Computer Graphics

Lecture 1

Images and Vectors

or: I ordered an image and all I got was this grid of colored boxes

Announcements

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  - Both due next Wednesday night

How do we graphics?

Let's design a simple graphics system.

The goal: draw a triangle on the screen.

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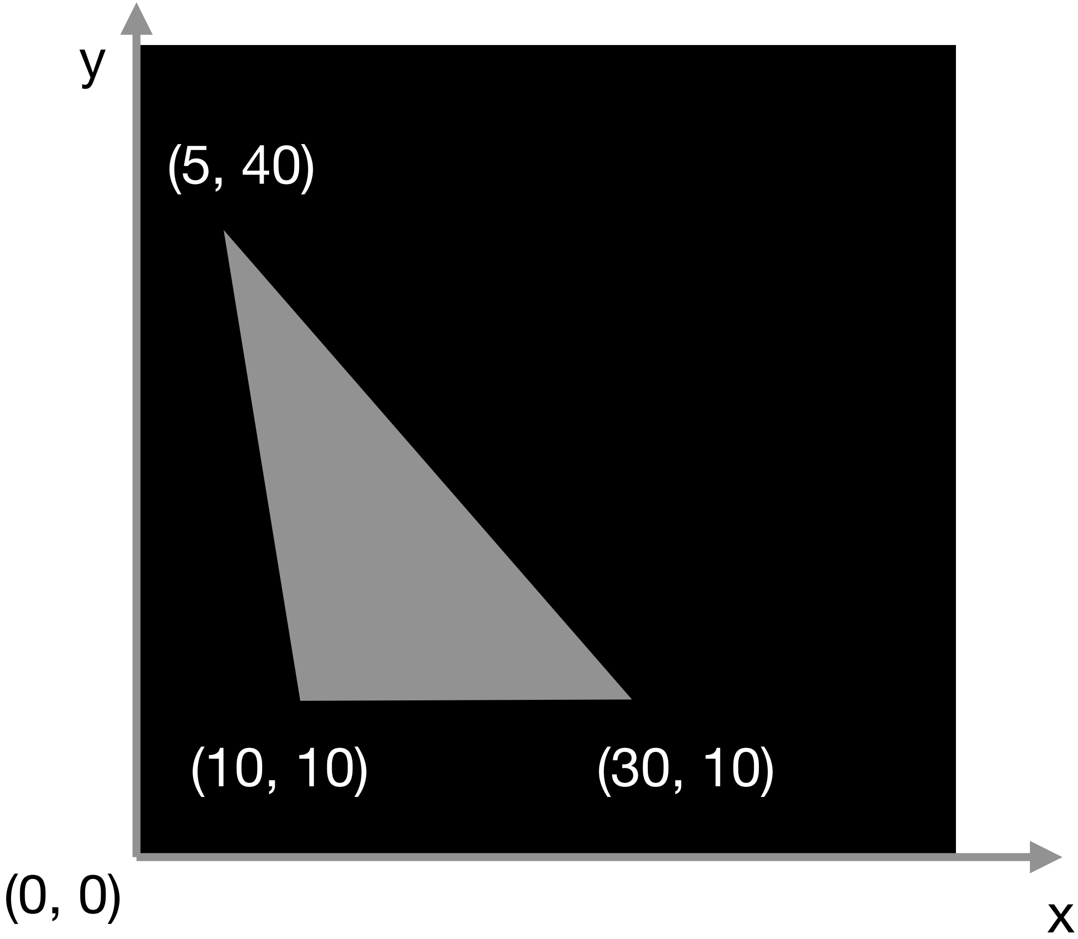
Pseudocode for graphics:

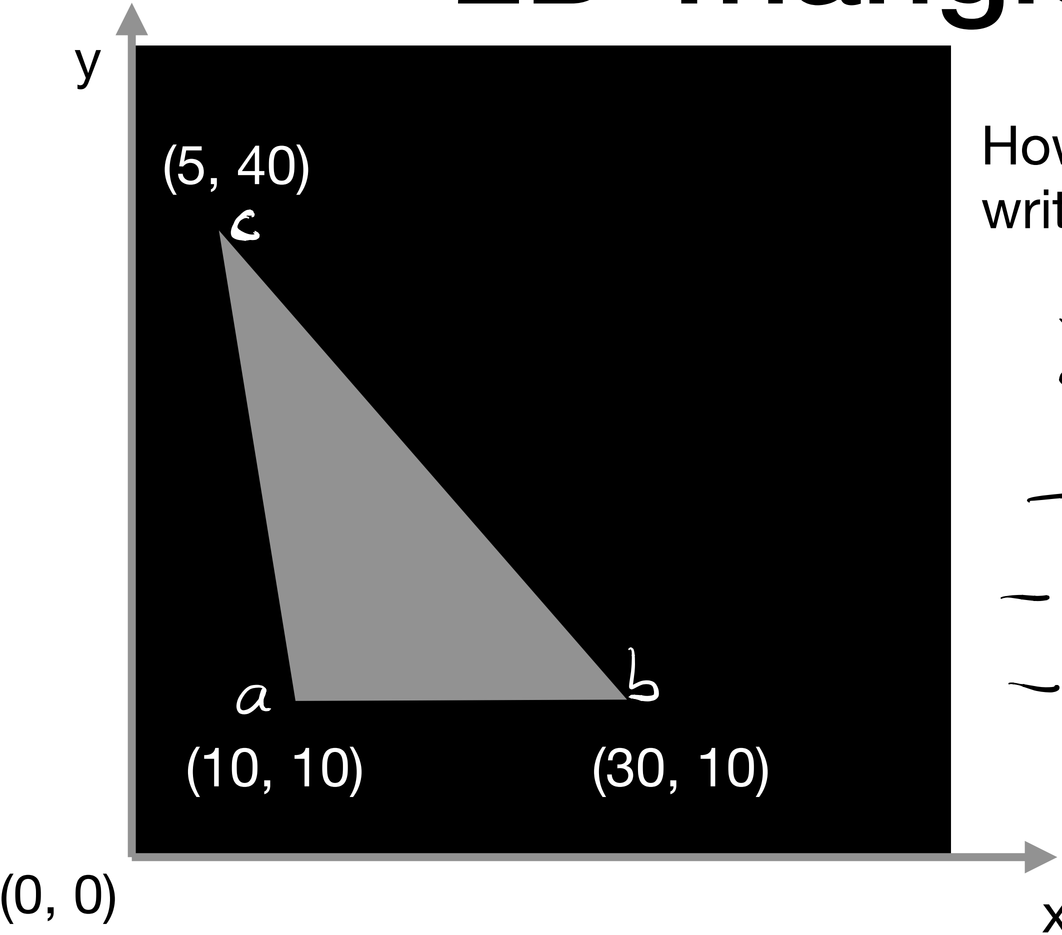
- Create a model of a scene represent triangle
- Render an image of the scene turn on pixels inside triangle

