For ink/printing



L*a*b*

- With the distance that “fit” to human perception
- Video from Wiki
  - https://upload.wikimedia.org/wikipedia/commons/transcoded/4/45/Visible_gamut_within_CIELAB_color_space_D65_whitepoint_mesh.webm/Visible_gamut_within_CIELAB_color_space_D65_whitepoint_mesh.webm.480p.vp9.webm

Interpolation

- For Color Changing e.g., fade
  - Weighting of two color for t = 0 to 1

$$C_t = t\,C_1 + (1-t)C_2$$

t = 0

(255,0,0)

t = 0.5

(255,128,128)

t = 1

(255,255,255)

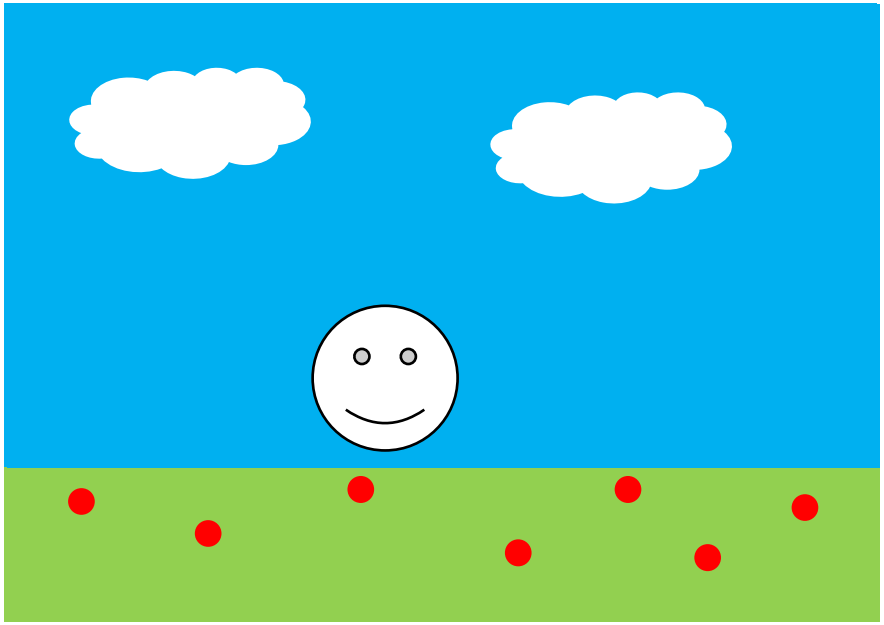
$$R_{0.5} = 0.5 \times 255 + (1-0.5) \times 255 = 255$$

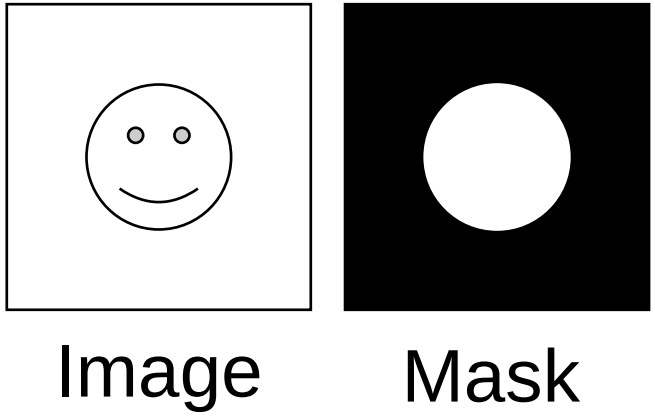
$$G_{0.5} = 0.5 \times 0 + (1-0.5) \times 255 = 128$$

$$B_{0.5} = 0.5 \times 0 + (1-0.5) \times 255 = 128$$

Mask

- Adding a new object on the image
  - Use mask to specify which parts are needed

