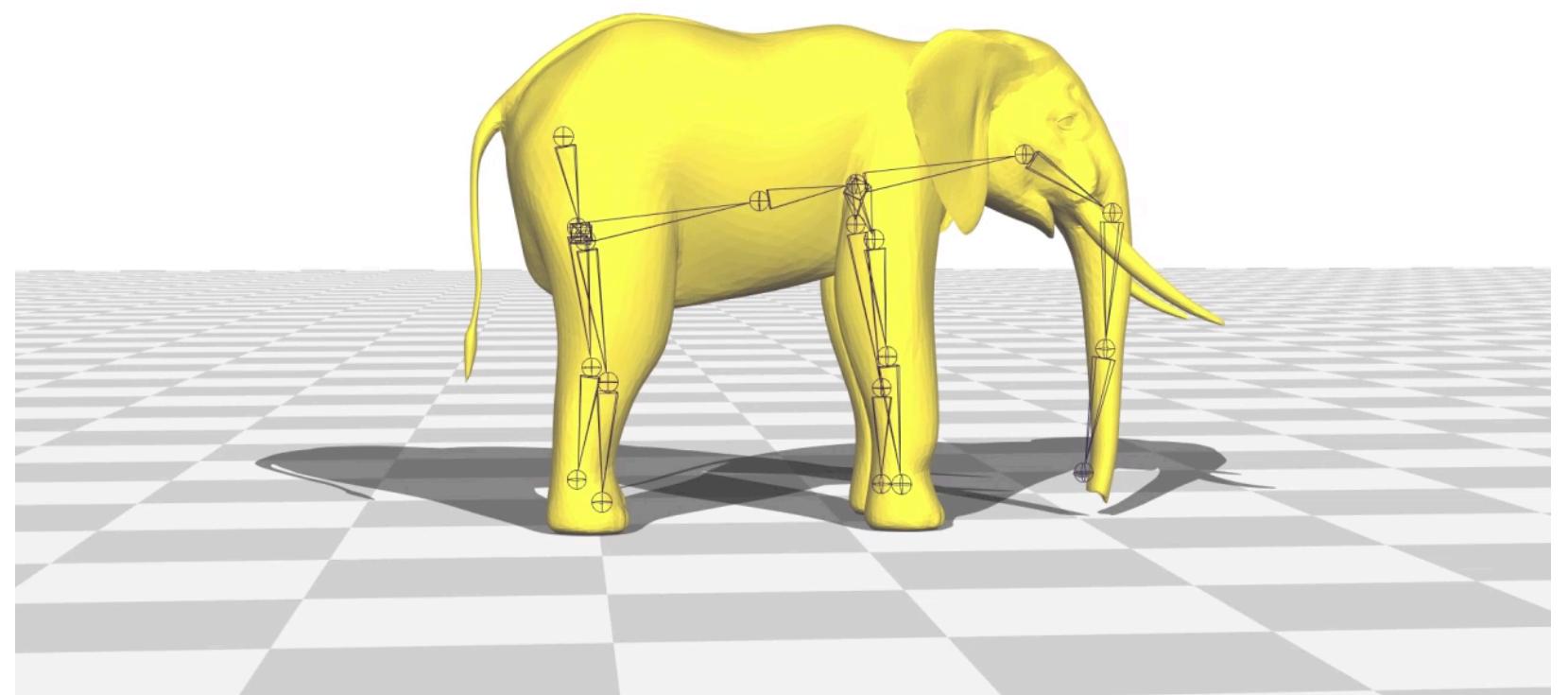
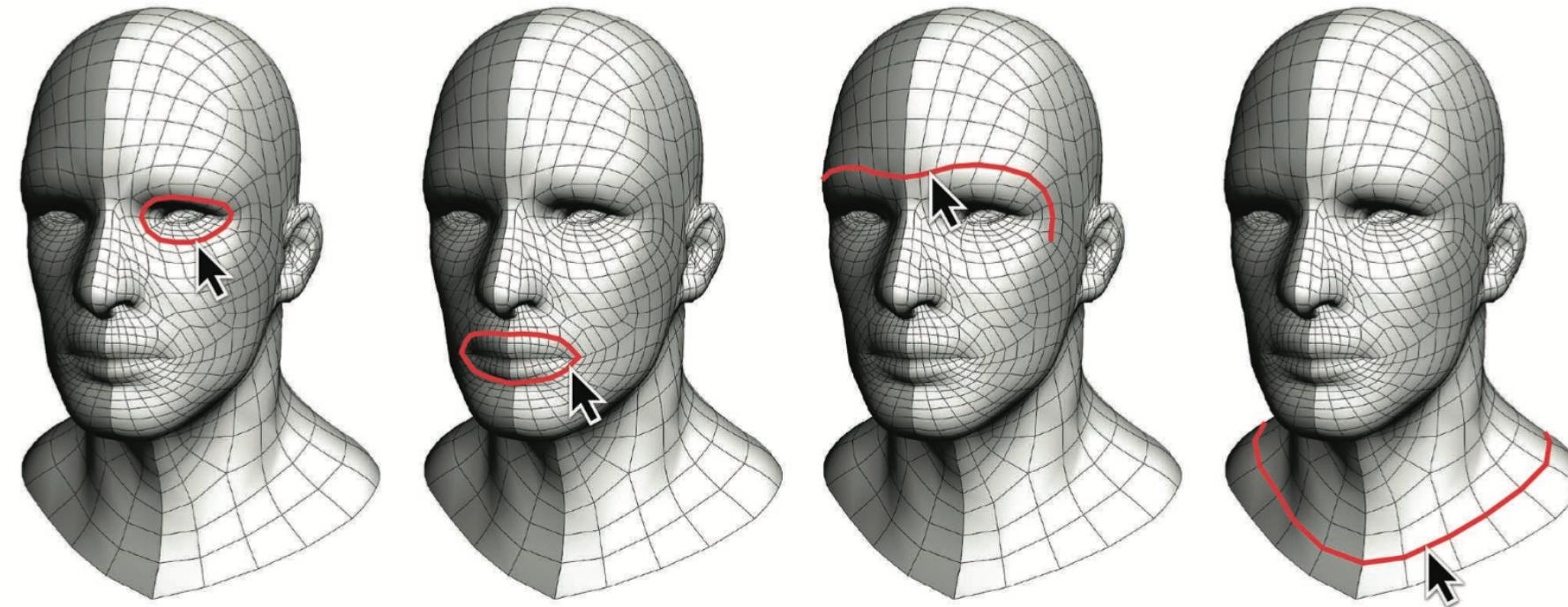
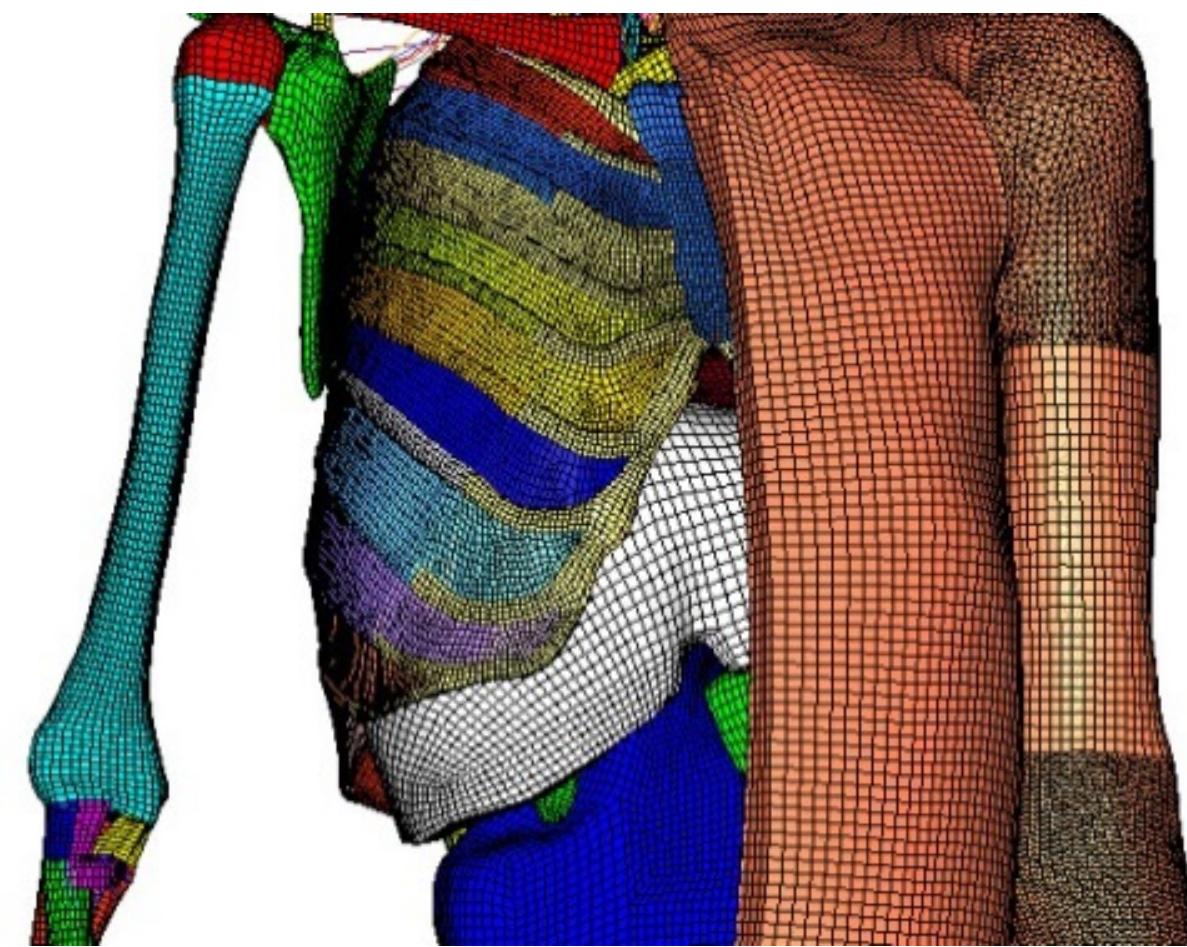
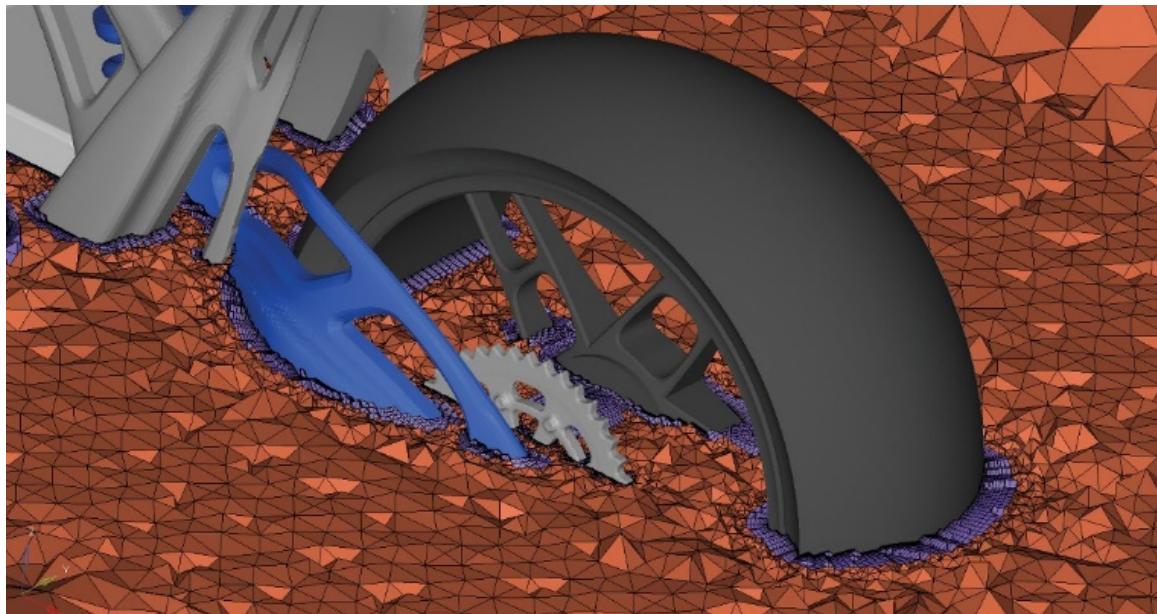
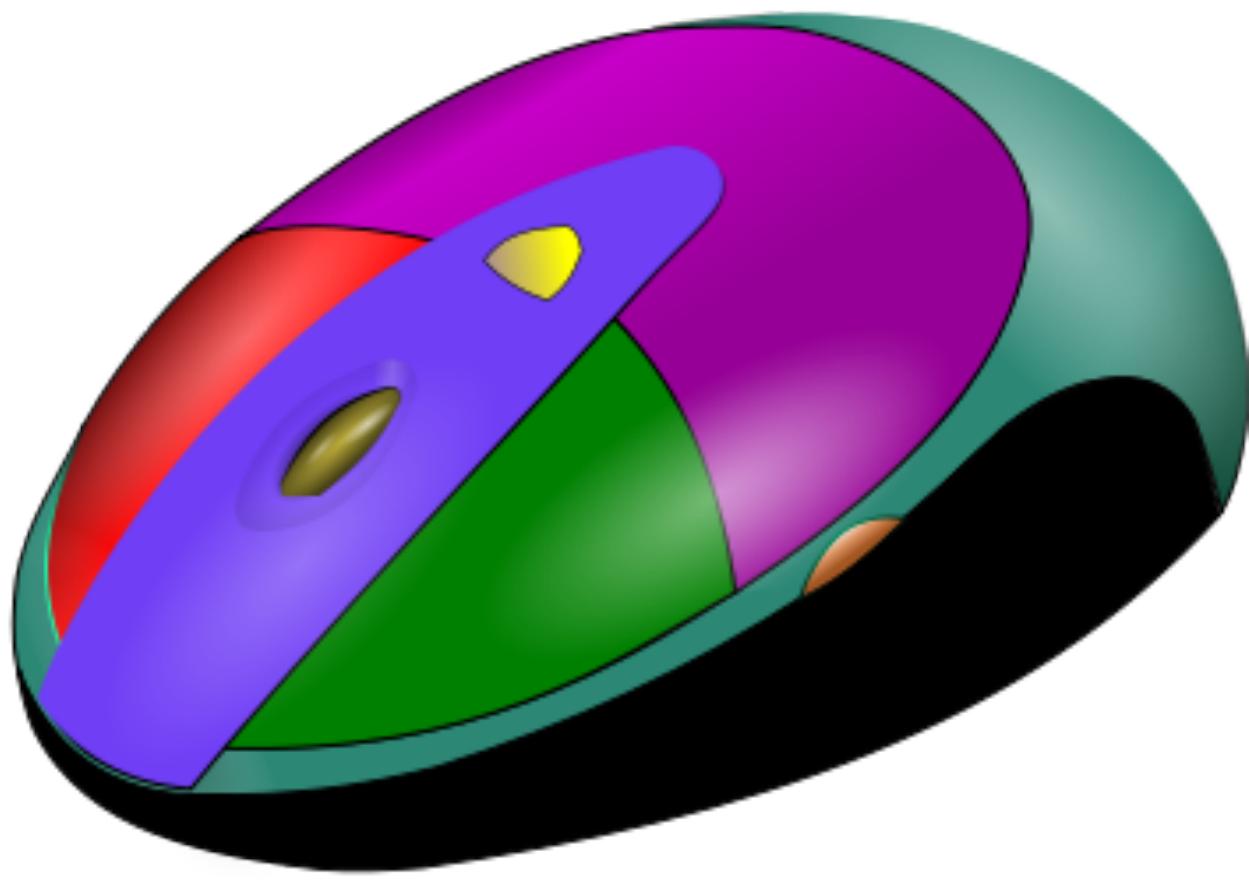