Create a model of the scene



Convention: list vertices in **counterclockwise** order.

2D Triangles



How many ways can I write down this triangle?

~~c b a~~

- a b c
- b c a
- c a b

Convention: list vertices in **counterclockwise** order.

Render an image of the model

what **is** that?

Render an image of the model

What **is** an image anyway?

- A photographic print?
- A photographic negative?
- The screen you're watching this on?
- Some numbers in RAM?

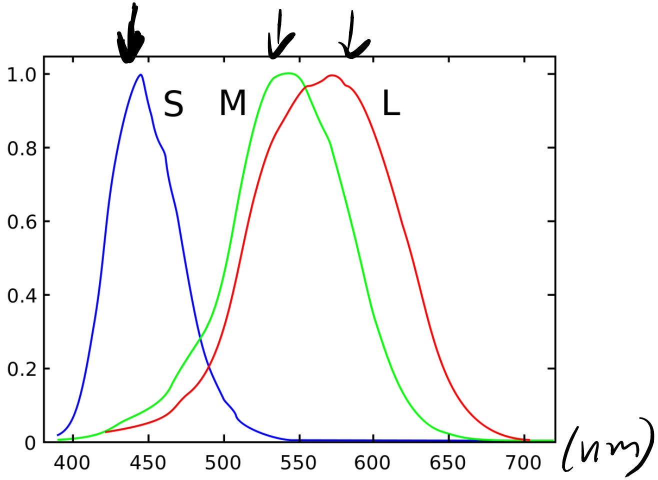
What is an image?

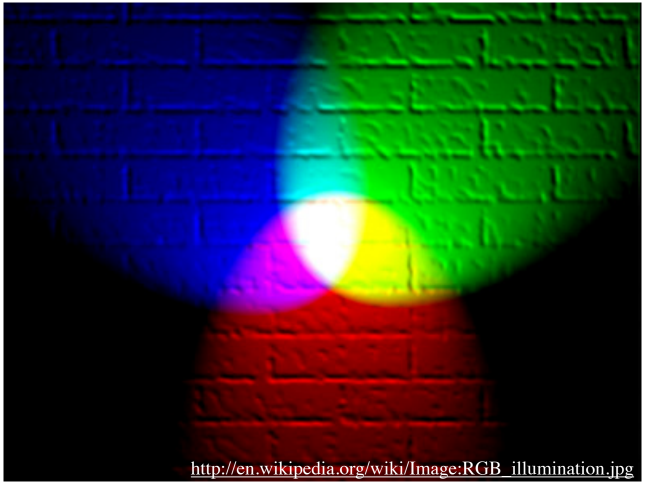
At its most formal and general: a **function** that maps *positions* in 2D to *distributions of radiant energy*

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

What about color?

- Humans are trichromatic, so we usually represent color as combinations or red, green, and blue





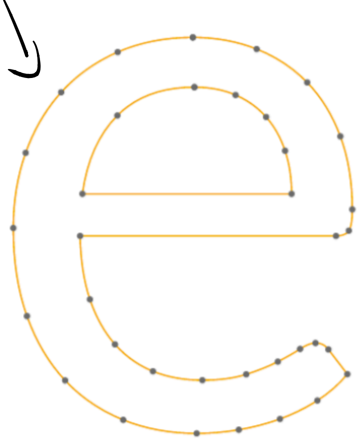
http://en.wikipedia.org/wiki/Image:RGB_illumination.jpg

How do we represent images?