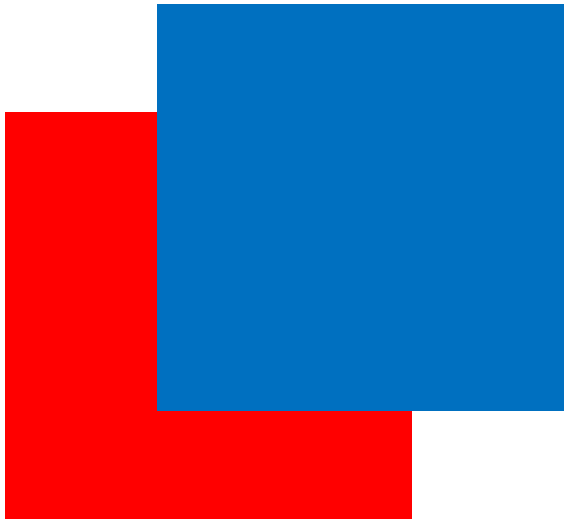




Alpha

- RGBA
  - Alpha is the transparency of the image

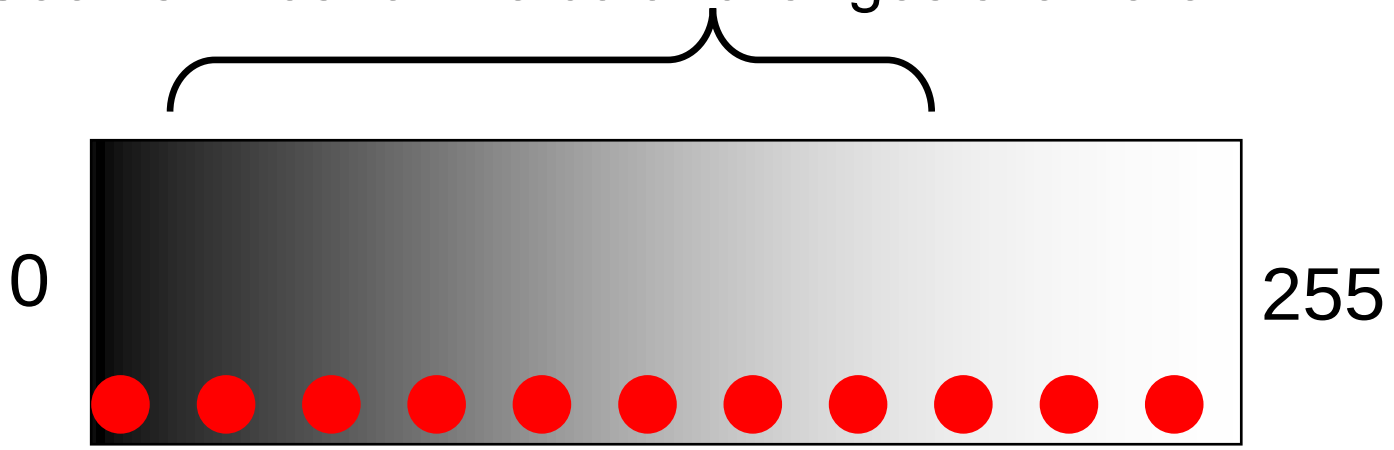
Without transparency



With transparency

Luminance Perception

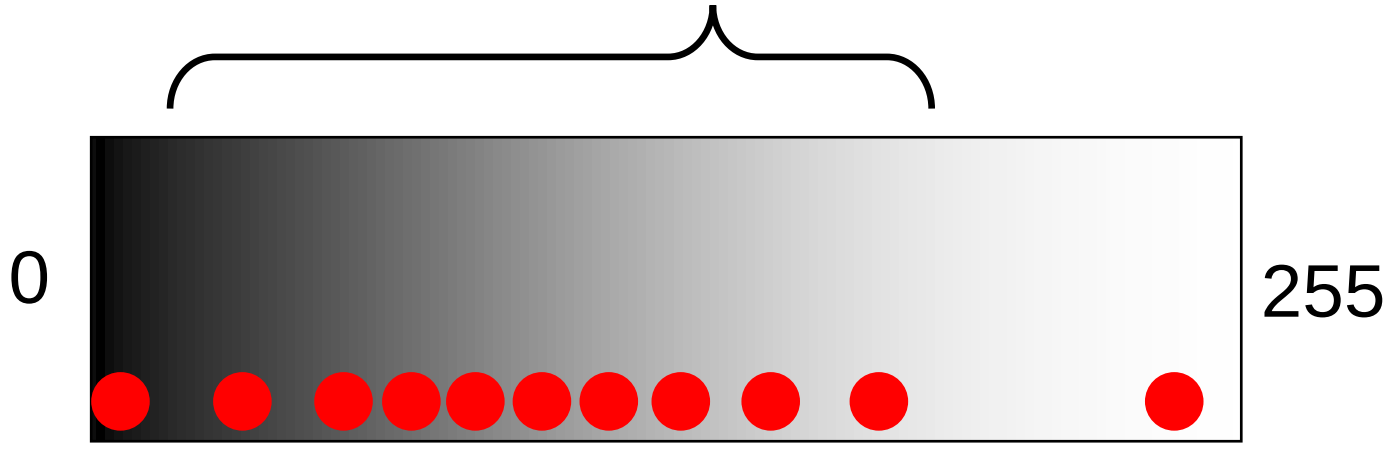
- Human perception is not linear
  - “Seems” most of the color changes are here



- Harder to tell the difference of other area

Better Representation

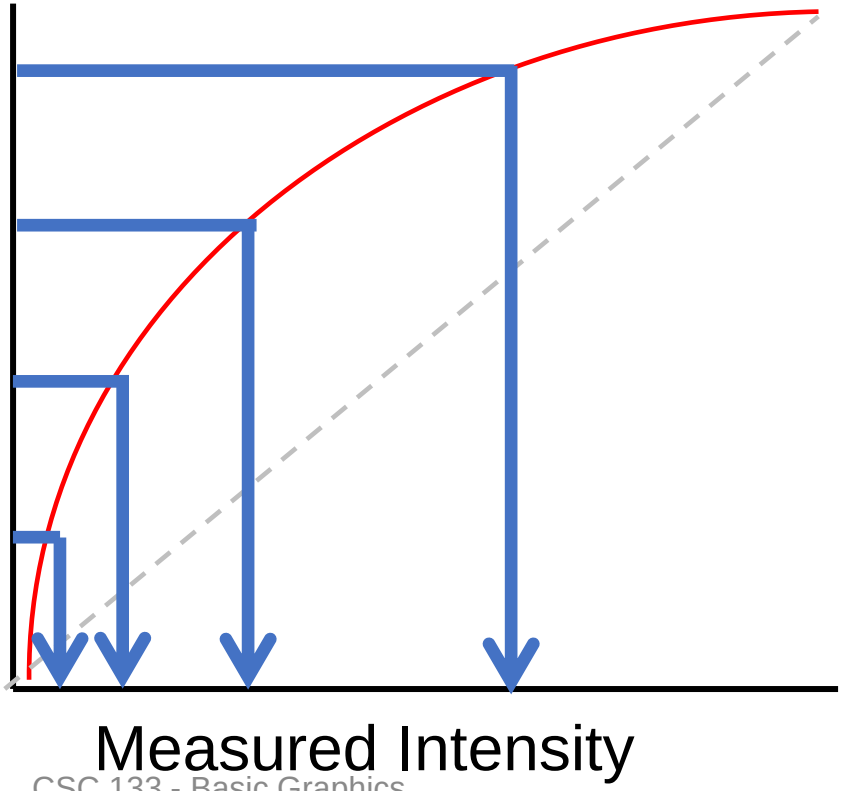
- Represent more “meaningful” colors



Gamma Correction

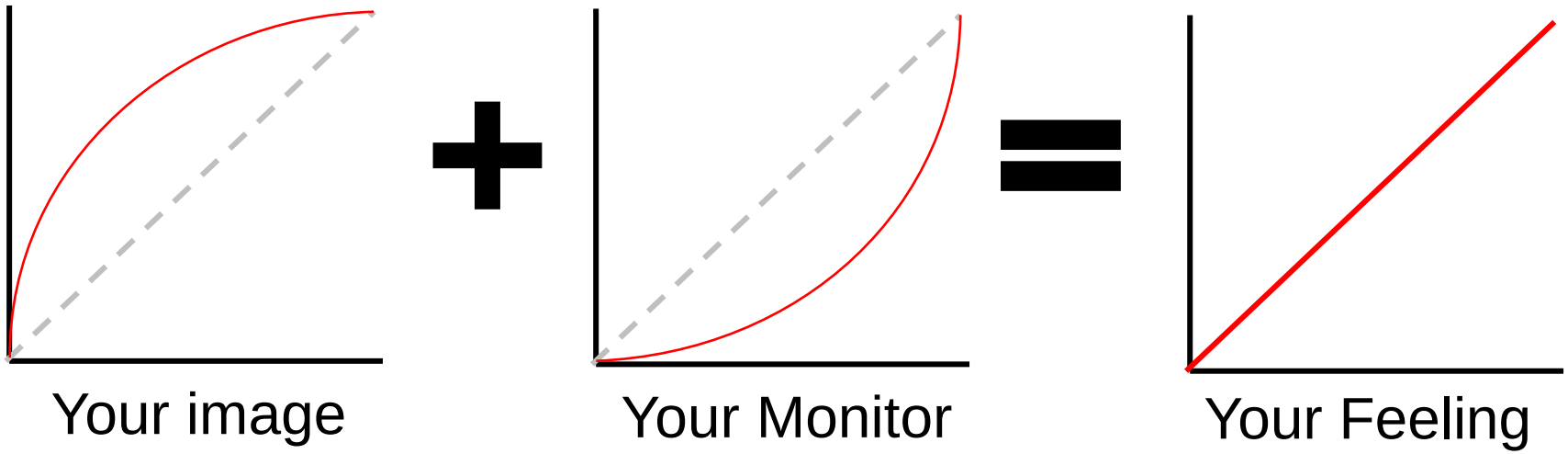
- “Correct” them to store more meaningful data