Recap: What is Computer Graphics?



Involves the creation and manipulation of 2D and 3D data

Recap: Why is Computer Graphics?



Basic Math

- Sets
- Functions/Maps
- Intervals
- Logarithm
- Solving Quadratic Equations
- Trigonometry
- Basic Linear Algebra
- Curves and Surfaces
- Linear Interpolation
- Triangles



Basic Math

- Sets
- Functions/Maps
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- Triangles

If you are not familiar with some of these topics,
refresh them before the next class!



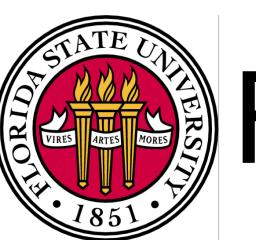
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What is an image?

- A 2D distribution of intensity or color
- A function defined on a two-dimensional plane,

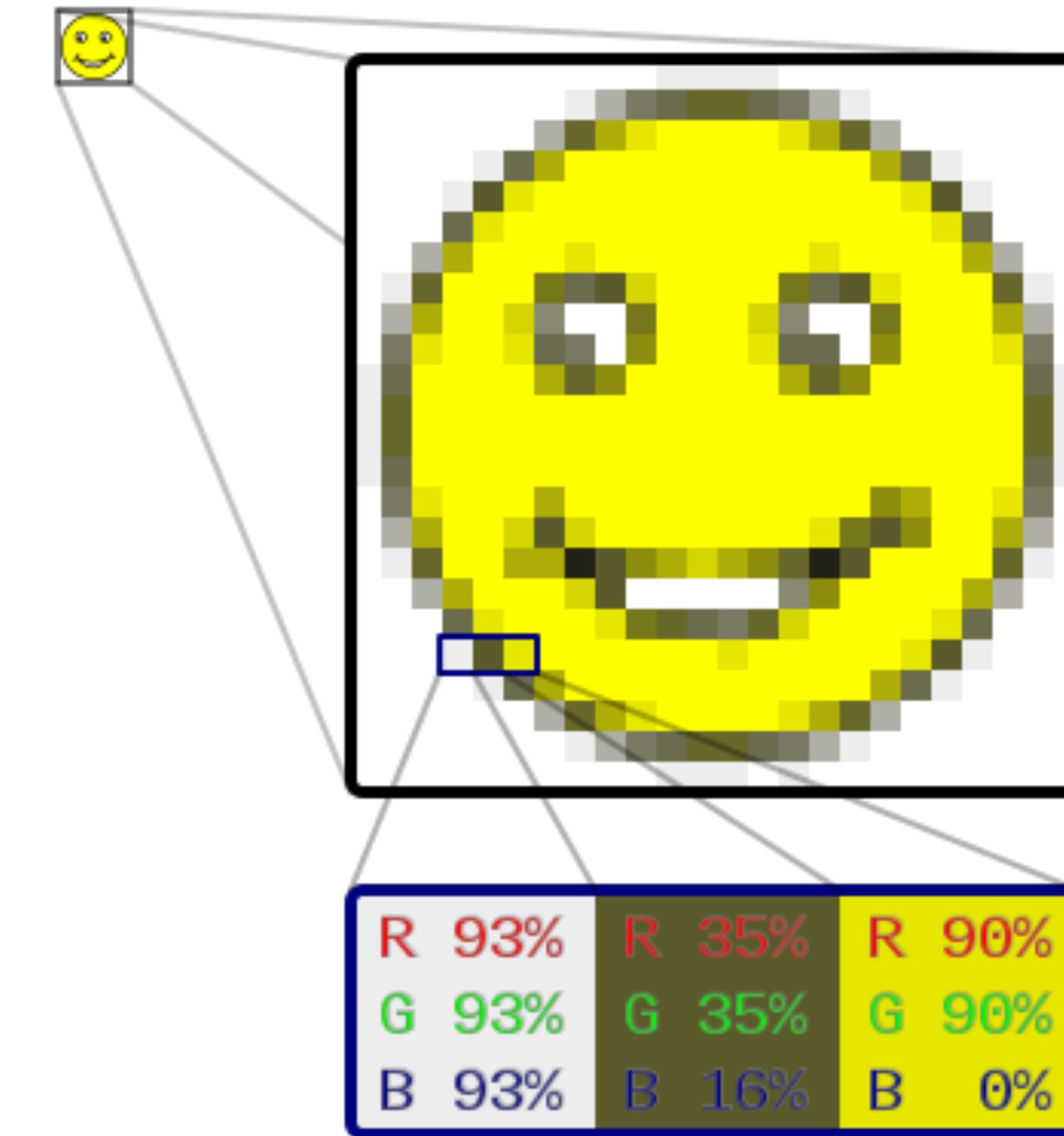
$$I: \mathbb{R}^2 \rightarrow V$$

- To do graphics,
 - represent images — encode them numerically
 - display images — realize them as actual intensity distributions

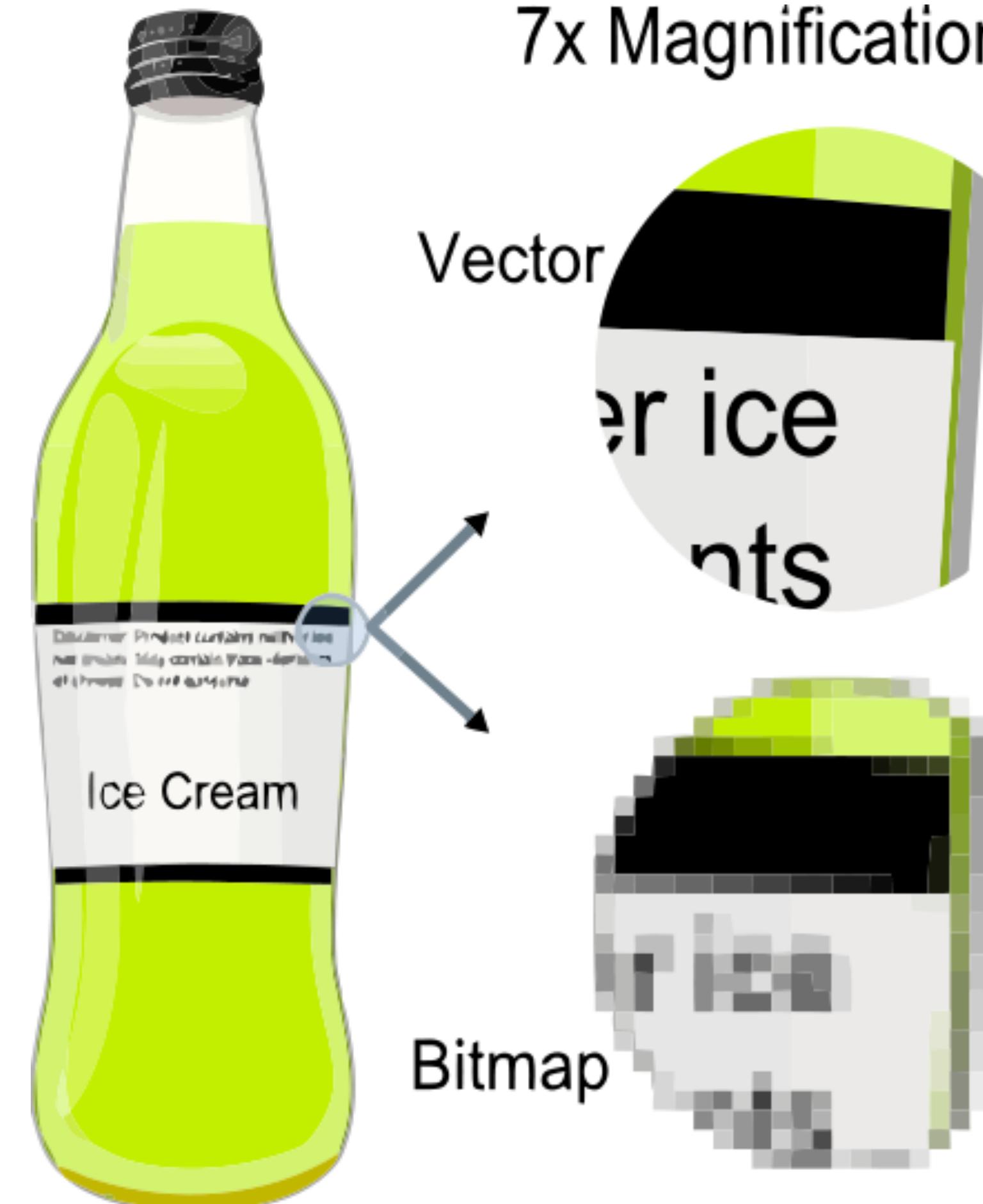


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Raster Images



Vector Image



<https://commons.wikimedia.org/w/index.php?curid=15789788>



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Vector Vs Raster

Advantages

- Small storage: the size of representation does not depend on the dimensions of the object
- Infinite precision: one can infinitely zoom in the image, and it remains smooth
- The parameters of objects are stored and can be later modified
- From a 3-D perspective, rendering shadows is also much more realistic with vector graphics