- Raster formats - a 2D array of numbers

- Vector formats - mathematical description

Raster Image

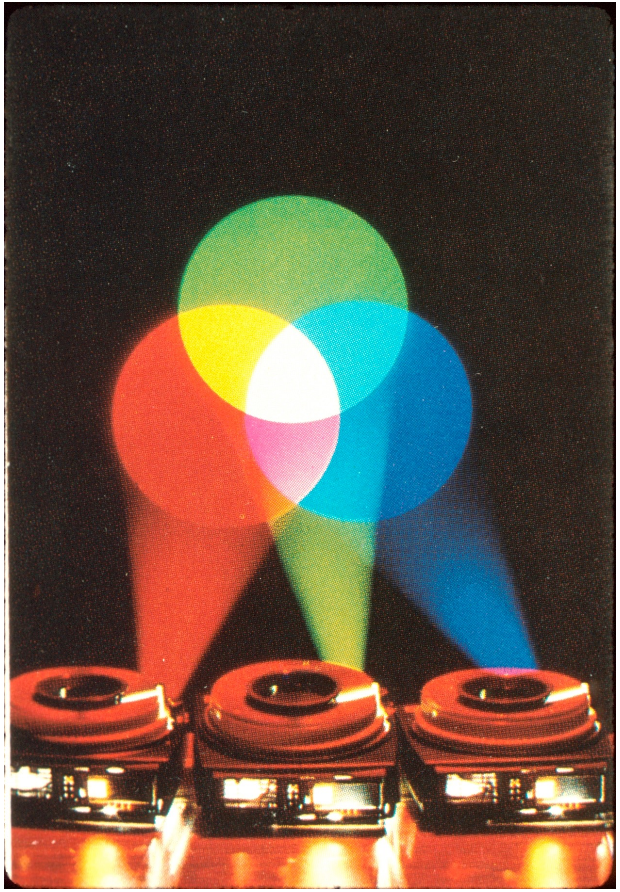


Pavithra Solai, kint.io

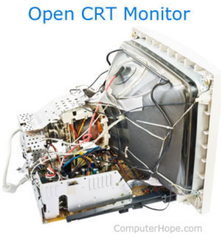
Vector Image

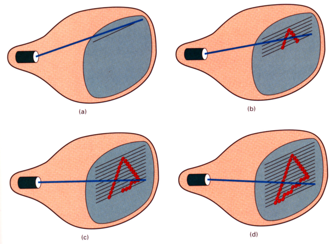
How do we display images?
Old School Edition

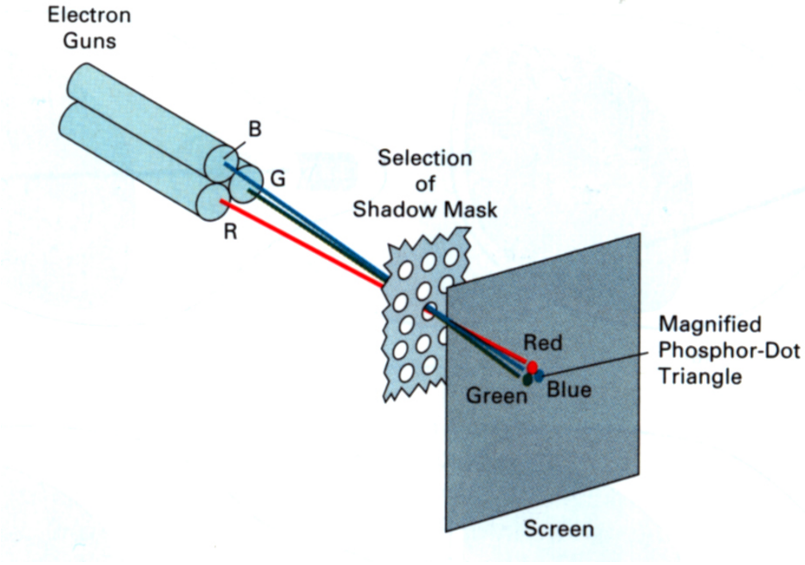
Color Projector



Cathode Ray Tube







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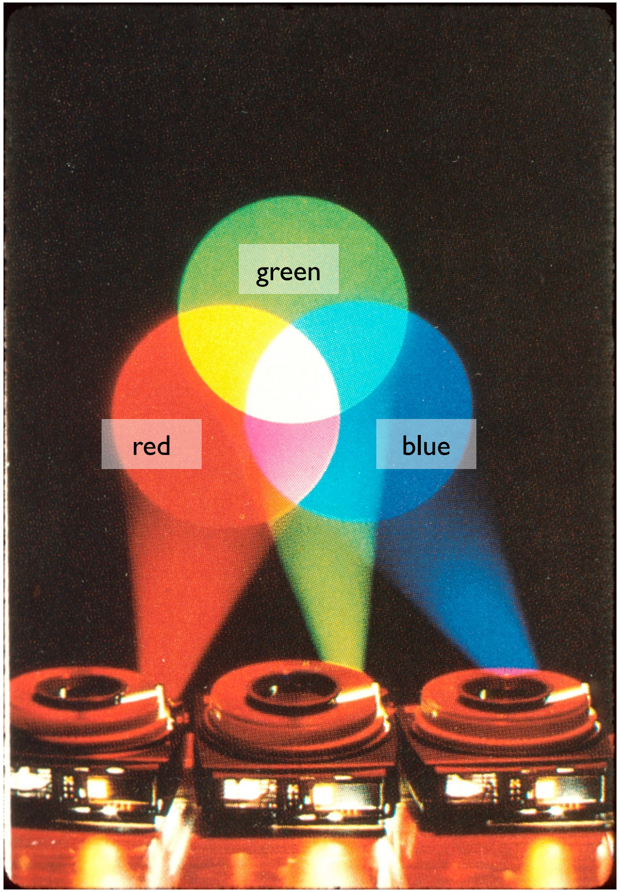

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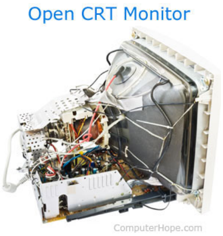