Data Representation Fixed (0-255)



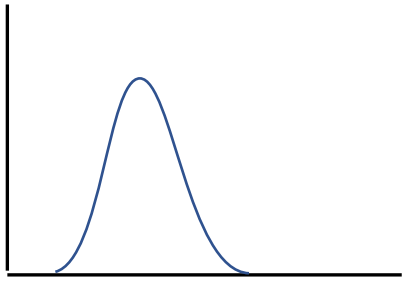
Output correction

- On your monitor, there is “another” correction

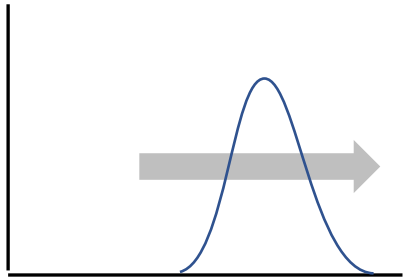


Brightness vs Contrast

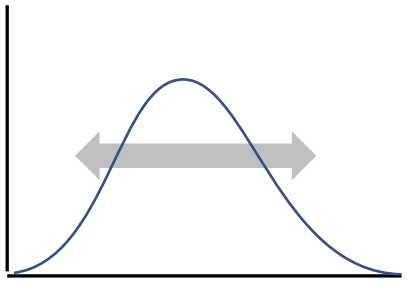
- Brightness = add/subtract all value
- Contrast = increase the range



Original

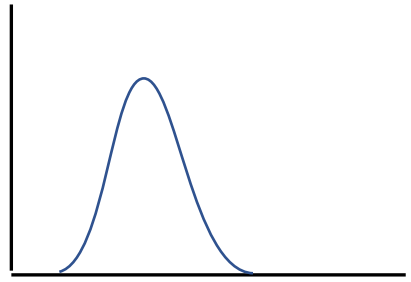


Add brightness

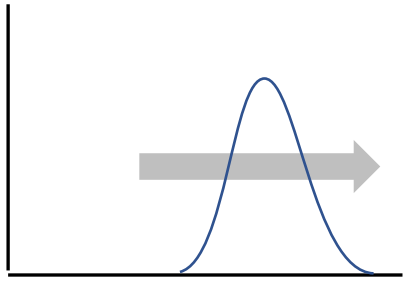


Add contrast

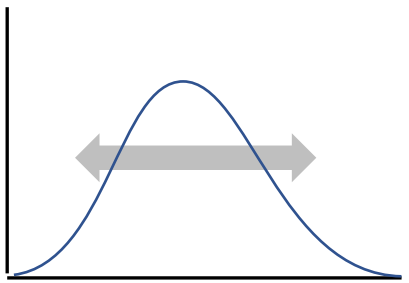
Brightness vs Contrast



Original



Add brightness



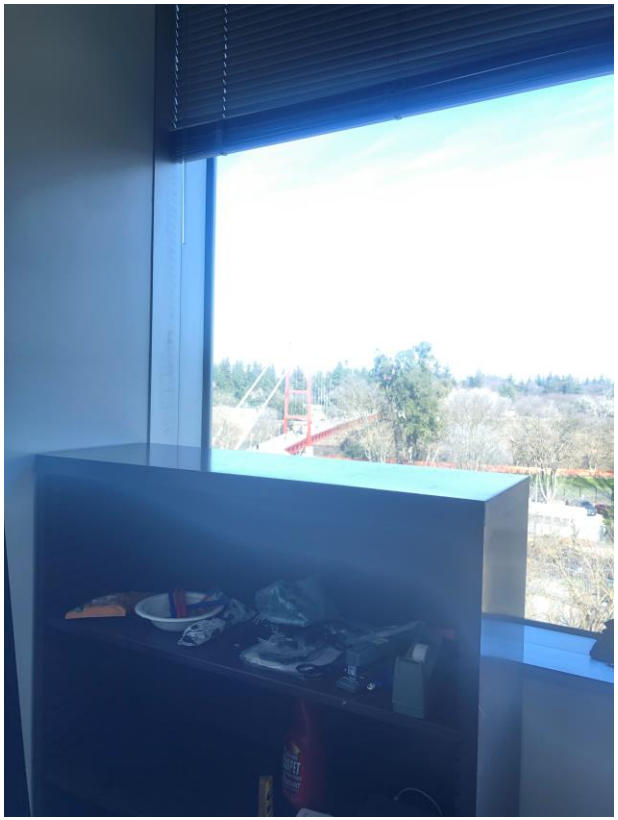
Add contrast

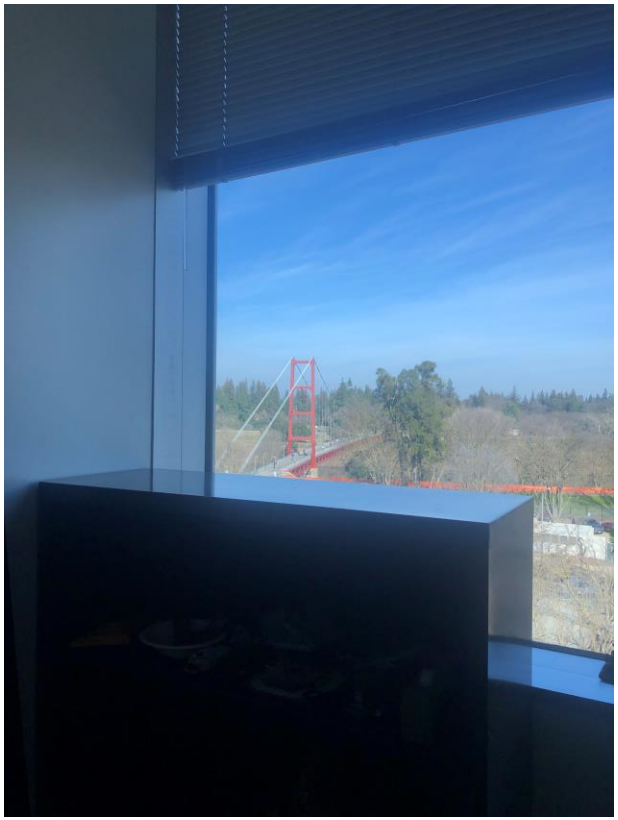
High Dynamic Range

- Most monitor can only display a range of light
  - What is the brightest?
  - As bright as sunlight which can hurt our eye
- Can your monitor display this strong light while keeping some area dark?