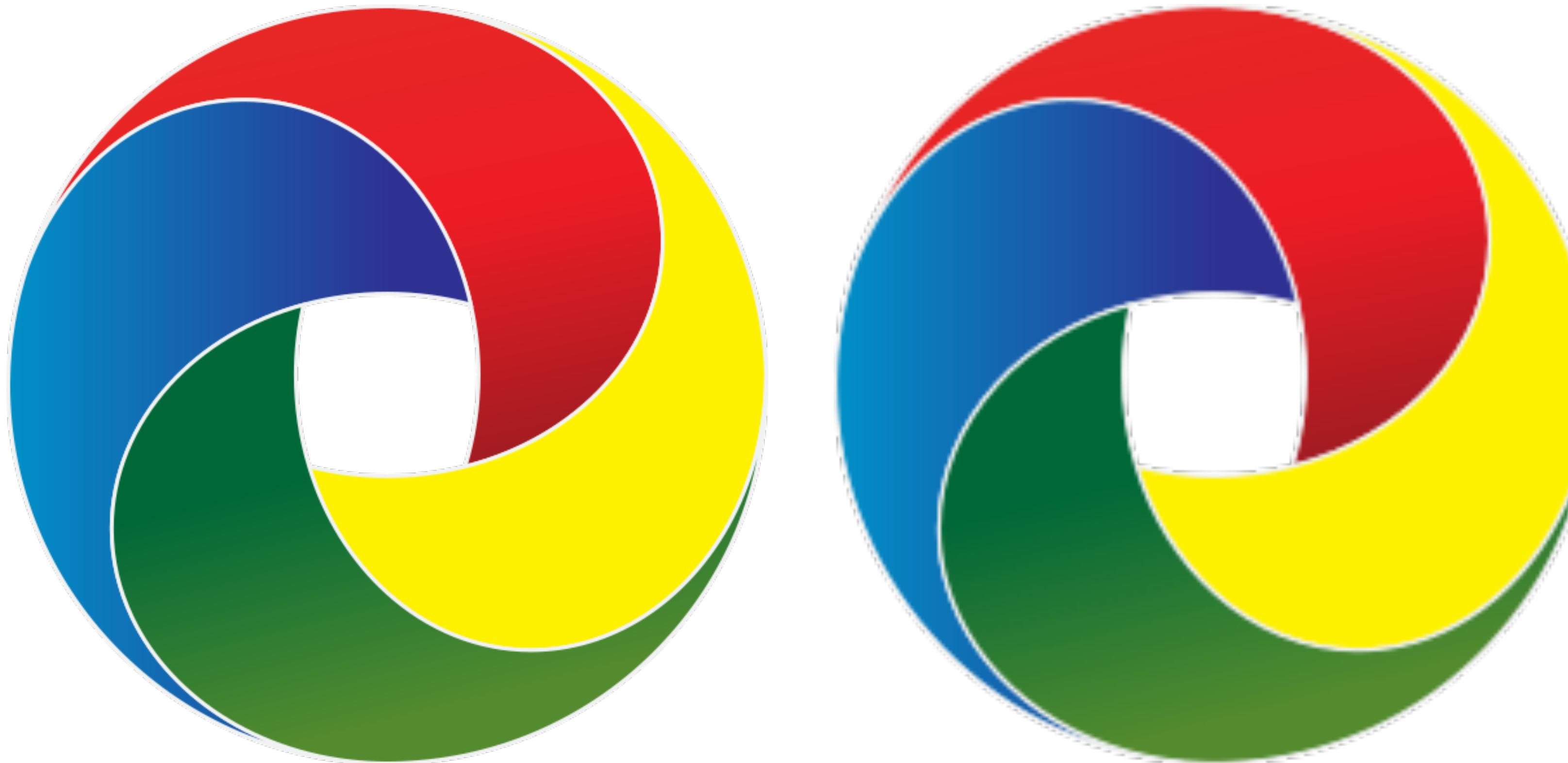
Disadvantages

- Incompatible with most imaging devices, such as camera and scanners
- Image editor software operates on the pixels rather than on drawing objects defined by mathematical expressions
- Hard to describe complicated scenes and shading



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Vector Image

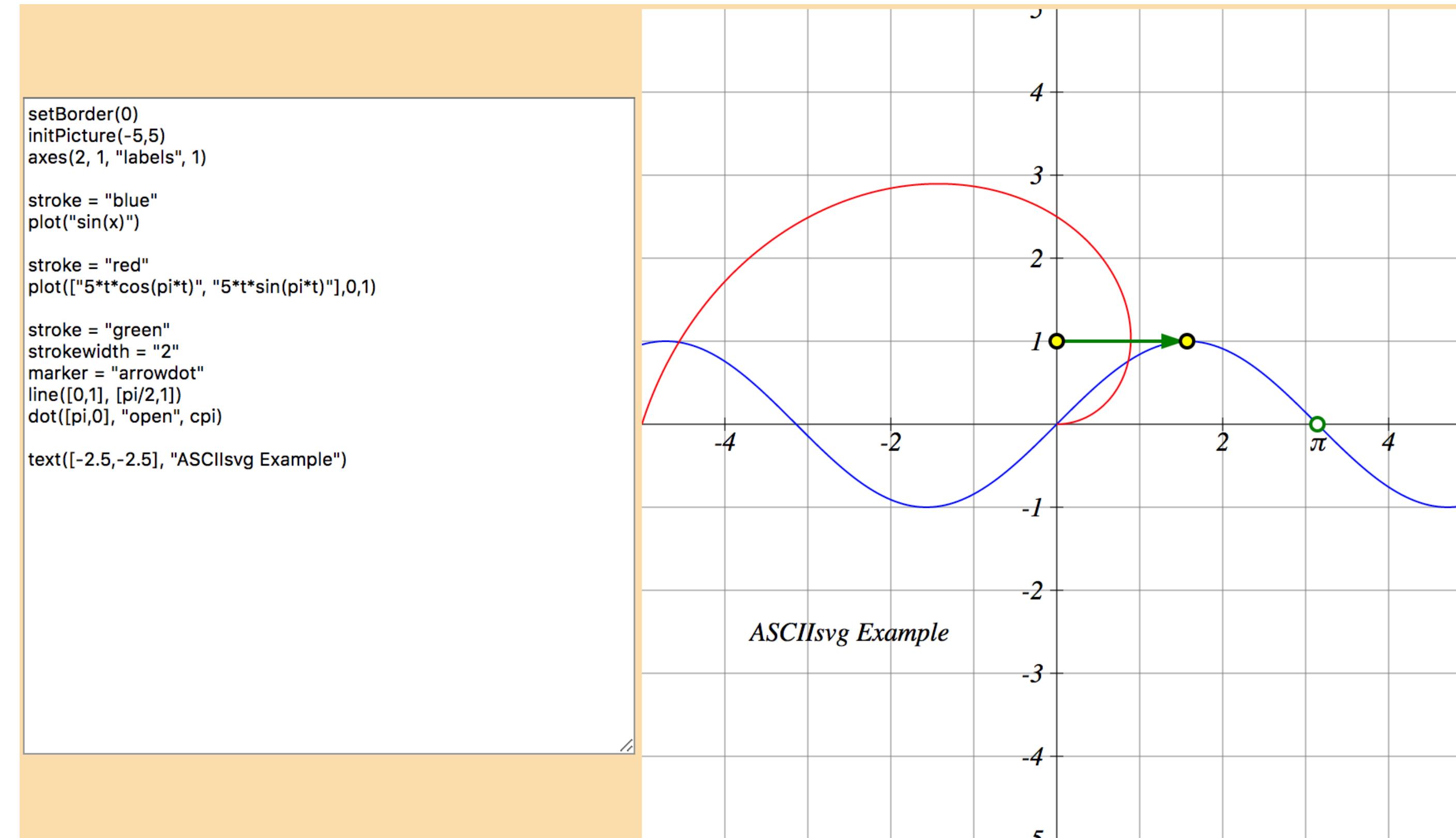


By Tonchino - Own work, CC BY-SA 3.0, <https://commons.wikimedia.org/w/index.php?curid=23776193>



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Vector Image



<http://www1.chapman.edu/~jipsen/svg/asciisvgeditor.html>

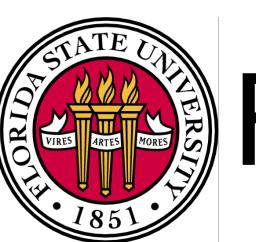


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Vector Image

Typical primitives

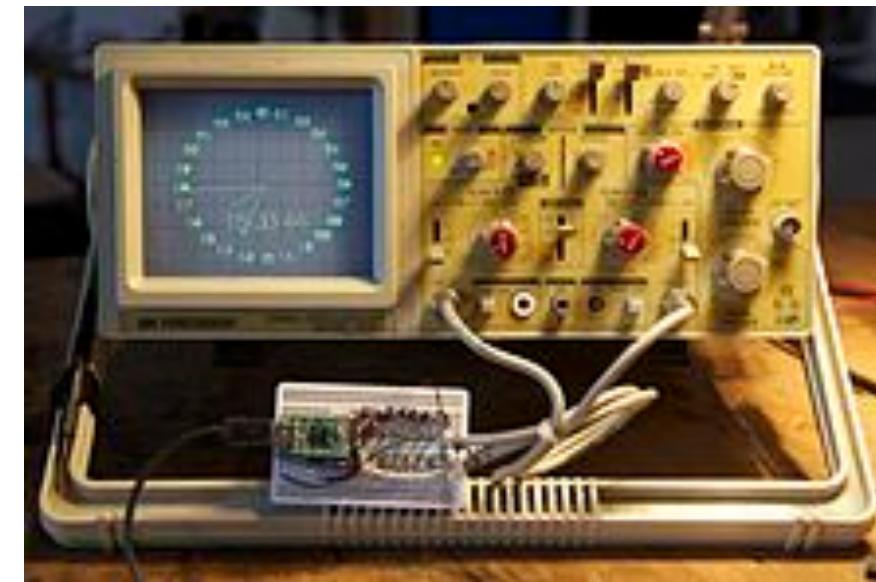
- Lines, polylines and polygons
- Bézier curves and bezigrams
- Circles and ellipses



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Vector Devices

- A 24-hour clock displayed on an [oscilloscope](#) configured as a vector monitor
- A free software [Asteroids](#)-like video game played on an [oscilloscope](#) configured in X-Y mode