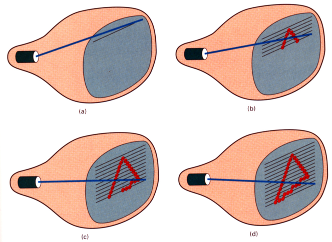

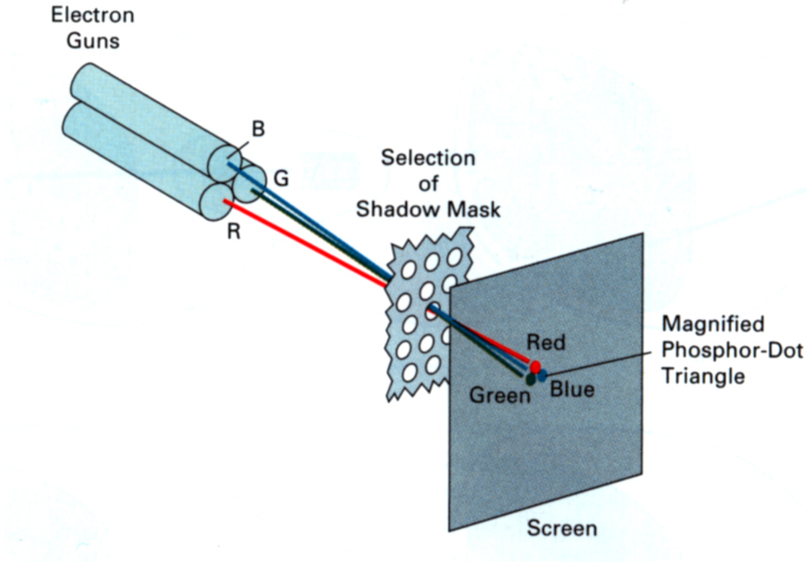

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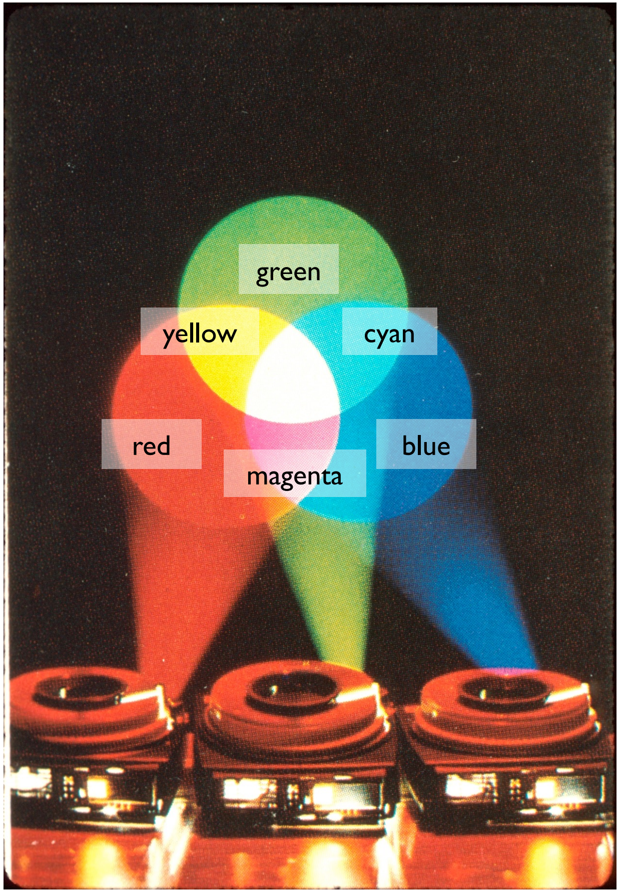

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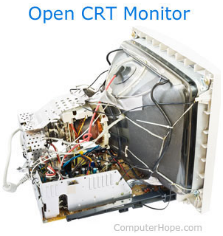

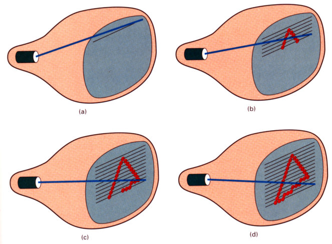

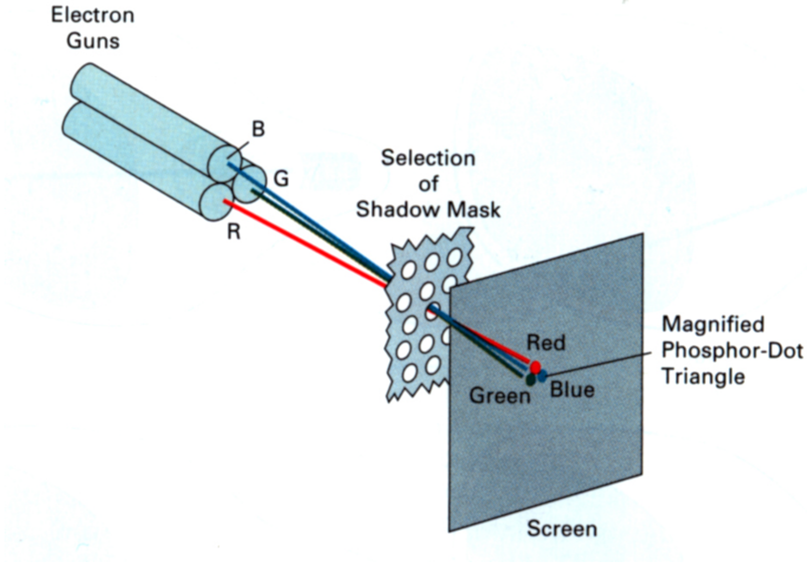

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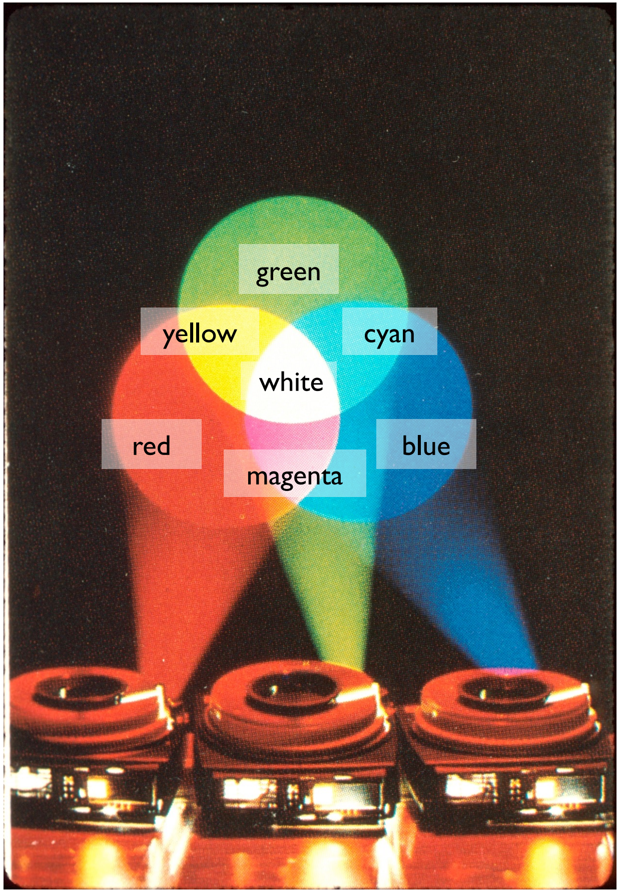