Problems for LDR

- Either too bright outside or too dark inside





Tone Mapping

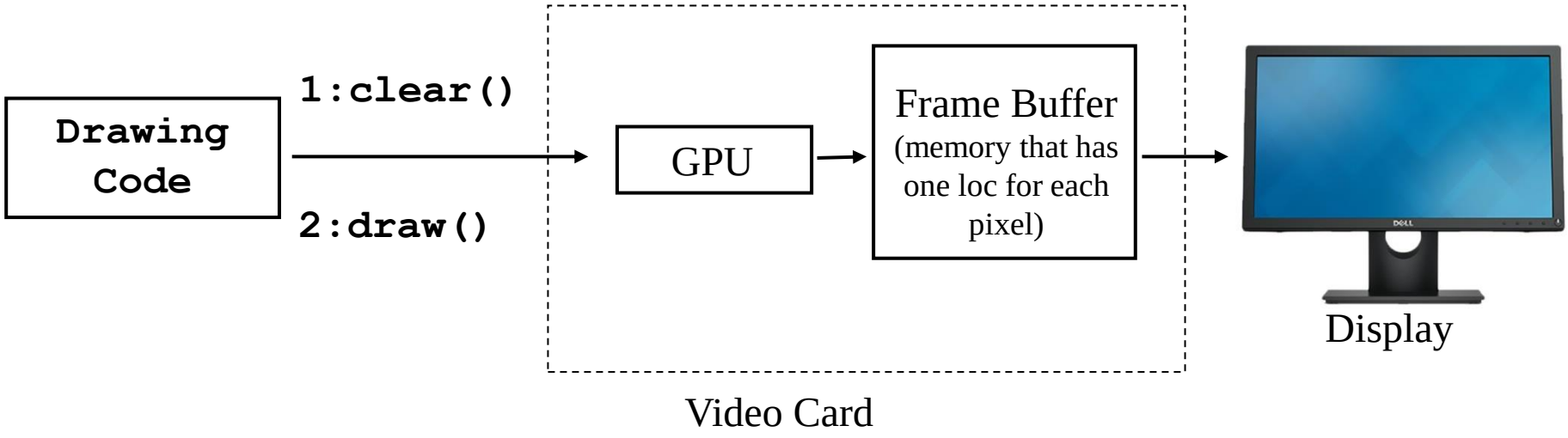
- A way to compress the range of lighting

Tone mapped image from wiki

Frame Buffers

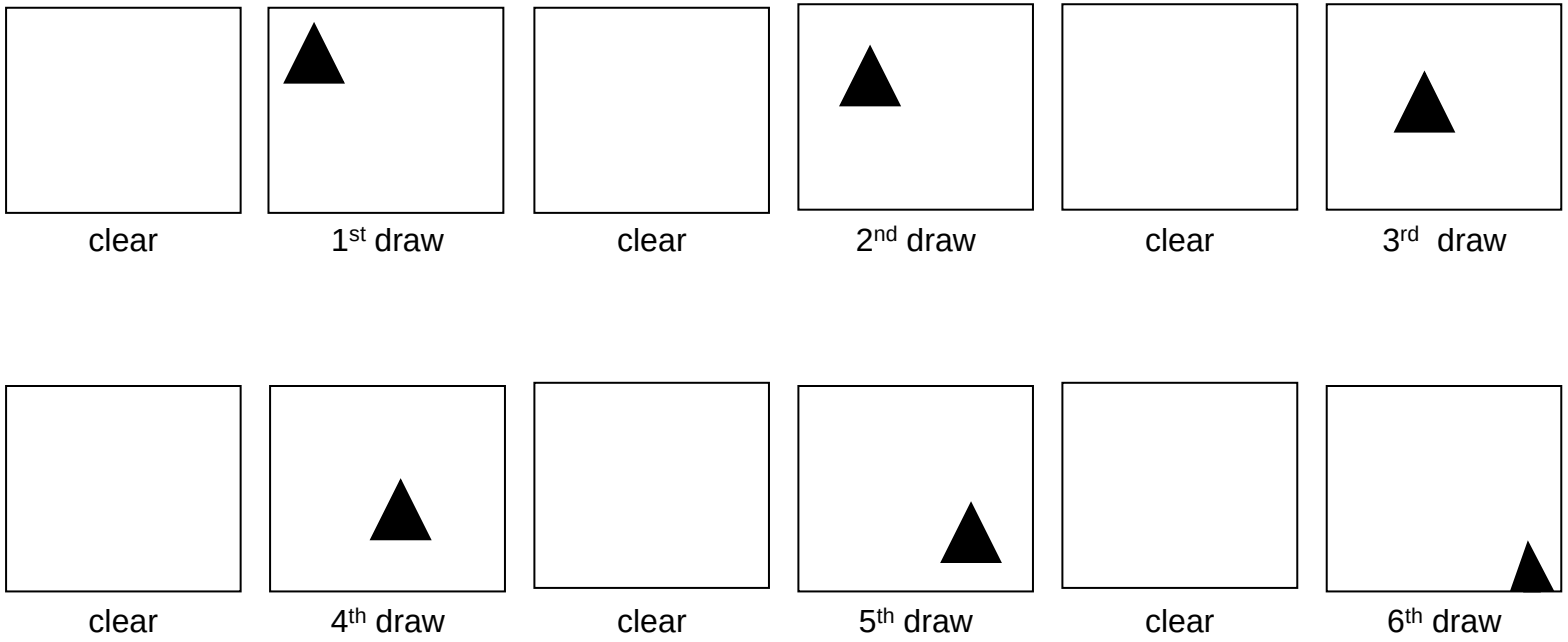
Frame Buffers

- Graphical Processing Unit (GPU) processes the commands sent from the drawing code and writes to the "*frame buffer*"
- The screen is refreshed from the frame buffer