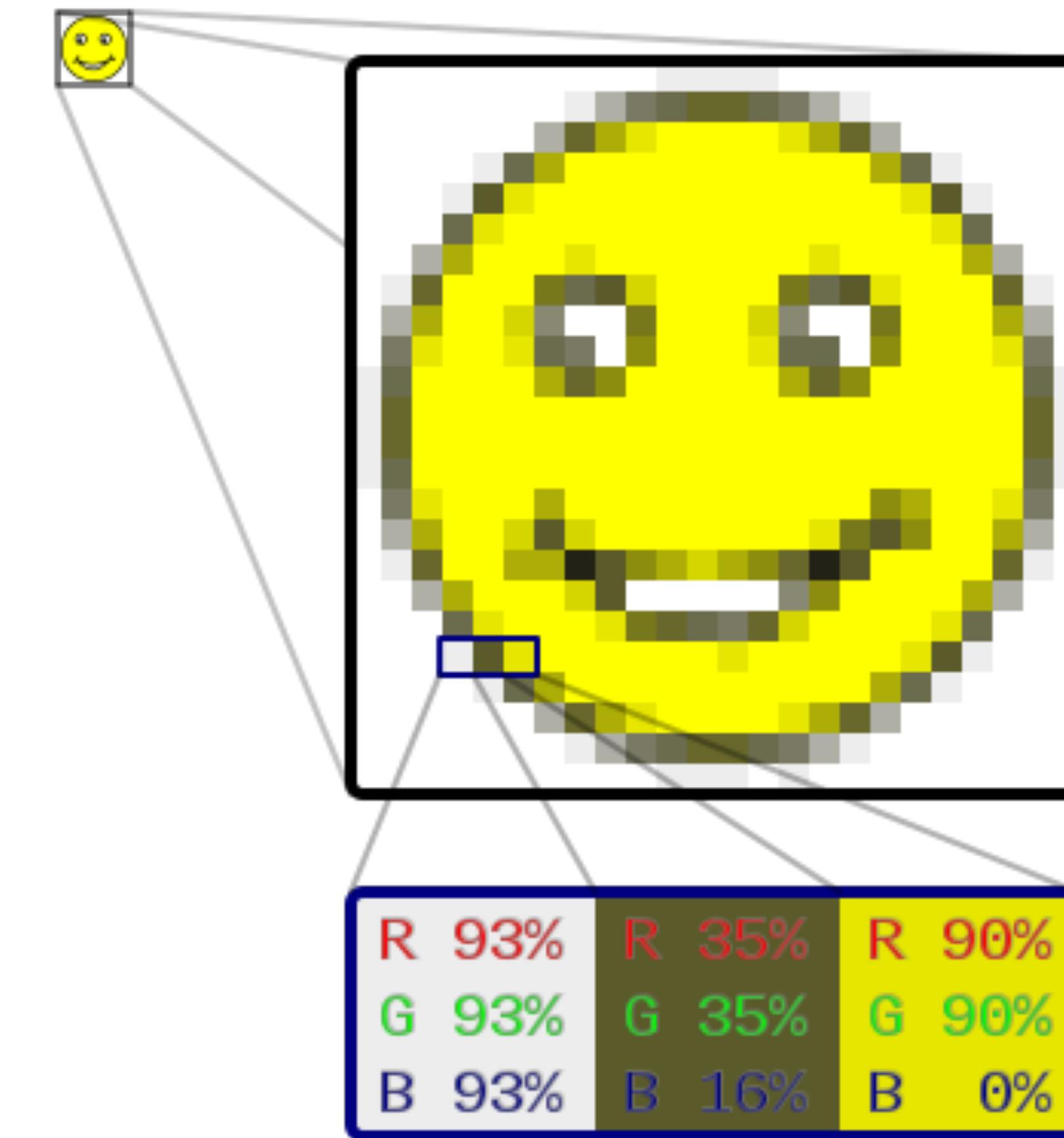


https://en.wikipedia.org/wiki/Vector_monitor

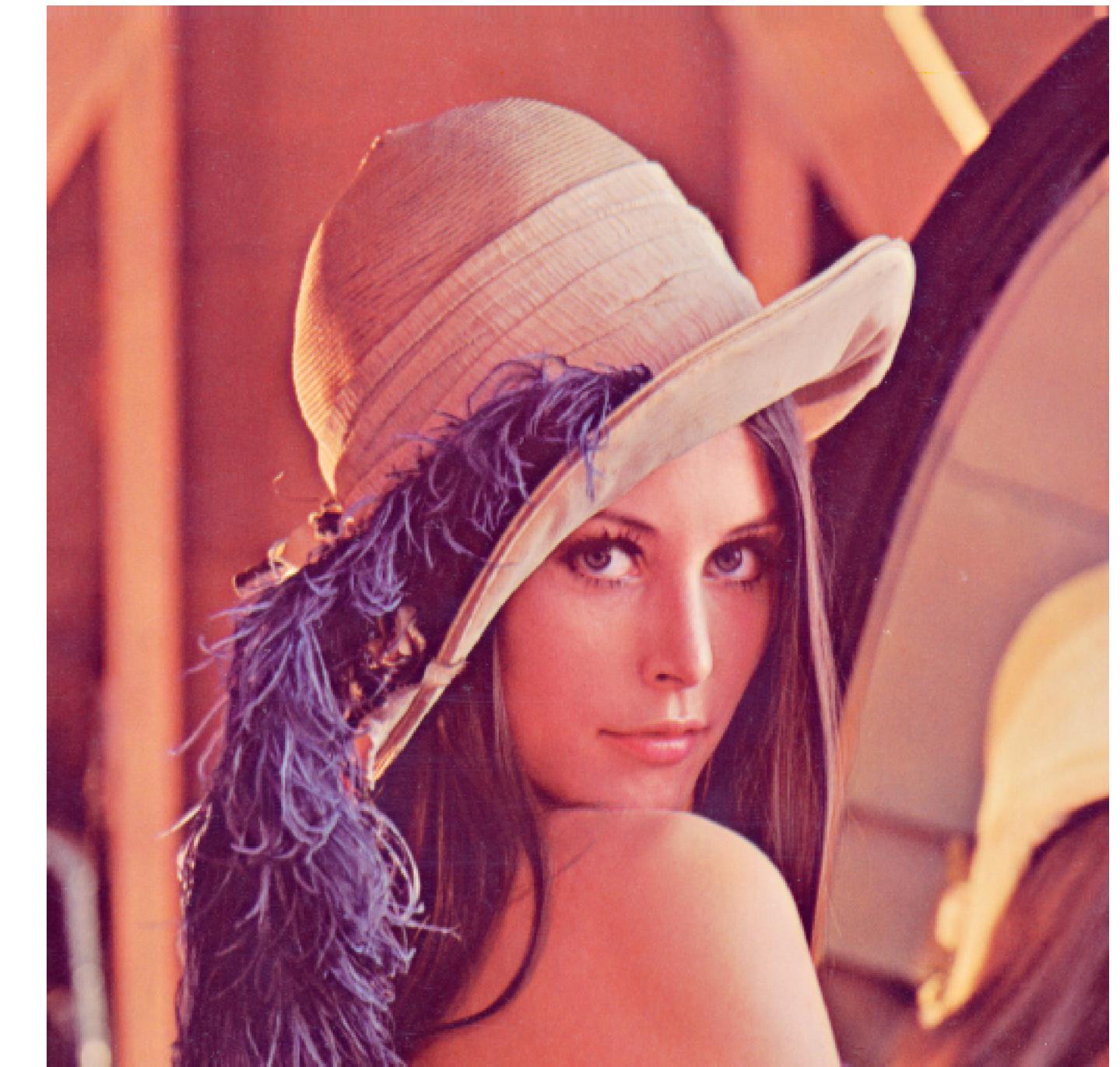
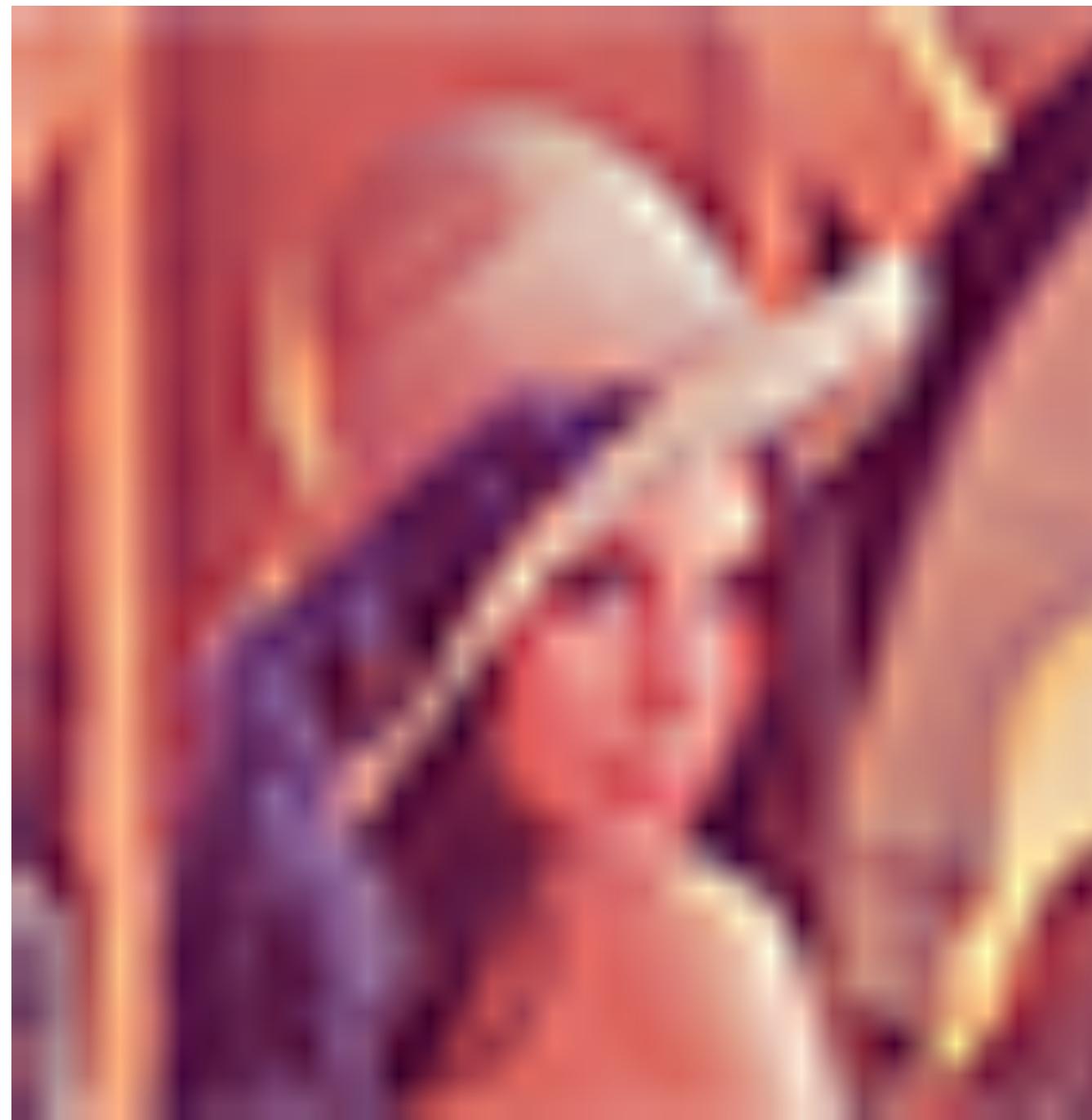