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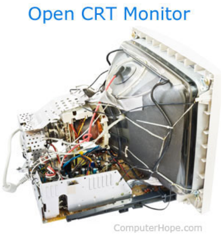
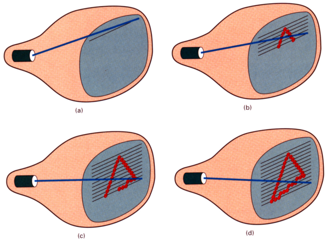
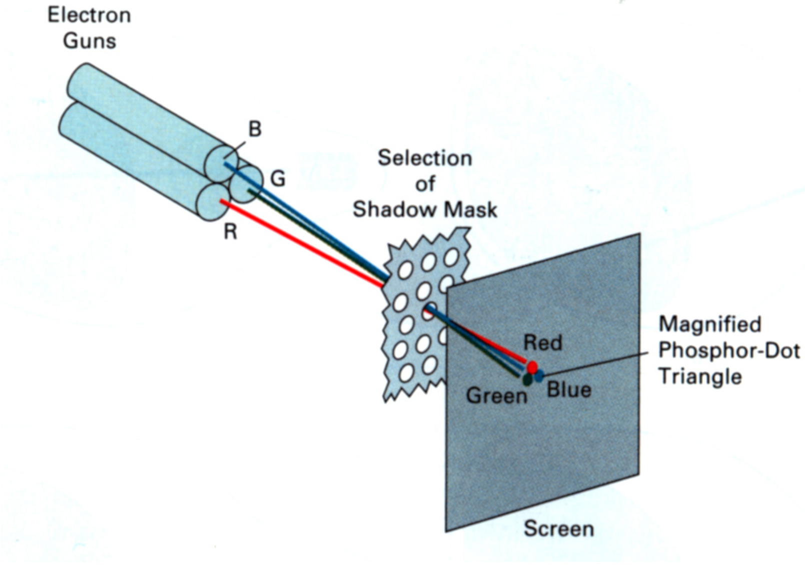
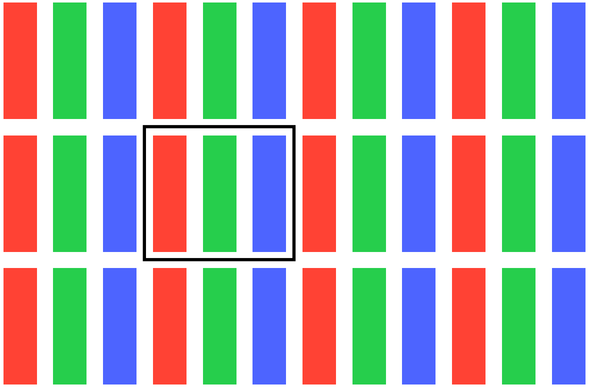




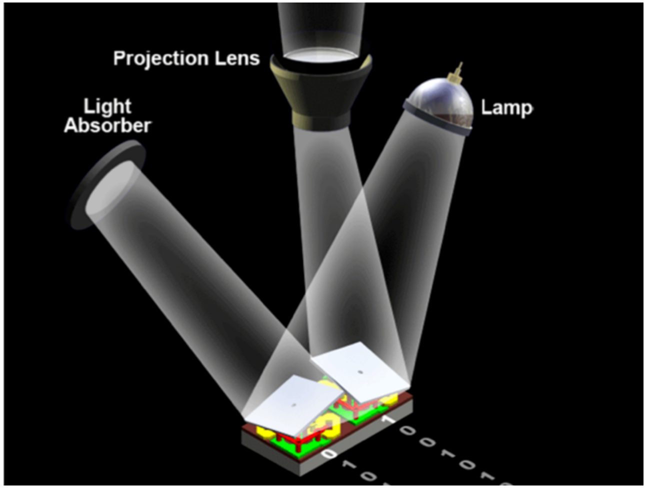


How do we display images?
Nowadays Edition

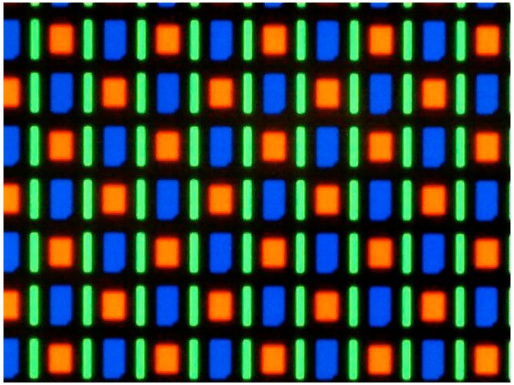
Liquid Crystal Display



Digital Light Processing



Light Emitting Diode Display



[Wikimedia Commons]

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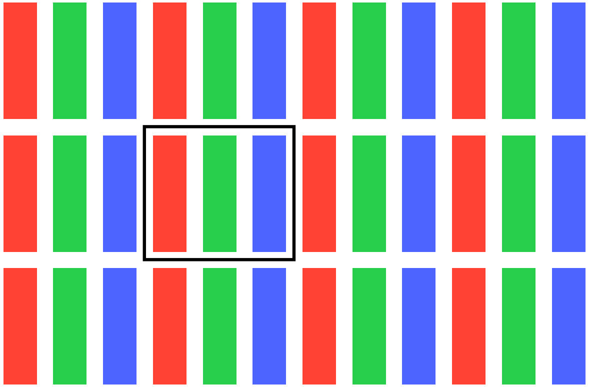