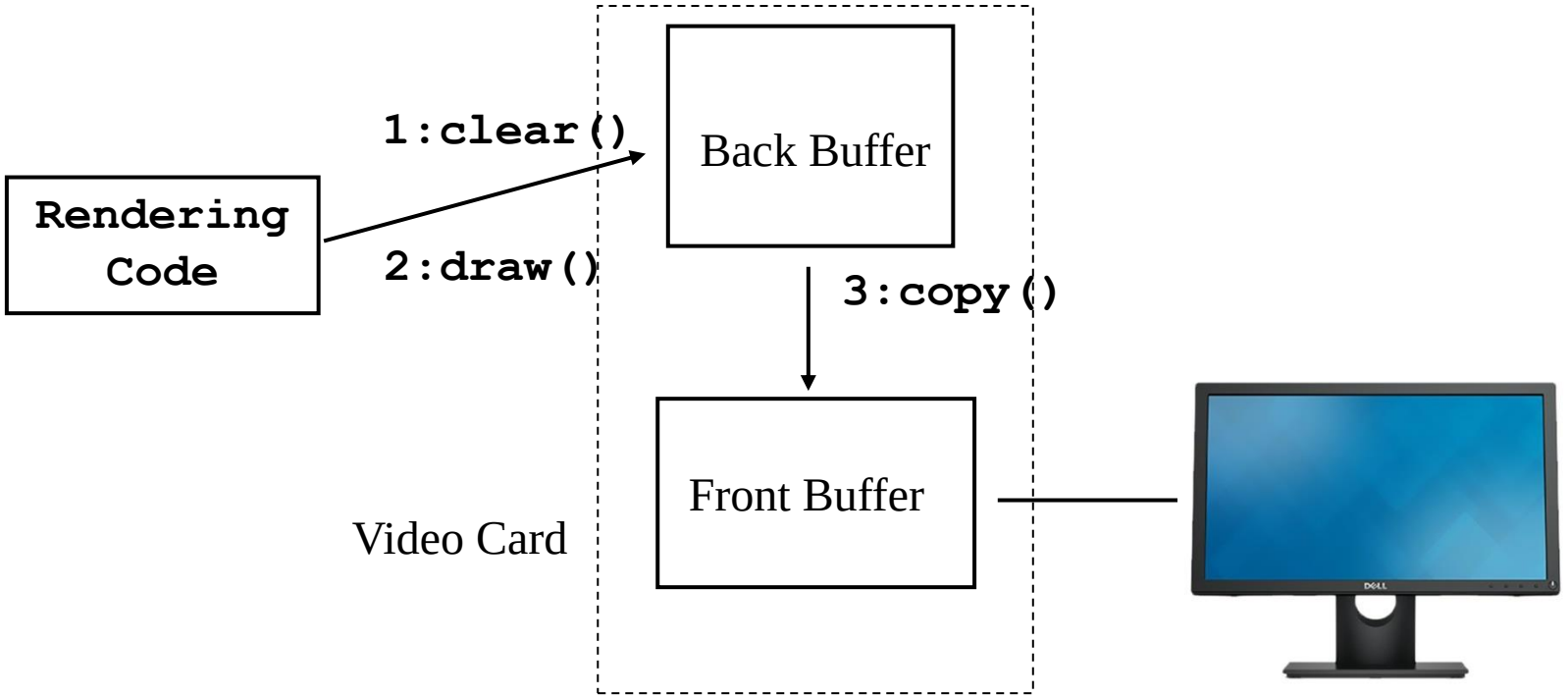
Flicker

- Suppose the drawn output contains a triangle, continually changing location:



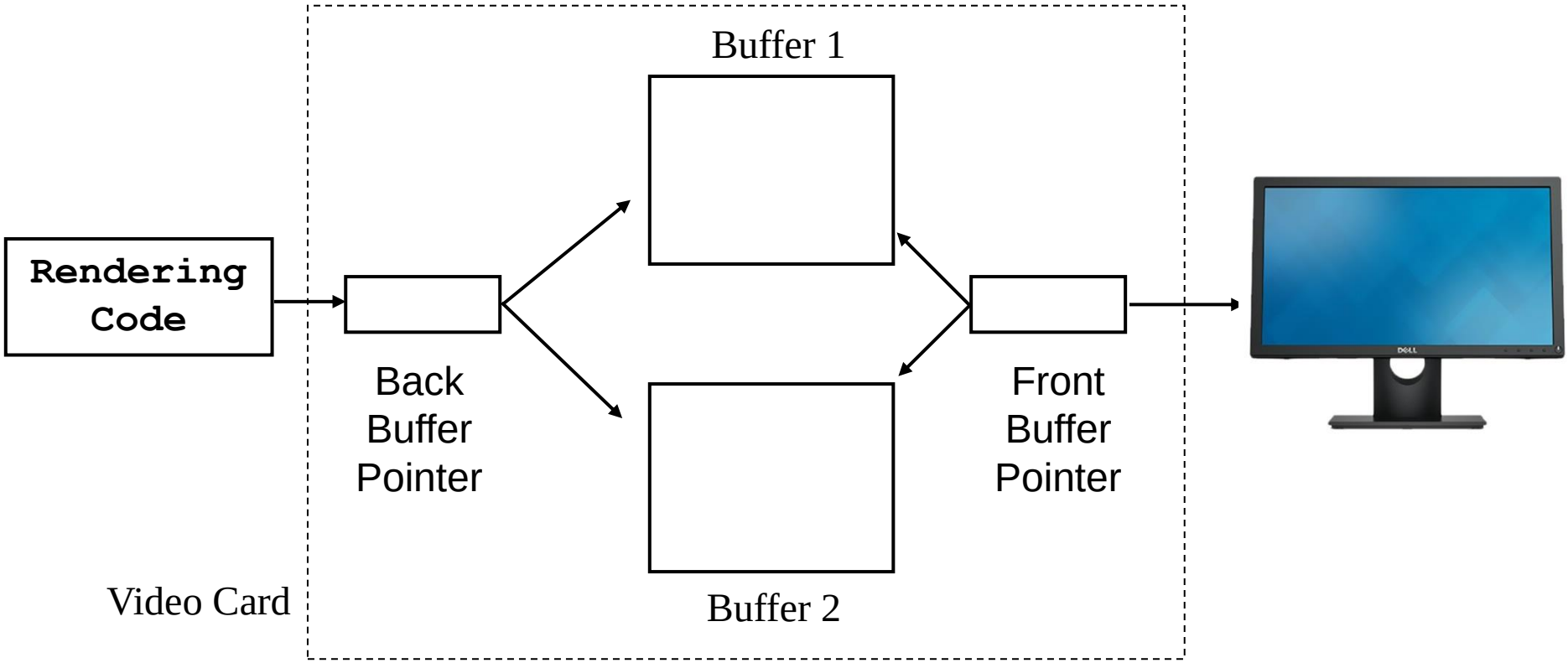
Double-Buffering

- Avoiding flicker:
  - Write to secondary or “back” buffer
  - Copy back buffer to “front” buffer when done