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Raster Images



Raster Images



It can approximate an arbitrary function with increasing resolution

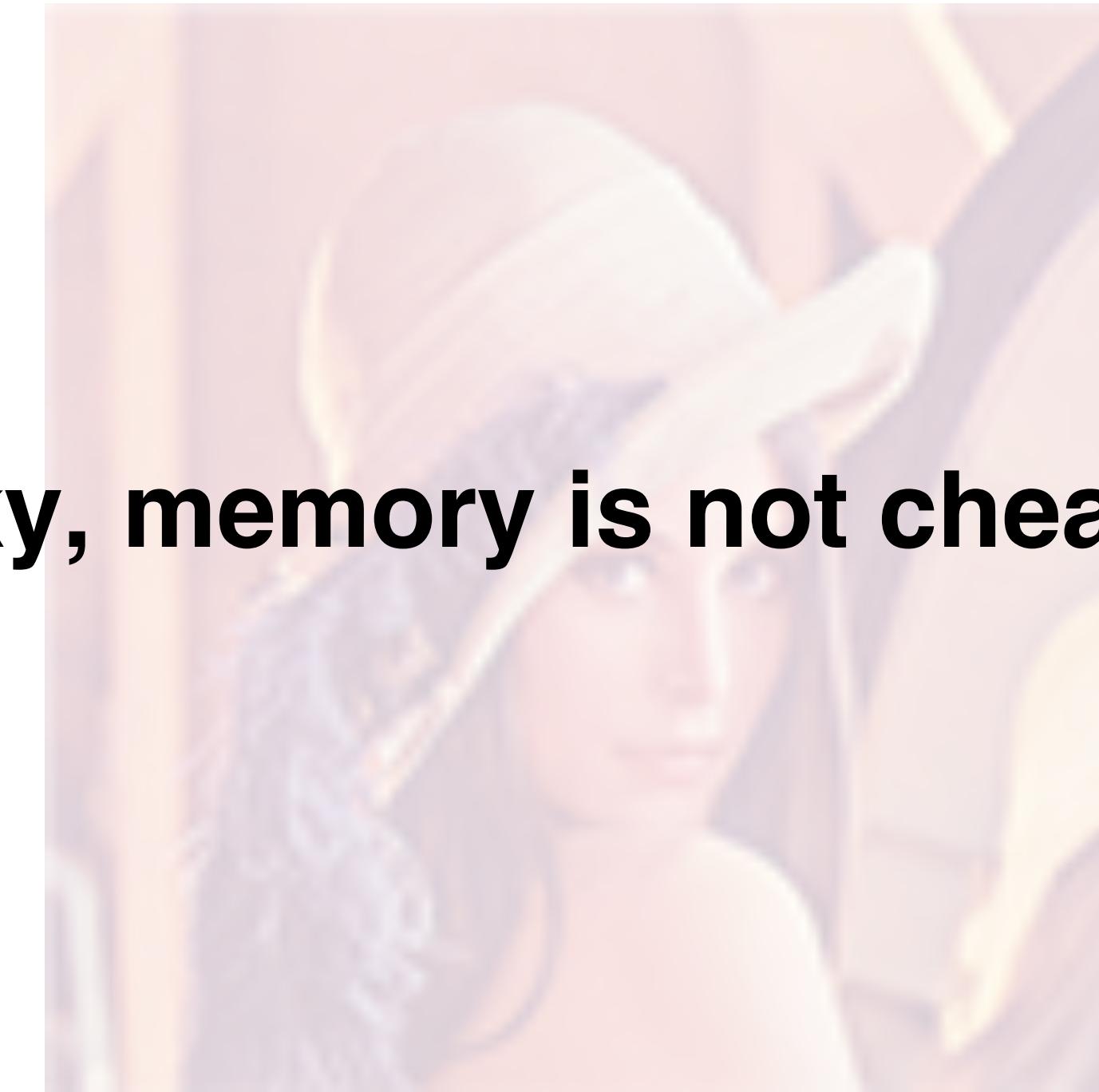


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Raster Images



3D is tricky, memory is not cheap anymore!



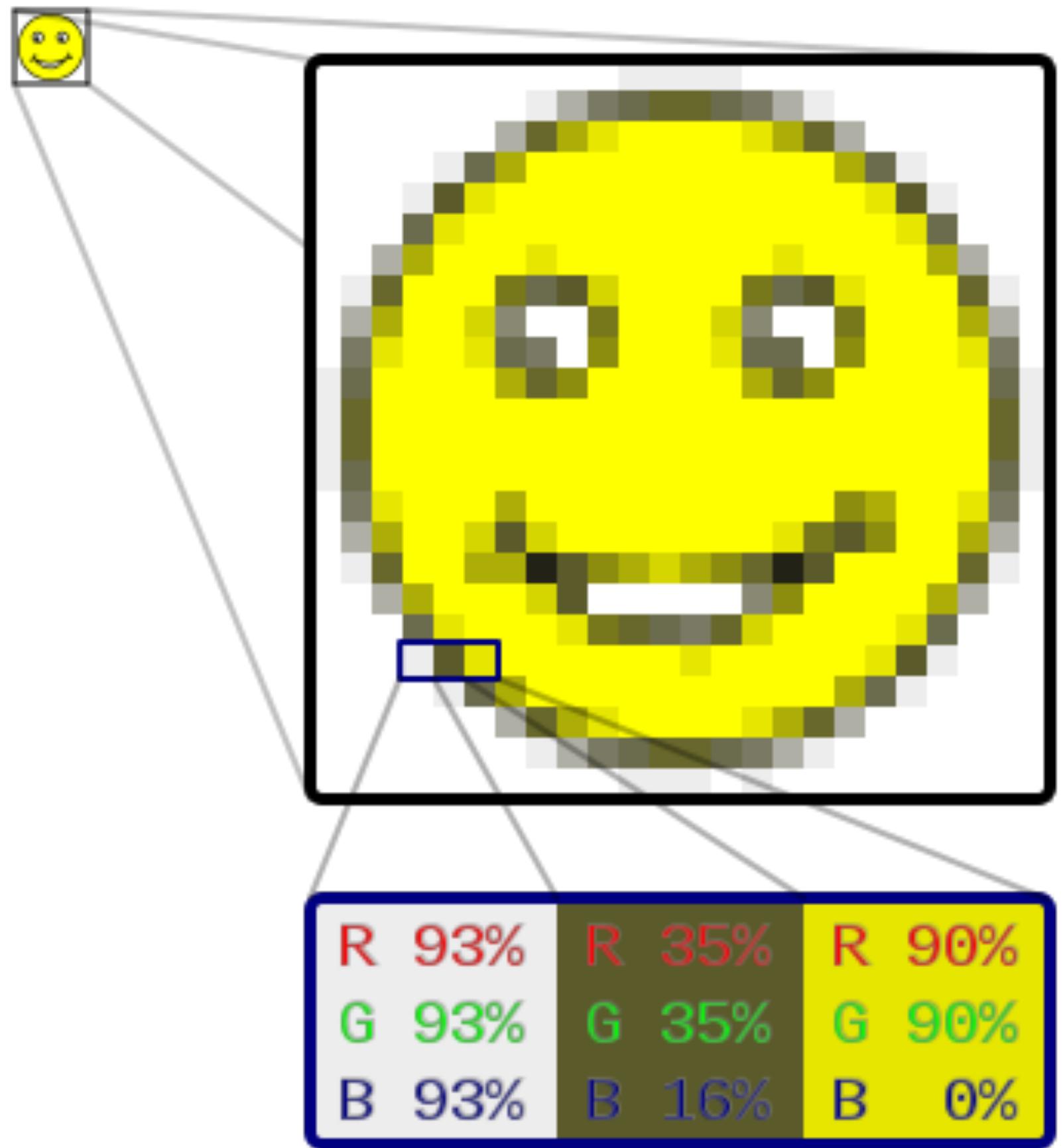
It can approximate an arbitrary function with increasing resolution



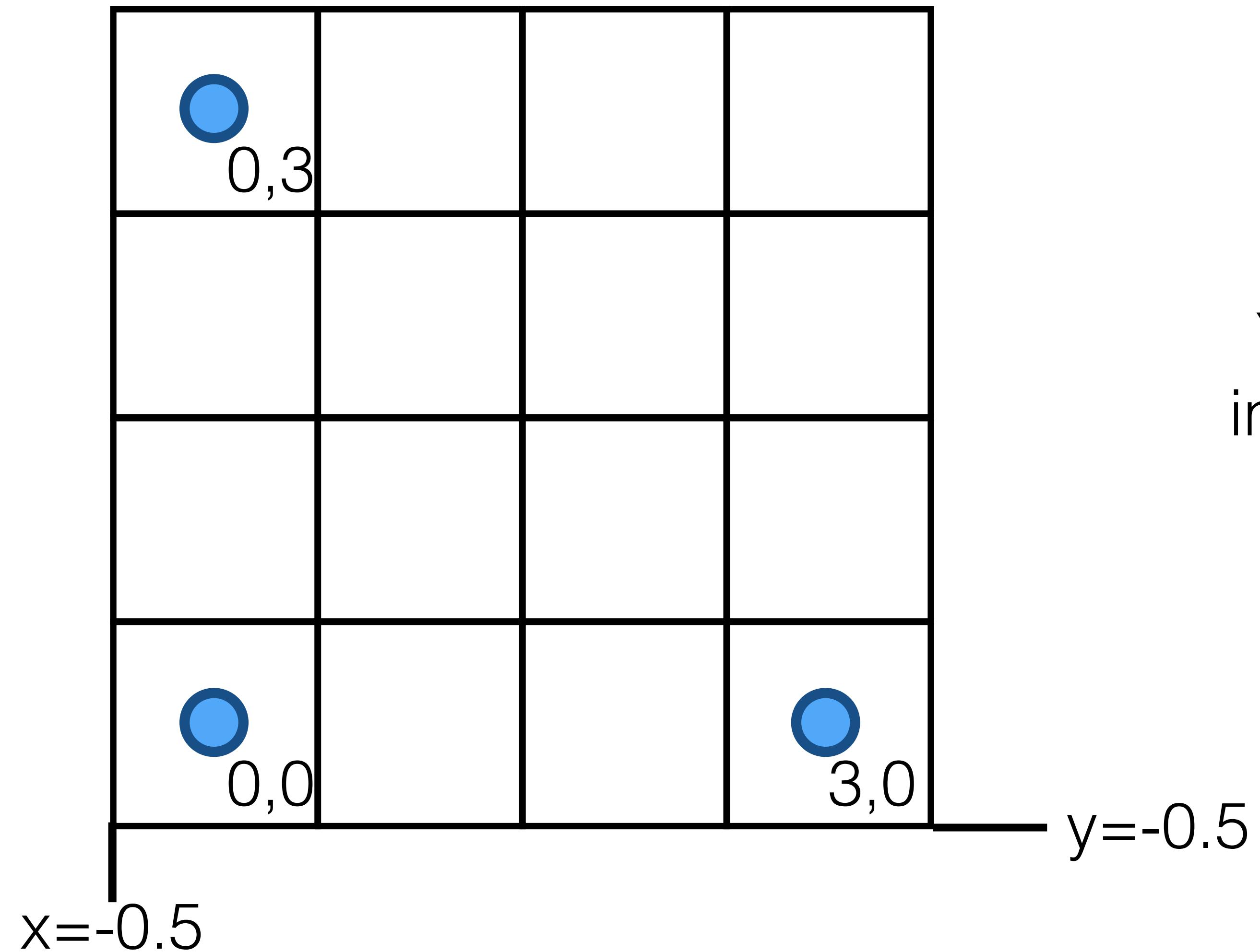
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Raster Images

- A discretization of a function in 2D
- An array of values = the resolution of a display?
 - The resolution of a screen is fixed, but, we don't have just one output device
 - want to define images we can't display
- A pixel is not a little square: “this is the intensity around here”



Pixel Coordinates - Raster Image



Be Careful:
Y is flipped
in some APIs

Pixel Values (Framebuffer format)

- 1-bit greyscale – text
 - black and white
- 8-bit RGB (24 bits) - web and email
 - full range of displayable color; e.g. color print
- 8-bit RGBA (32 bits) - alpha channel, see next slide
- 16/24/32bits - high accuracy for photography and high dynamic range (HDR)
 - represent real scenes independent of display

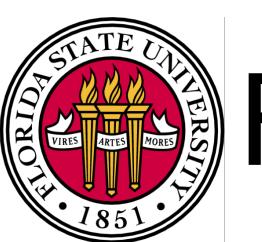


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Storage Sizes

1024x1024 image (1 megapixel)

- bitmap: 128KB
- grayscale 8bpp: 1MB
- grayscale 16bpp: 2MB
- color 24bpp: 3MB
- floating-point HDR color: 12MB