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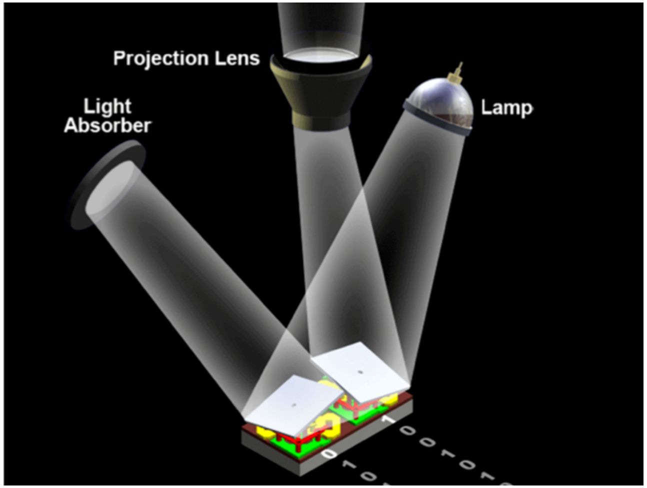

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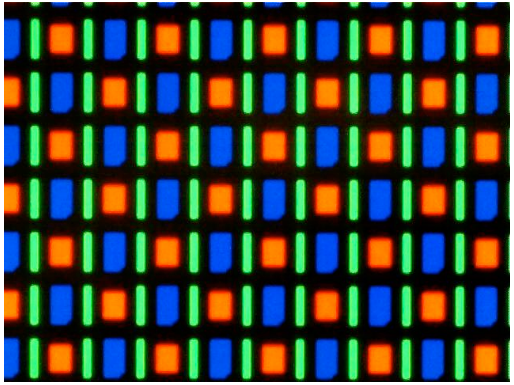
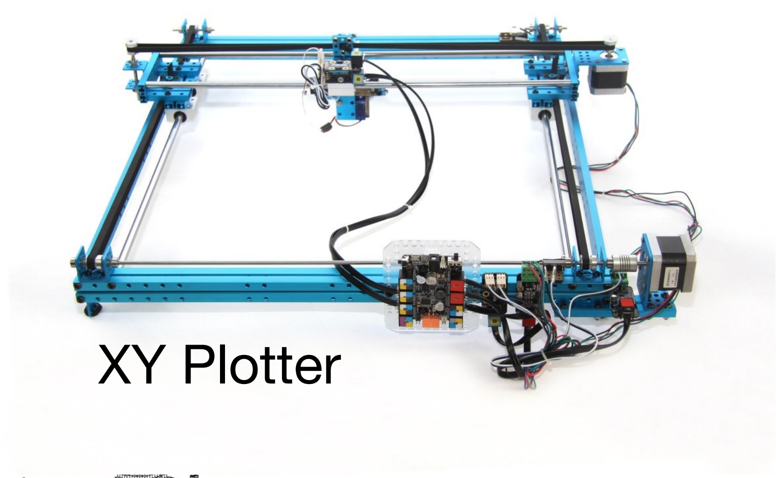


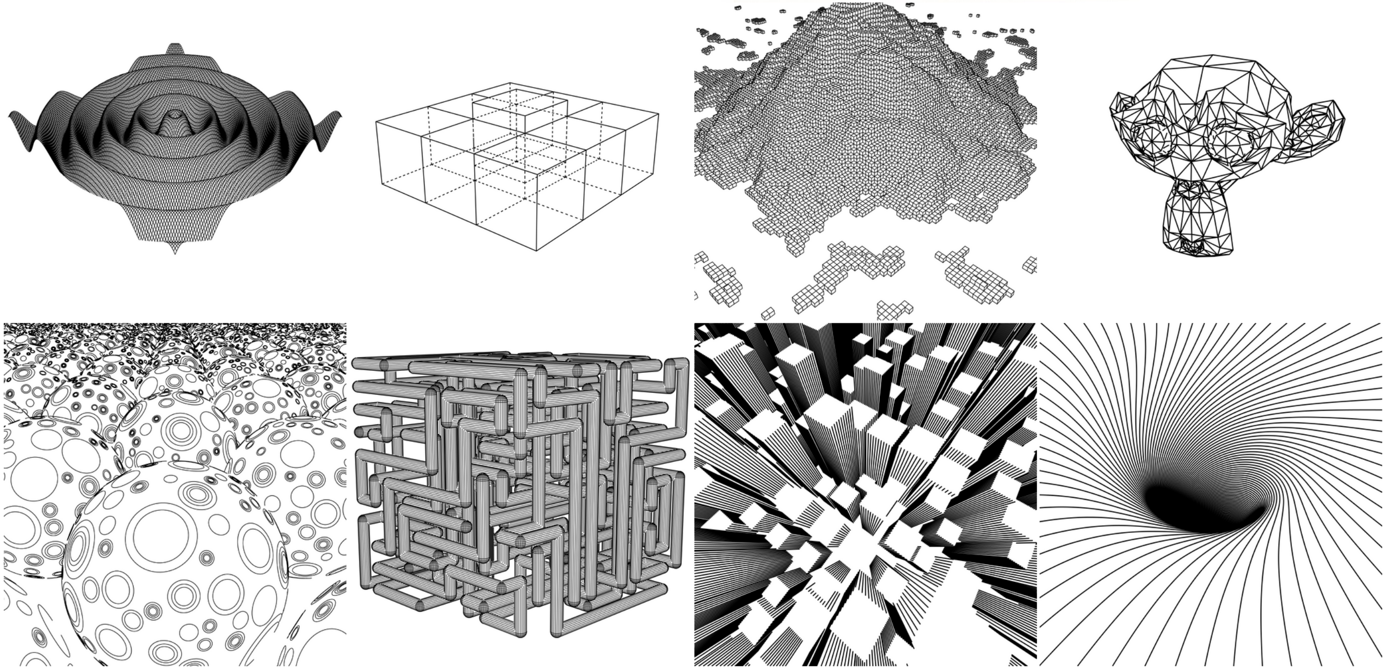
[Wikimedia Commons]

these are all examples of **raster displays**

Aside: It doesn't have to be this way...