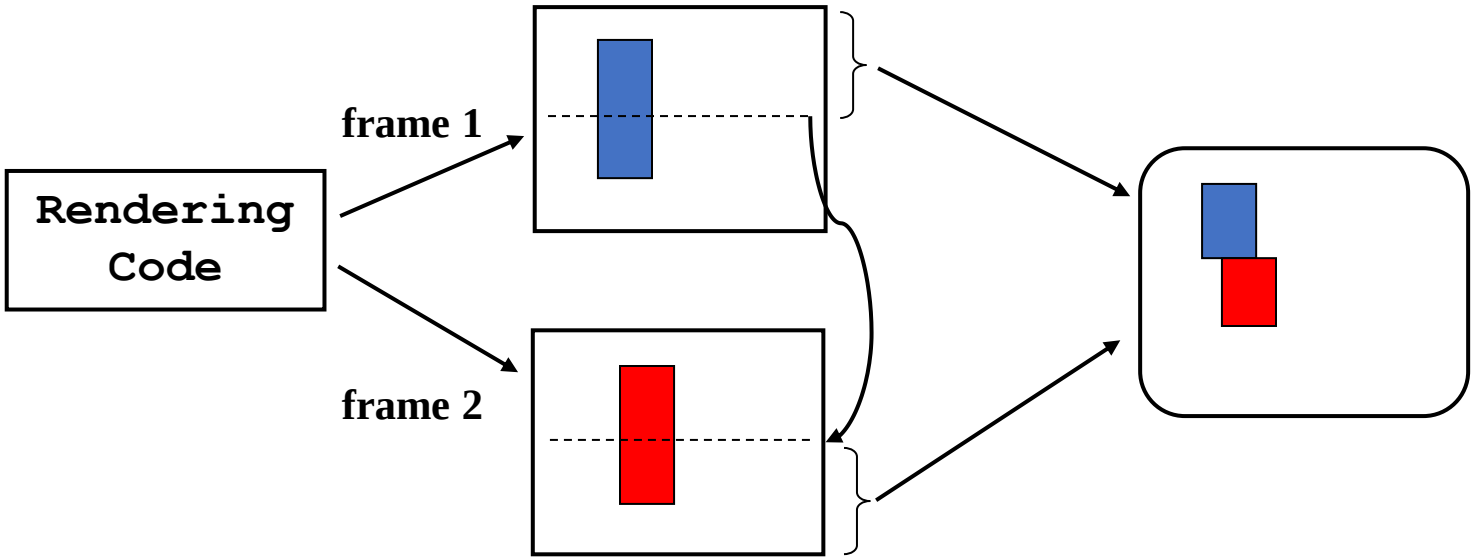
Page-Flipping

- Avoid copy() by changing a *pointer*



Tearing

- Problem: swapping ½ way through scan
- Result: “torn image”
- Solution: hold off swap until “VSync”