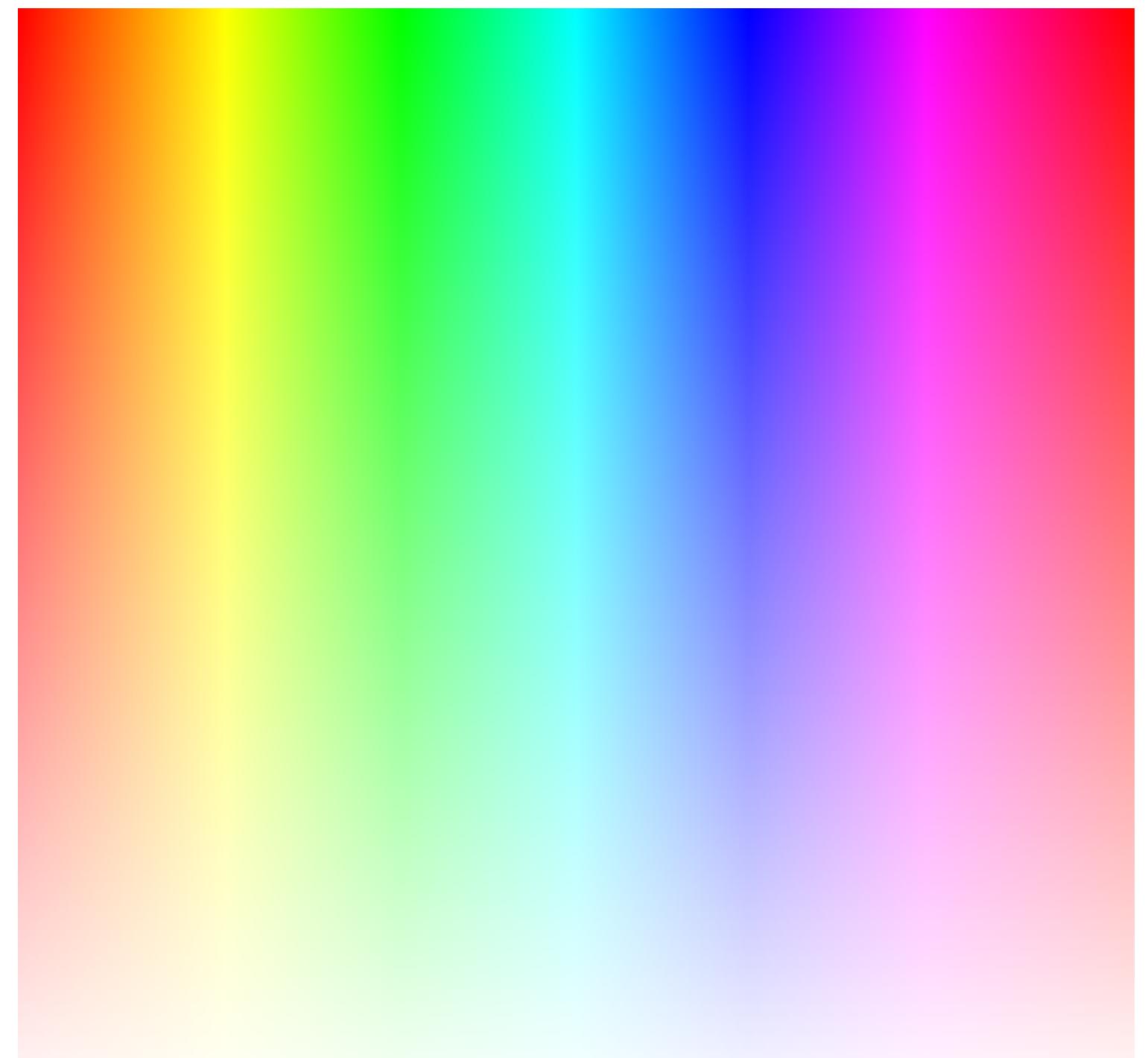
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Alpha Compositing

- A way to represent transparency
- The pixels of an image are blended linearly with the image below

$$\mathbf{c} = \alpha \mathbf{c}_{\text{new}} + (1 - \alpha) \mathbf{c}_{\text{old}}$$

$$\alpha = 1$$



More info: https://en.wikipedia.org/wiki/Alpha_compositing



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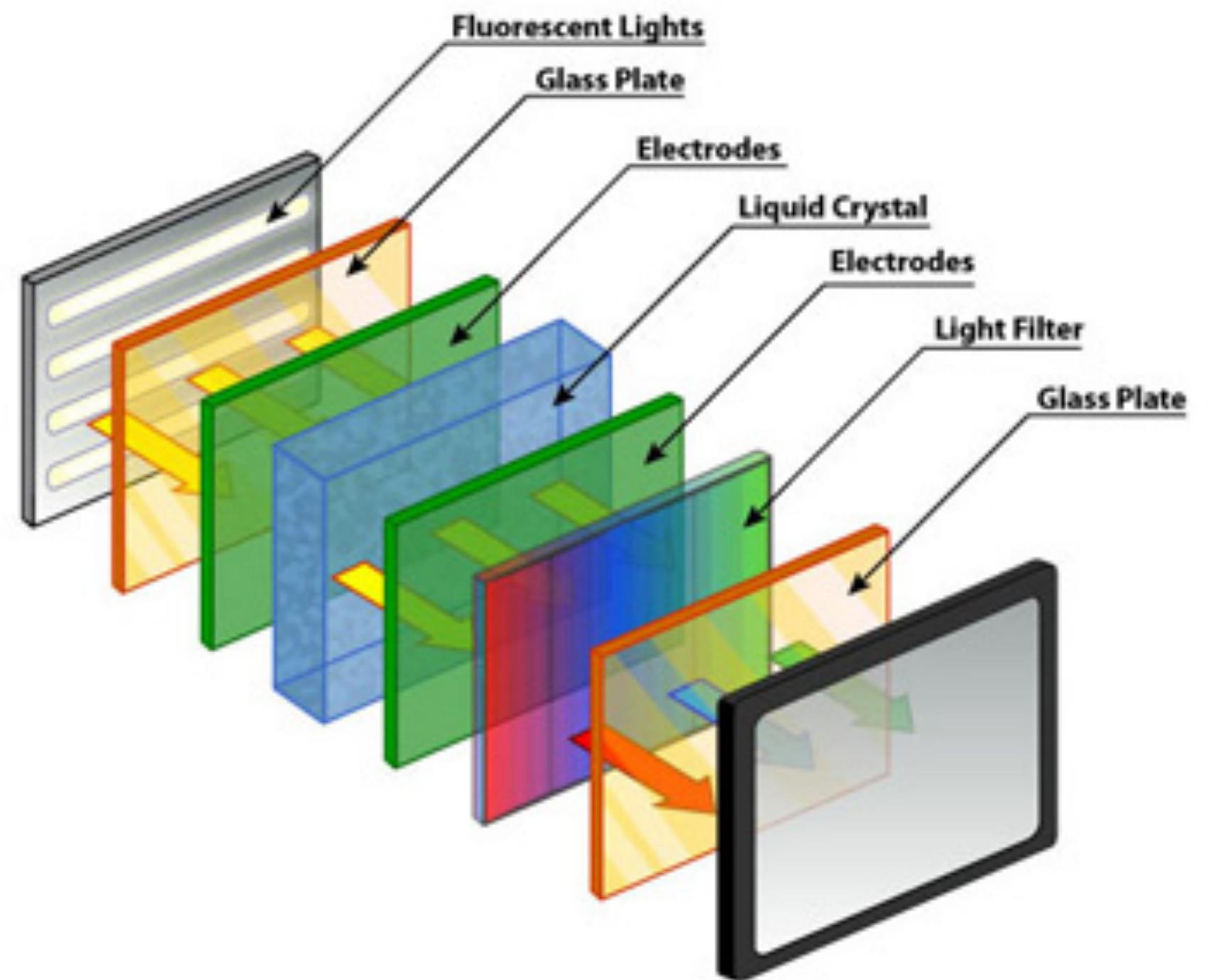
Image Formats

- Lossy:
 - **jpeg** - compact, introduces artifacts, works well for natural images
- Lossless:
 - **png** - common for web applications
 - **ppm** - very simple, not compressed
 - **tiff** - mostly scientific use

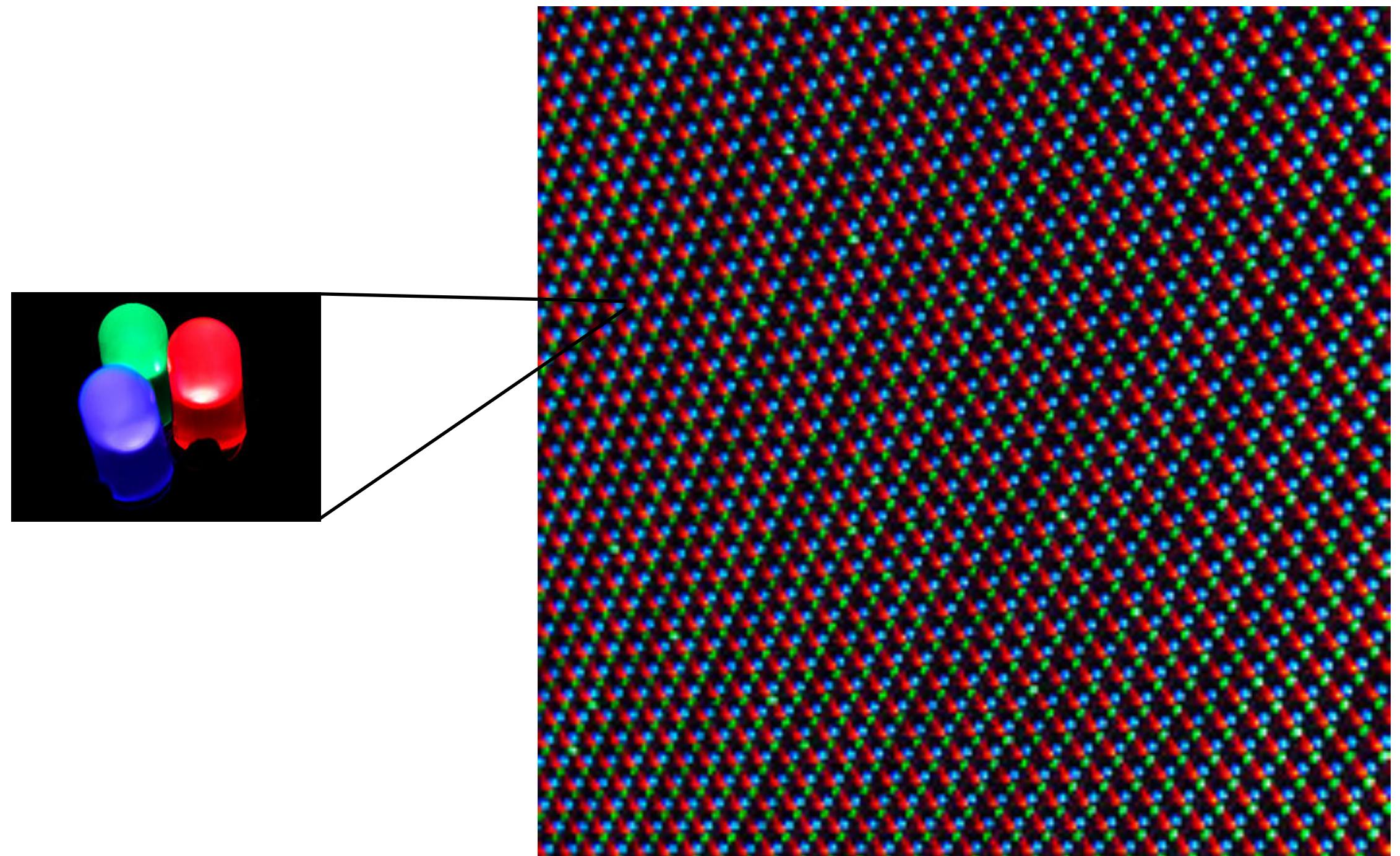


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Raster Output Devices: Display



**Transmissive
Liquid Crystal display (LCD)**



**Emissive
Light-emitting Diode (LED) display**

Monitors Intensity, Gamma Correction

- What is the minimal and maximal light intensity?
- The intermediate intensities are different for each person, and it is non-linear
- Monitors needs to be calibrated for a certain viewer, using a procedure called “Gamma Correction”
- The rule is simple: displayed intensity = (max intensity) * a^γ

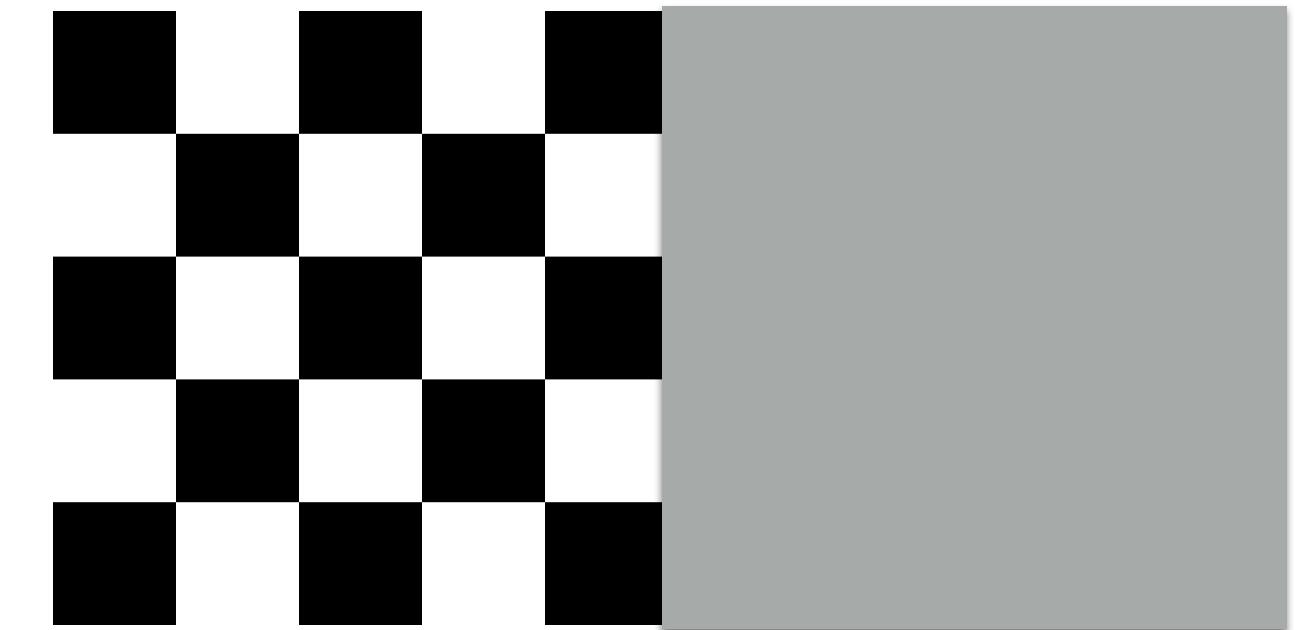




Gamma Correction



- Find the neutral gray: $0.5 = a^\gamma$
- Compute
$$\gamma = \frac{\ln 0.5}{\ln a}$$
- Gamma correct
$$a' = a^{\frac{1}{\gamma}}$$
- The colors will not be uniform on normal screens, one of the major factor affecting the cost of screens is their ability to be consistent on all pixels!