XY Plotter

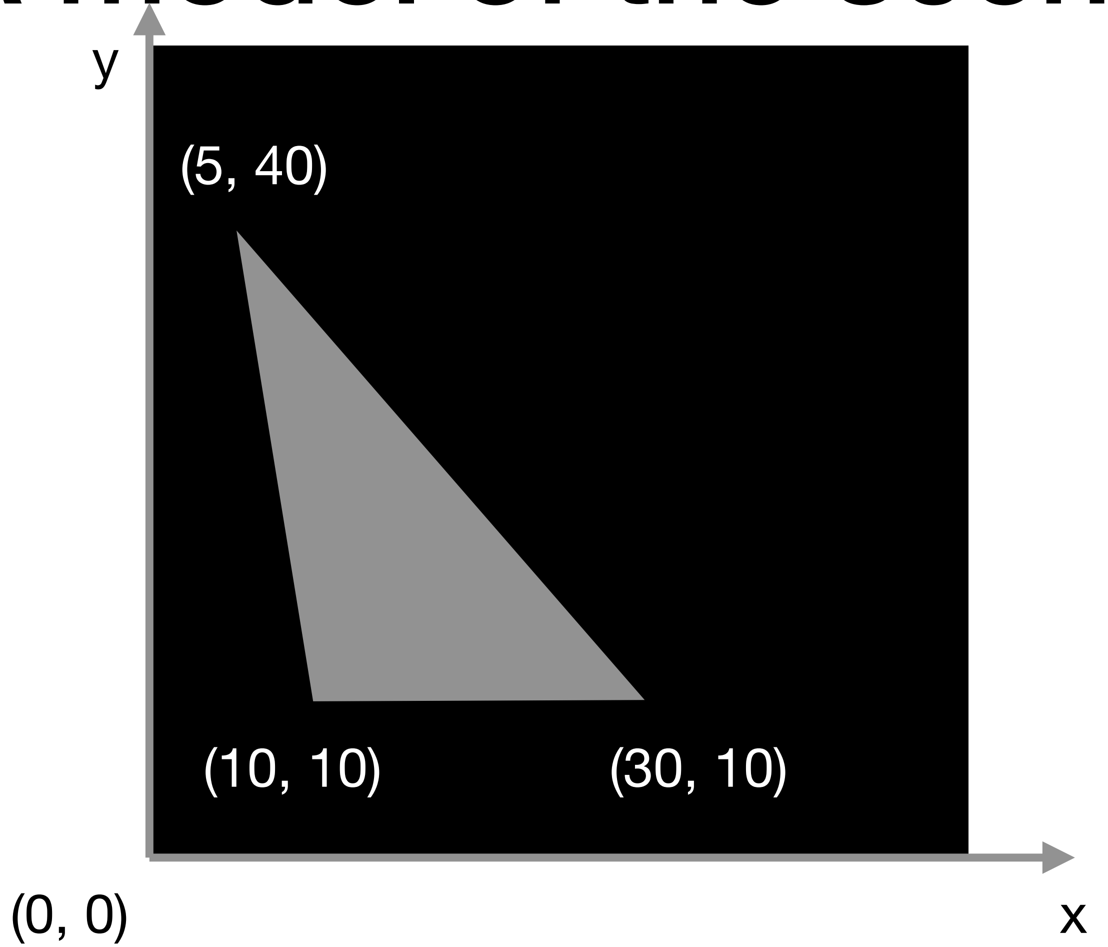


images: https://github.com/fogleman/ln

Raster Images

- Flexible
- Display-native
- Expensive
- Not ideal
- But darn useful

A model of the scene



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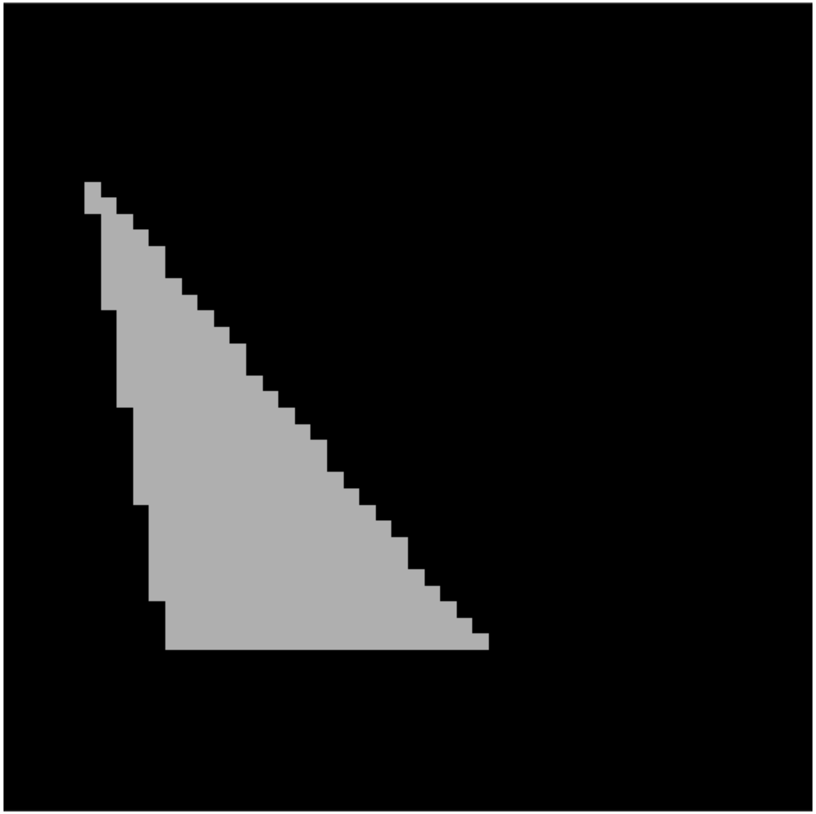