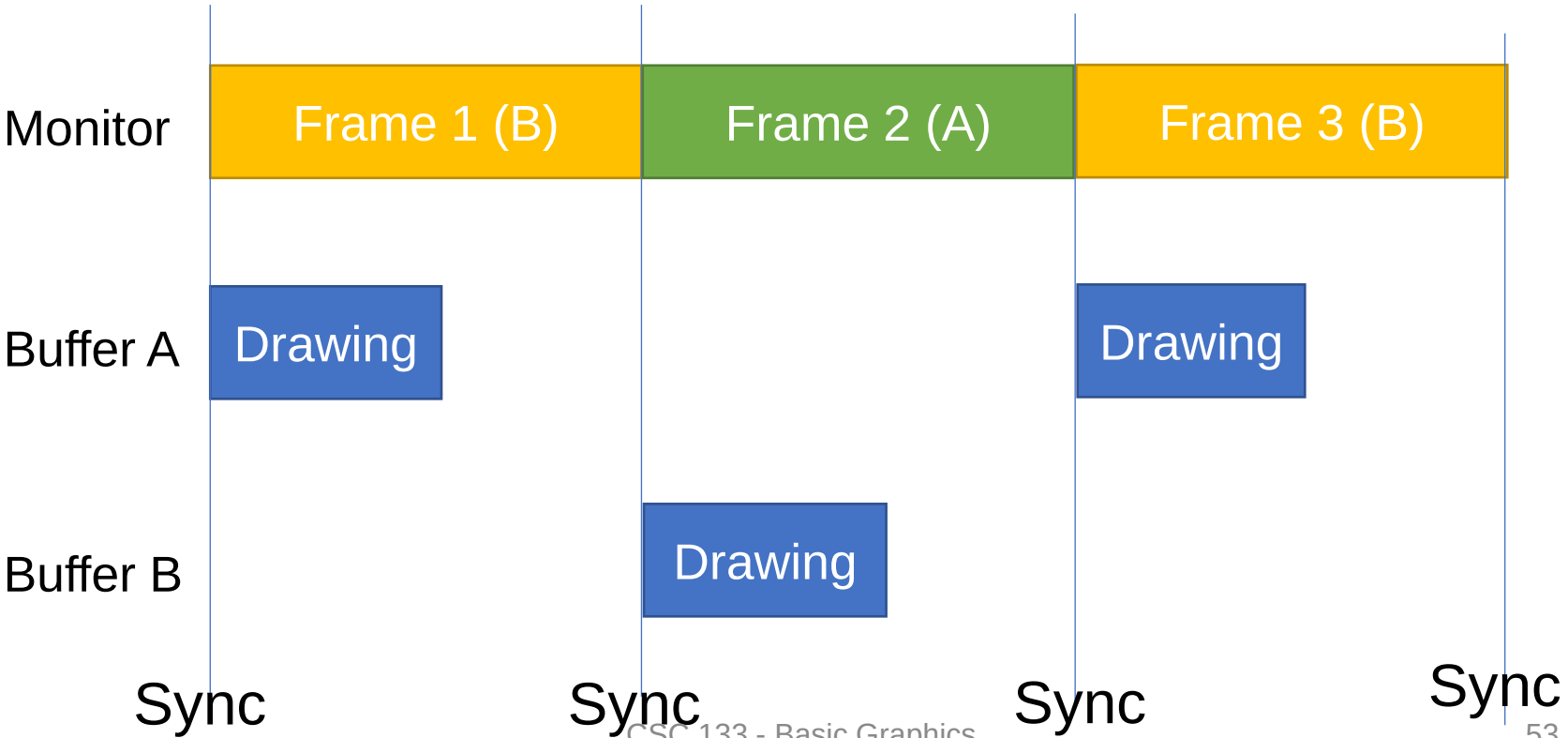


Tearing

Tearing example from wiki

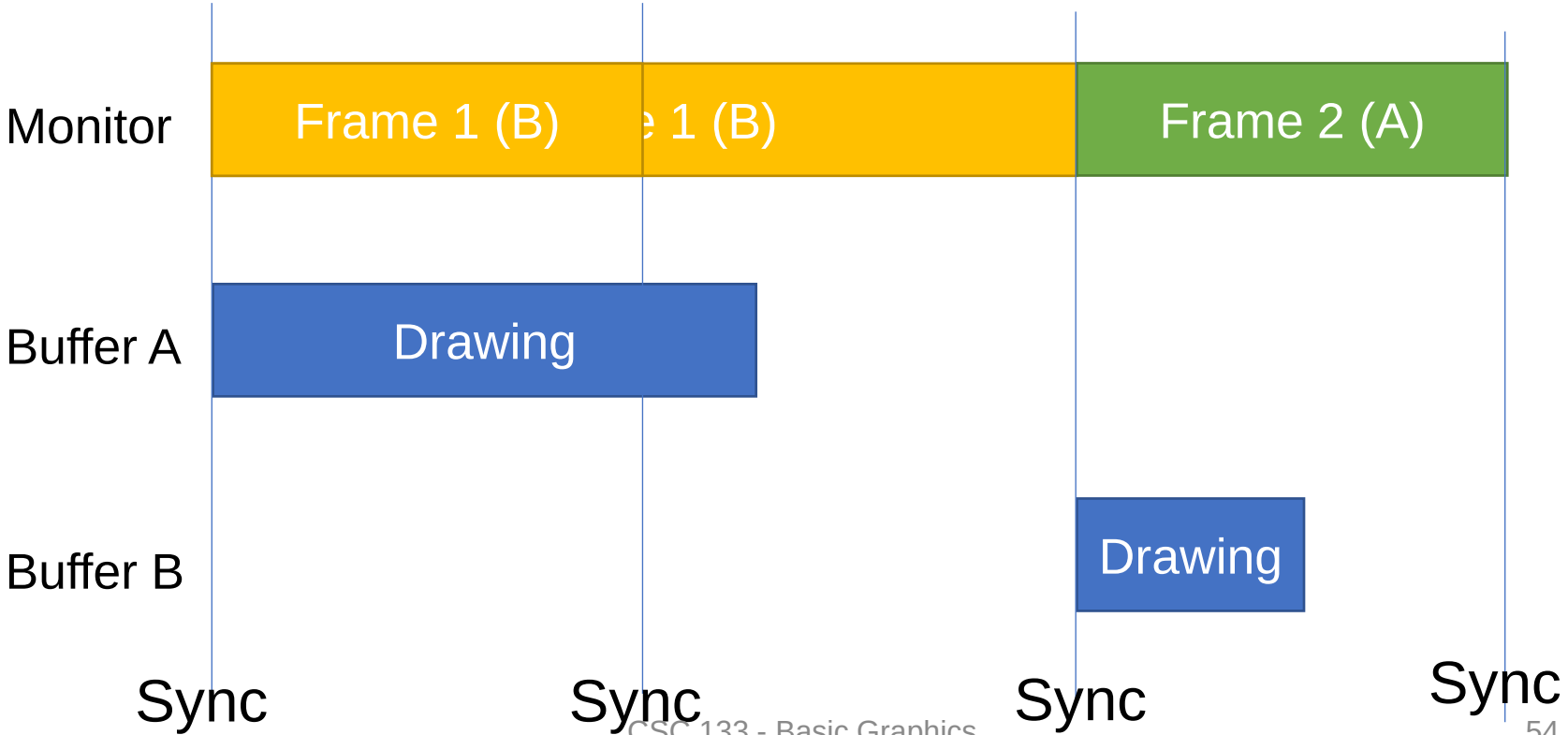
VSync

Only flip with a fixed rate and after the buffer is fully drawn



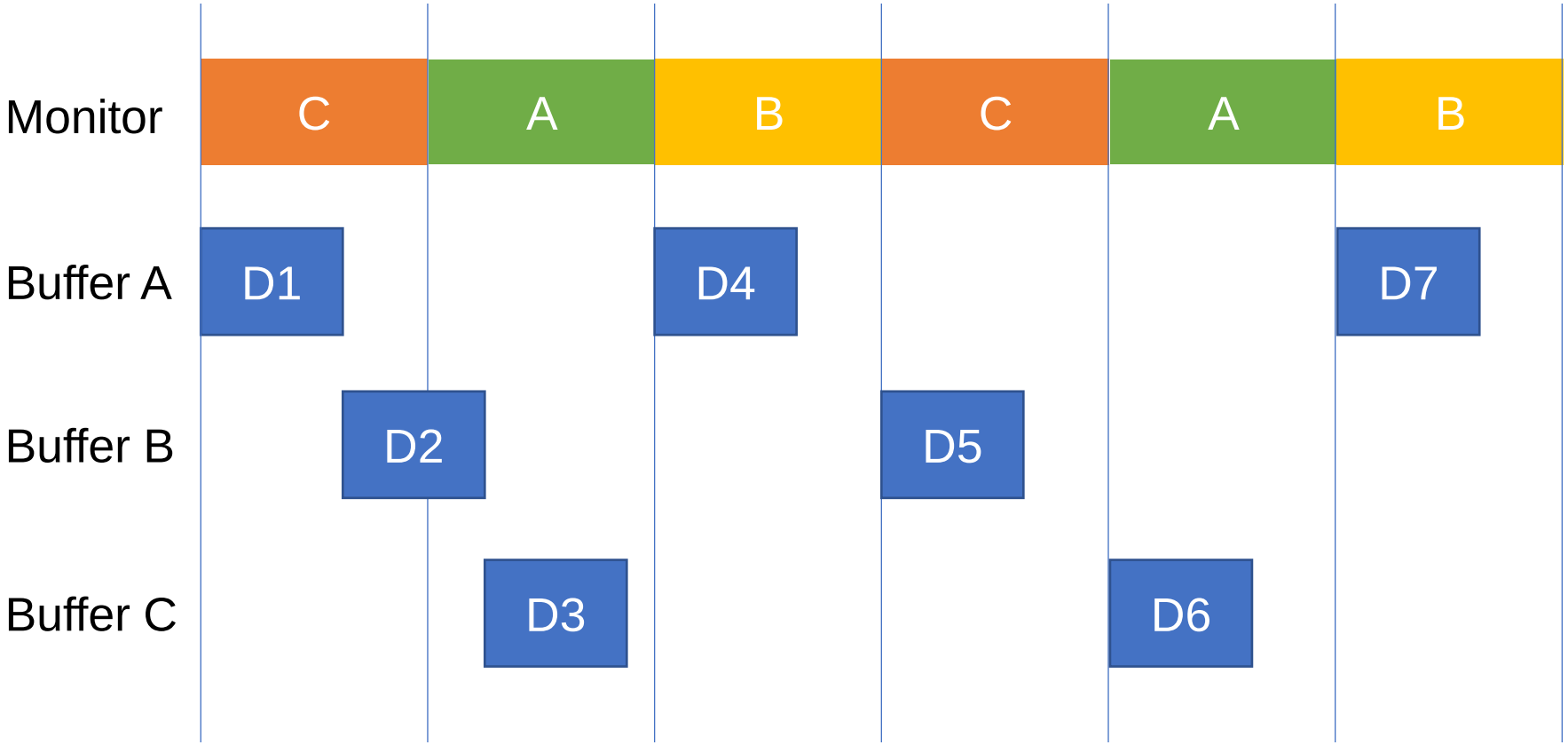
Delayed Draw

- It will not update if a frame is not ready
  - i.e., Lag…



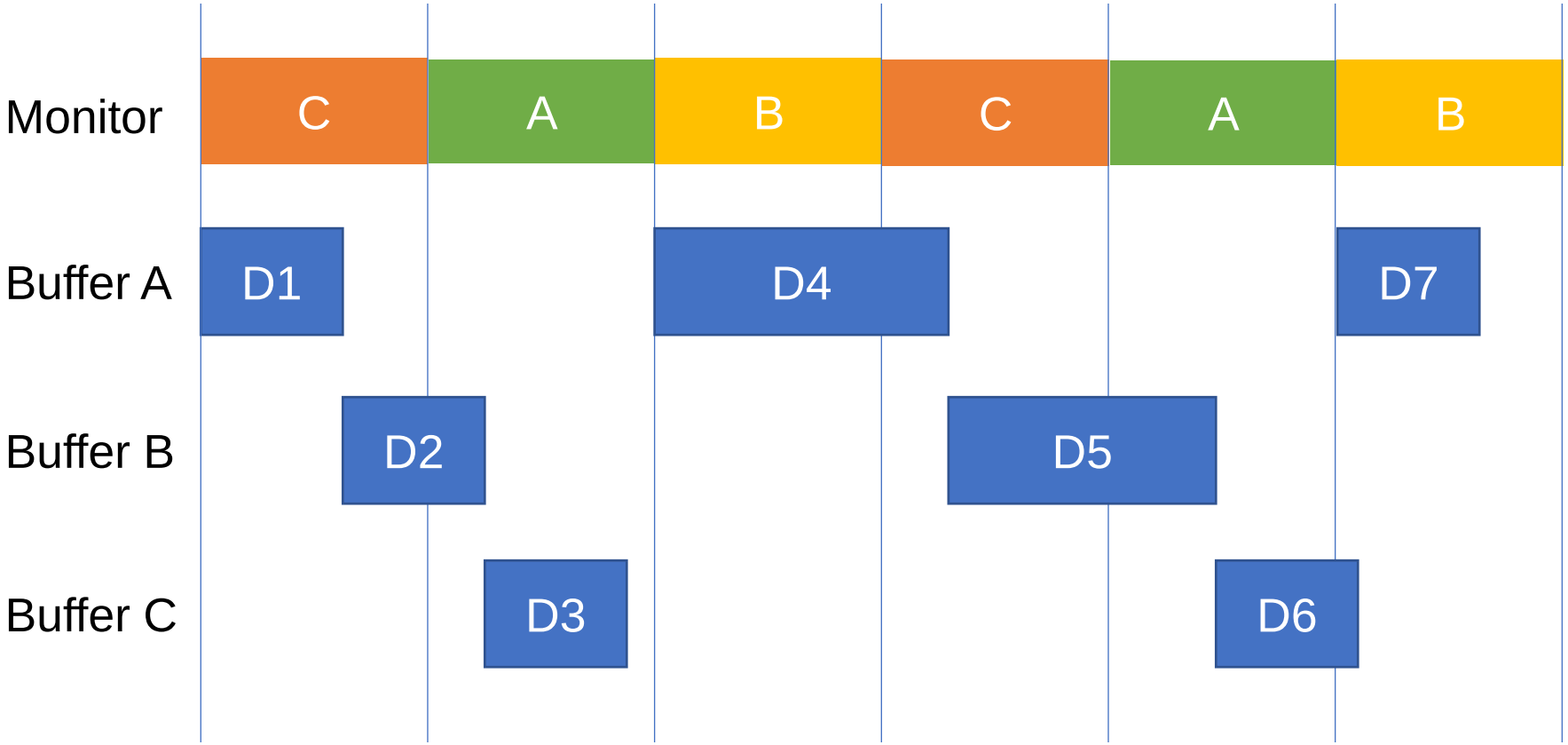