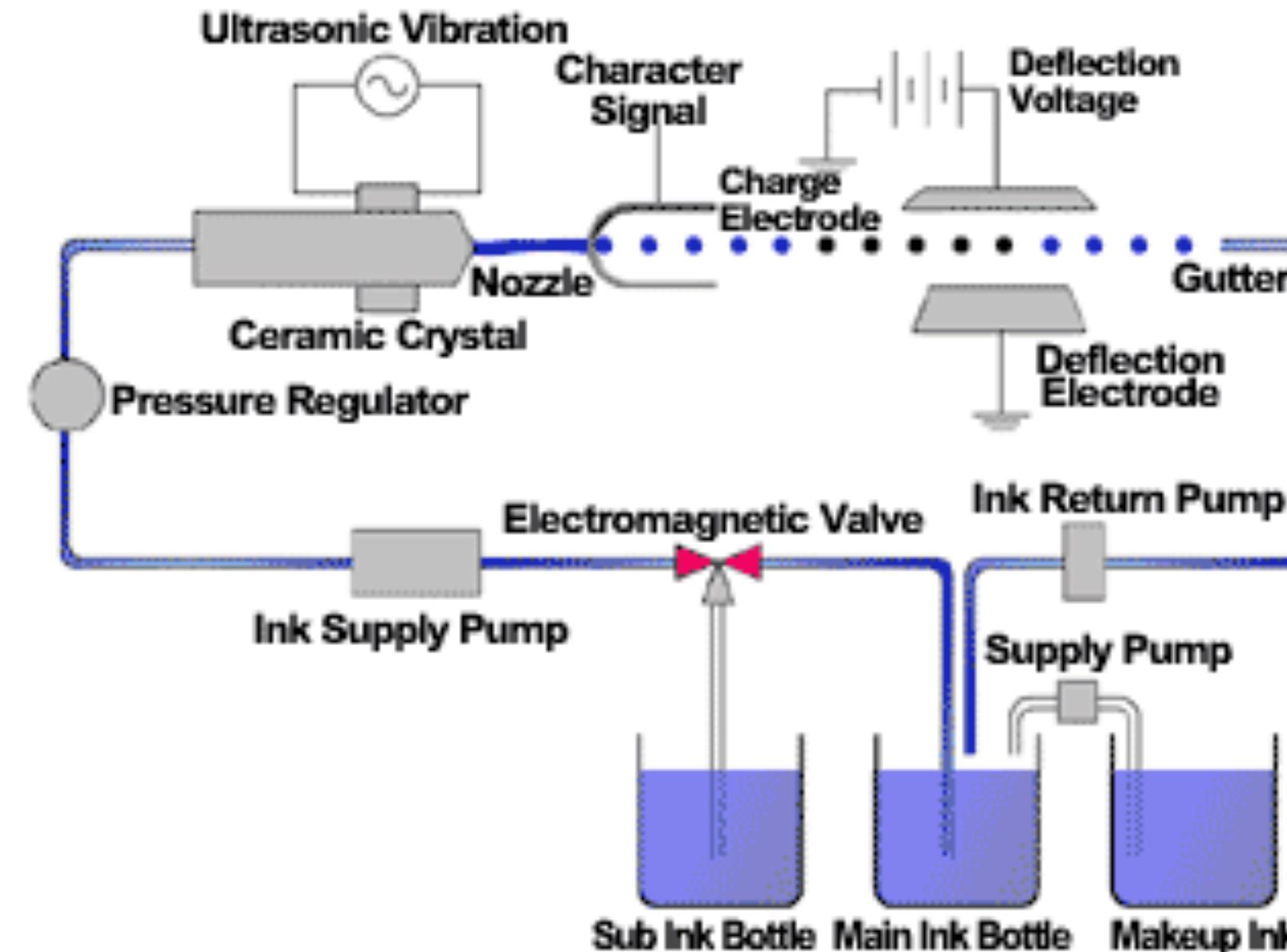


By X-romix 10:00, 7 June 2008 (UTC), Updated by --Rubybrian (talk) 14:25, 14 September 2010 (UTC); Photographer: Toni Frissell - This file was derived from: Weeki Wachee spring 10079u.jpg, GFDL, <https://commons.wikimedia.org/w/index.php?curid=4176109>



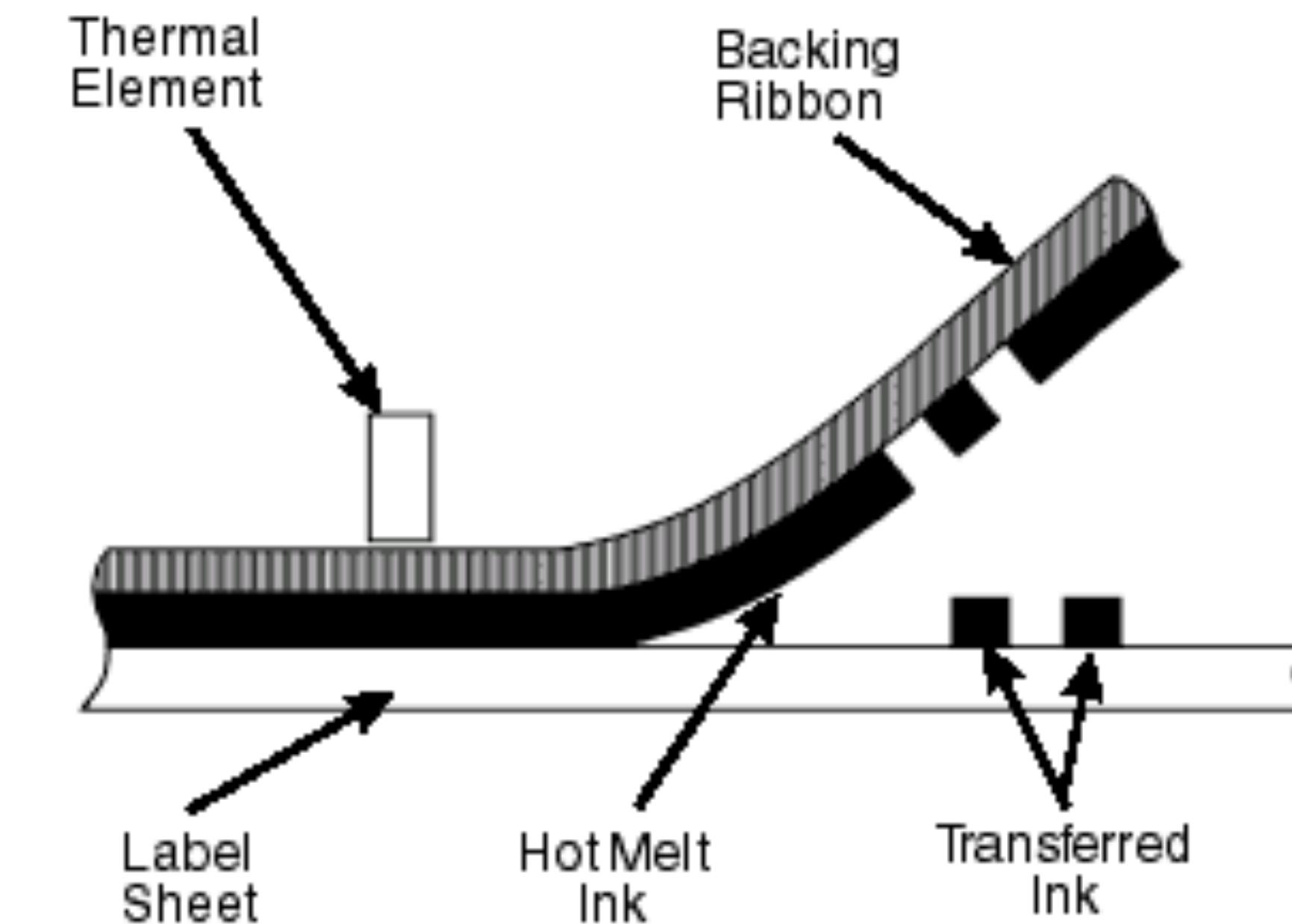
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Raster Output Devices: Printer



<https://www.hitachi-ies.co.jp/english/products/ijp/outline/principle.htm>

Ink-Jet Printer



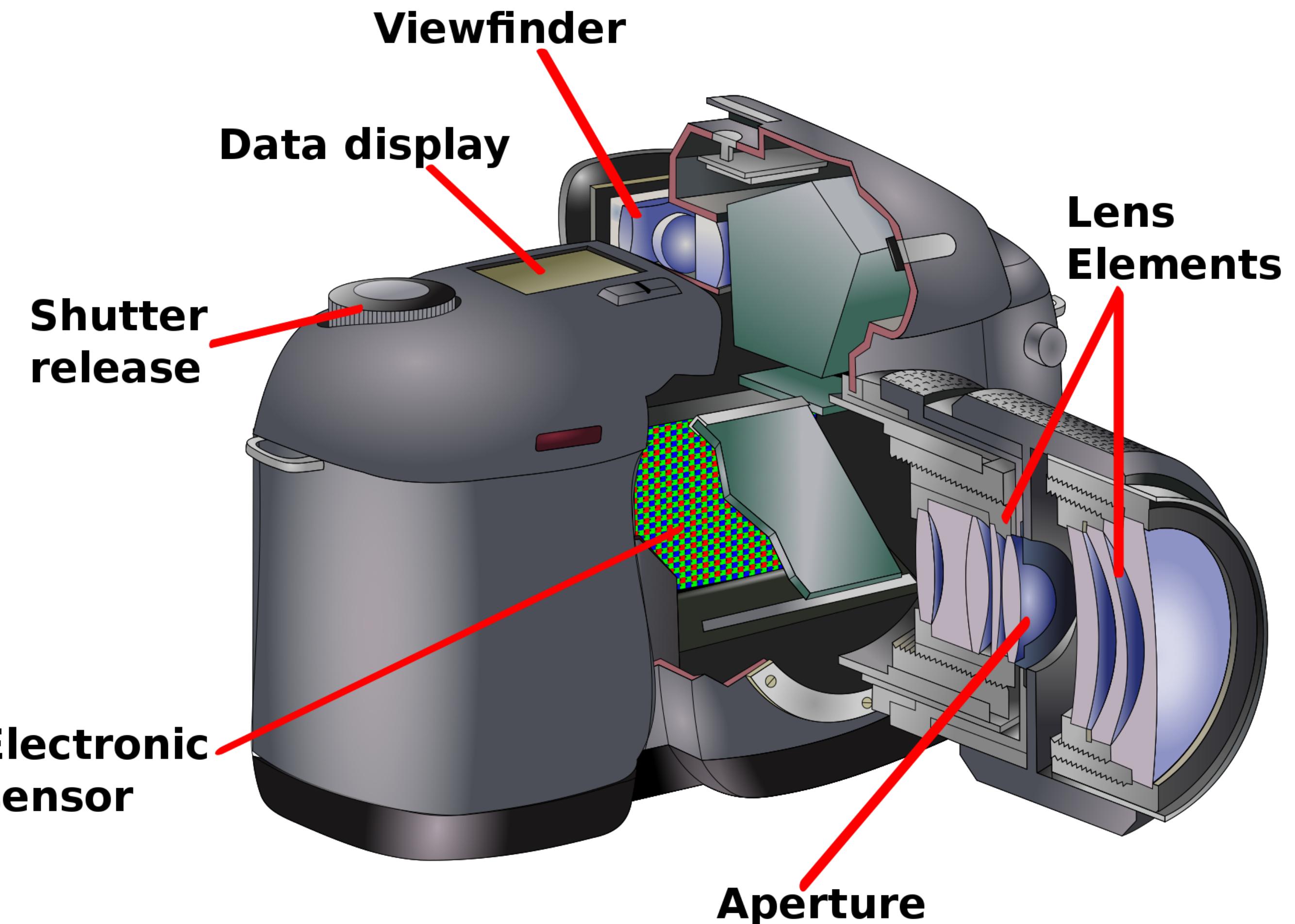
https://en.wikipedia.org/wiki/Thermal-transfer_printing

Thermal Dye Transfer Printer

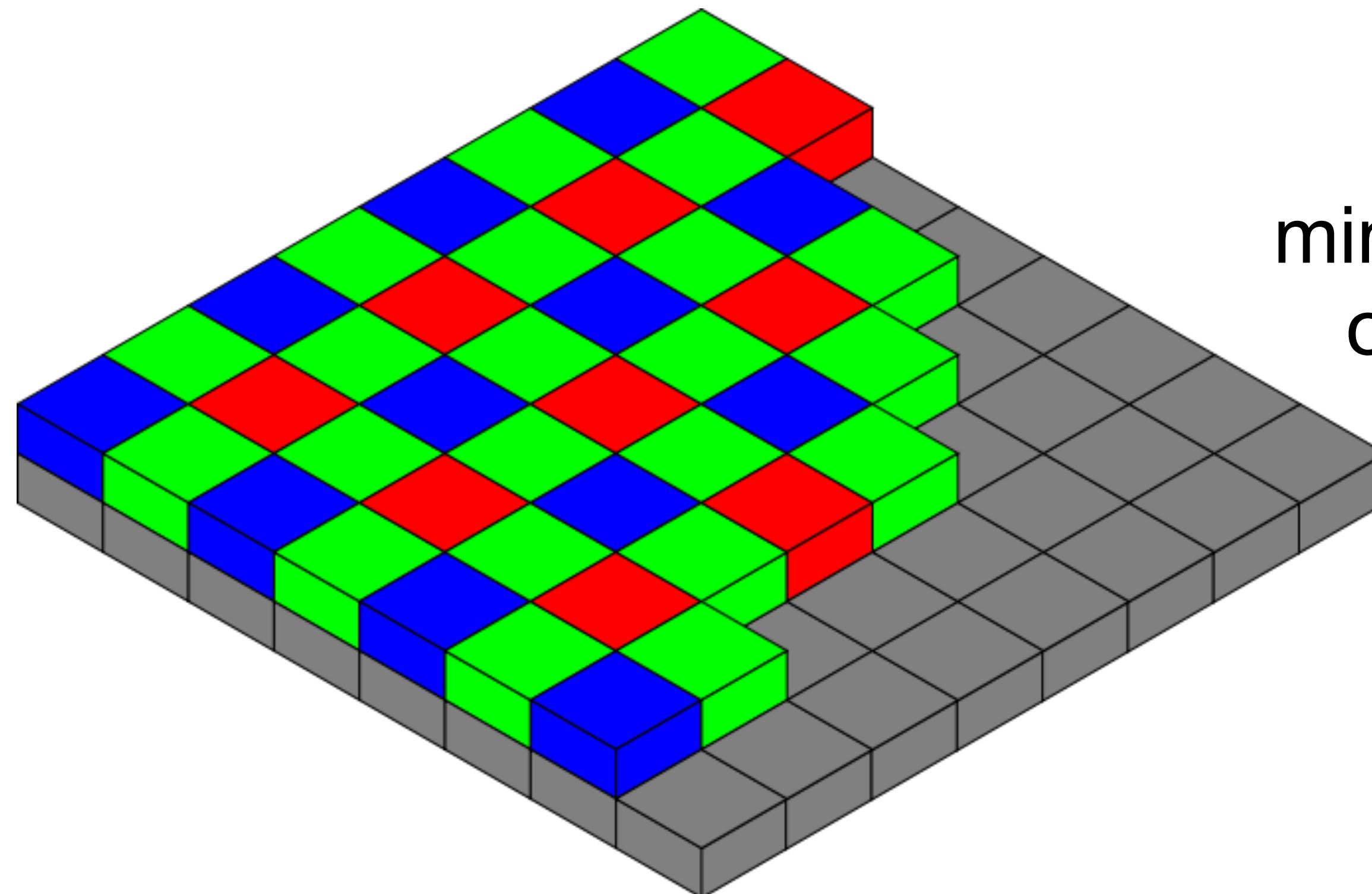


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Raster Input Devices: Camera



Bayer Color-Filter



mimic the physiology
of the human eye

By en:User:Cburnett - Own workThis vector image was created with Inkscape., CC BY-SA 3.0, <https://commons.wikimedia.org/w/index.php?curid=1496858>



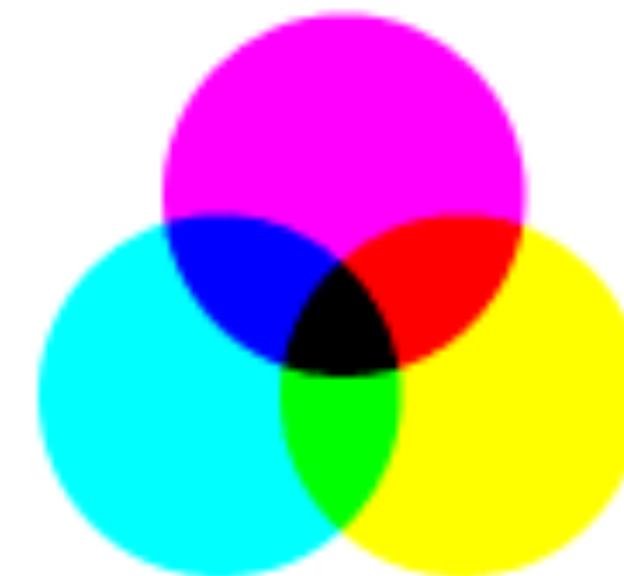
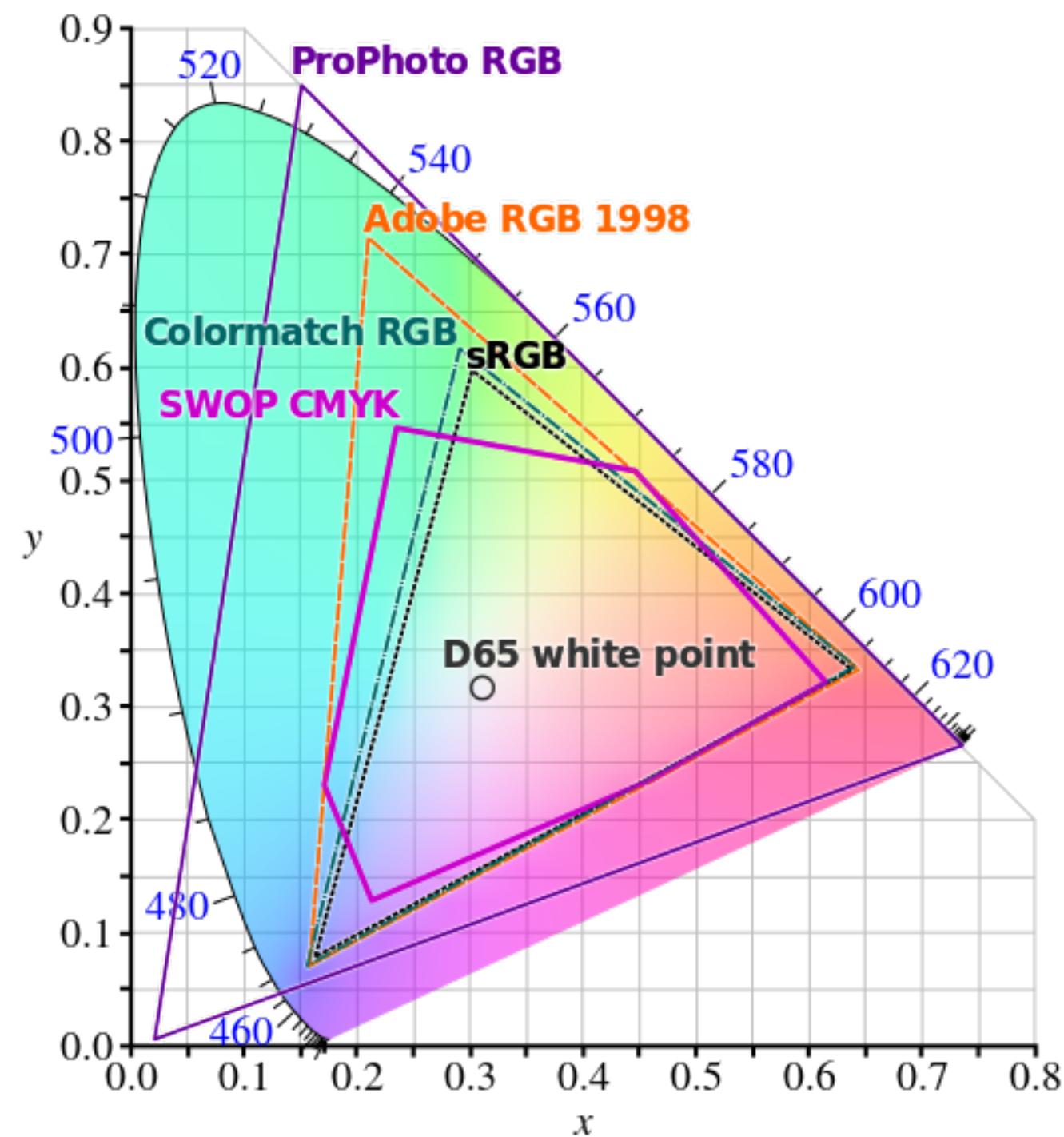
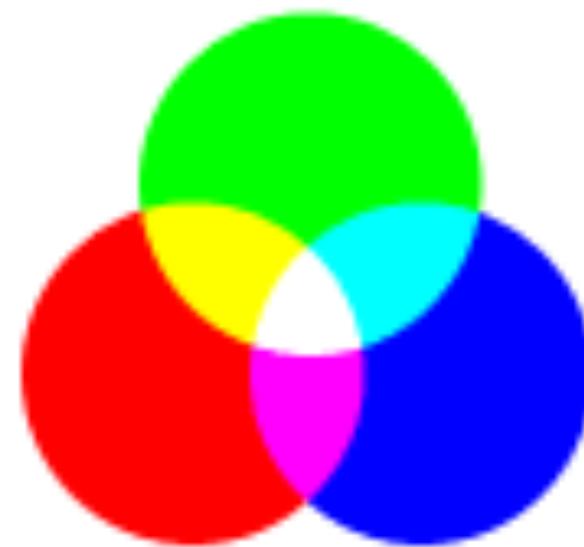
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Raster Input Devices: Scanner



RGB vs CMYK colors

- RGB is additive
- CMYK is subtractive



By BenRG and cmglee - http://commons.wikimedia.org/wiki/File:CIE1931xy_blank.svg, CC BY-SA 3.0, <https://commons.wikimedia.org/w/index.php?curid=32158329>

References

Fundamentals of Computer Graphics, Fourth Edition
4th Edition by [Steve Marschner, Peter Shirley](#)

Chapters 2, 3, 19