Triple-Buffering

- Adding more buffers



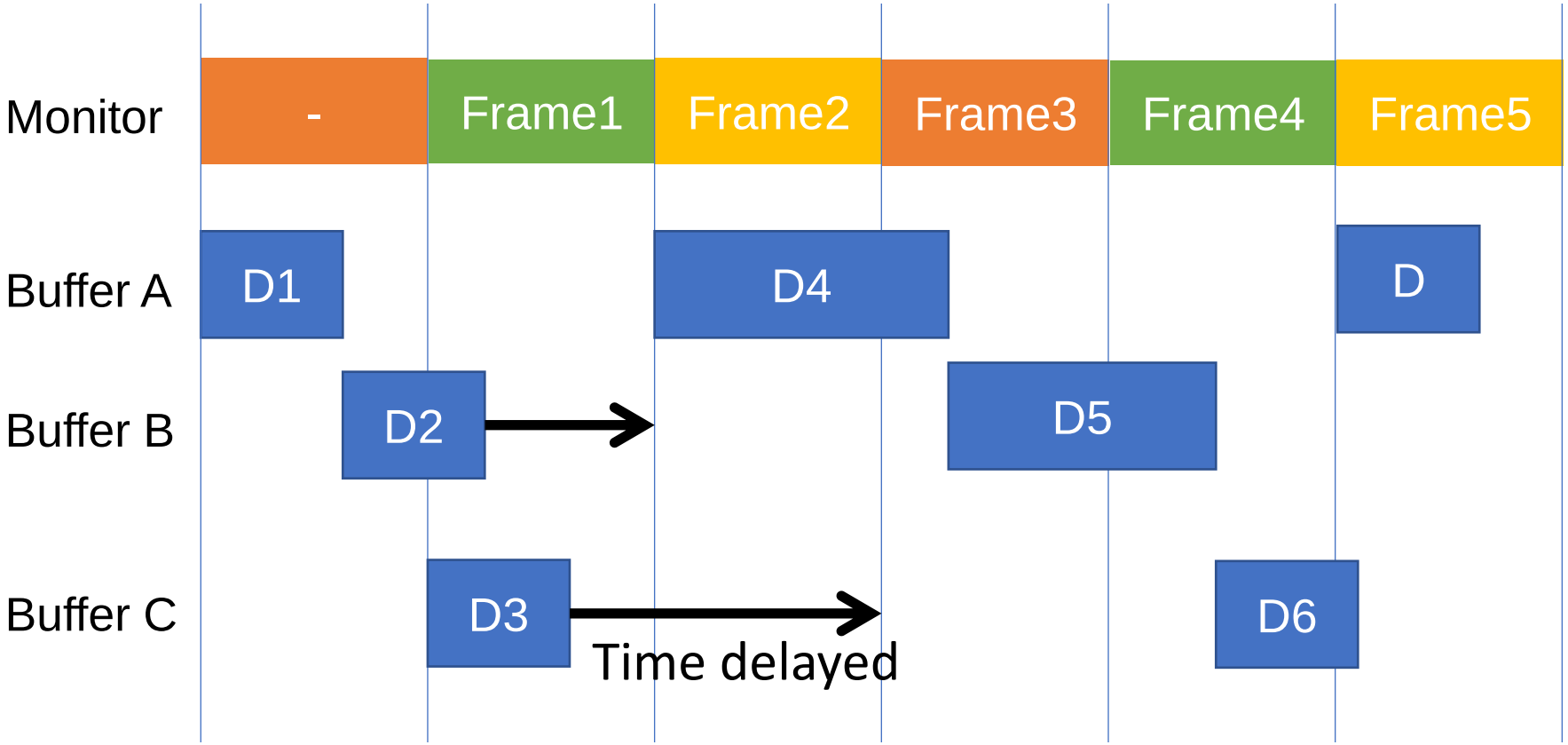
Delayed Draw

- Less affect on the frames



More Buffers?

- Not good as there is time delay



More Buffers?

- More buffers = more time delayed

- Imagine what you see is rendered 3s before
  - Input response time will be longer
  - Not good for real-time applications

Any Questions?