Representing Raster Images: 2D Arrays of Numbers

- Bitmap (1 bit per pixel) $I : \mathbb{R}^2 \to \{0, 1\}$
- Grayscale (usually 8 bpp) $I : \mathbb{R}^2 \to [0 .. \mathrm{MAX}]$ (e.g. 255)
- Color (usually 24 bpp) $I : \mathbb{R}^2 \to [0 .. \mathrm{MAX}]^3$ (R, G, B)
- Floating-point (gray or color) $\mathbb{R}^2 \to \mathbb{R}^3$
  - Bad for display, but good for processing
  - Allows **high dynamic range**
  - For LDR, values range from 0-1 by convention

Raster Images: Storage

1 **megapixel** image - 1024x1024:

- Bitmap (1 bit per pixel) - **128 KB**
- Grayscale (8 bpp) - **1 MB**
- Color (24 bpp) - **3 MB**
- Floating-point (color) - **12MB**

Aside: Performance

Fact: A 1 **megapixel** image has 1024x1024 = 1048576 = 2^{20} pixels.

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Implication: performance matters.

2D Arrays in Julia

- Image: A height-by-width array of pixels.

- For a color image, each pixel is 3 single-precision floats:

```
                      type                  h        w
canvas = zeros(RGB{Float32}, height, width)
```

- Matrix-style 1-based indexing (row, column):

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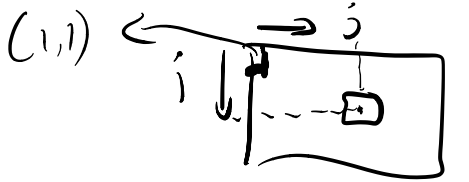


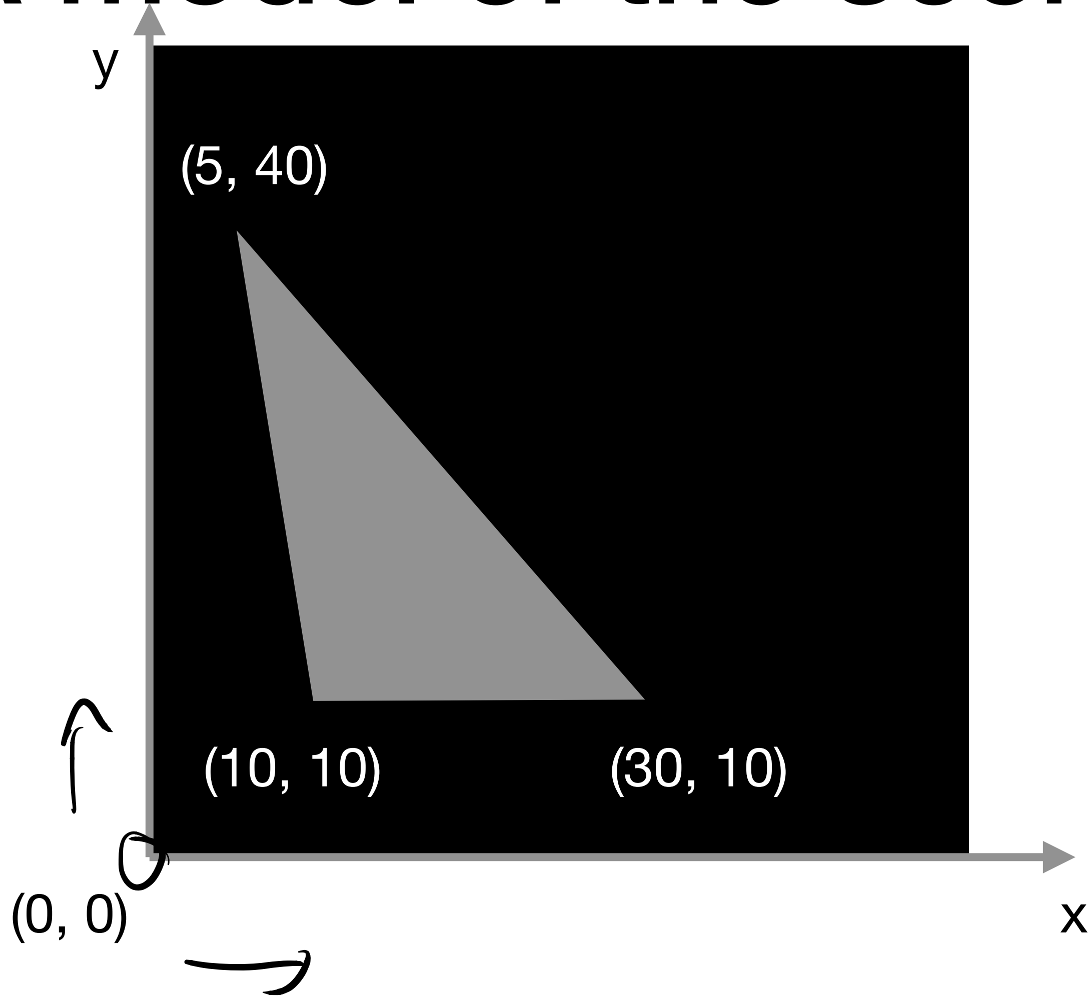
- Matrix-style 1-based indexing (row, column):

```
canvas[i, j] # is the i'th row, j'th column
```

Images in Julia: Demo

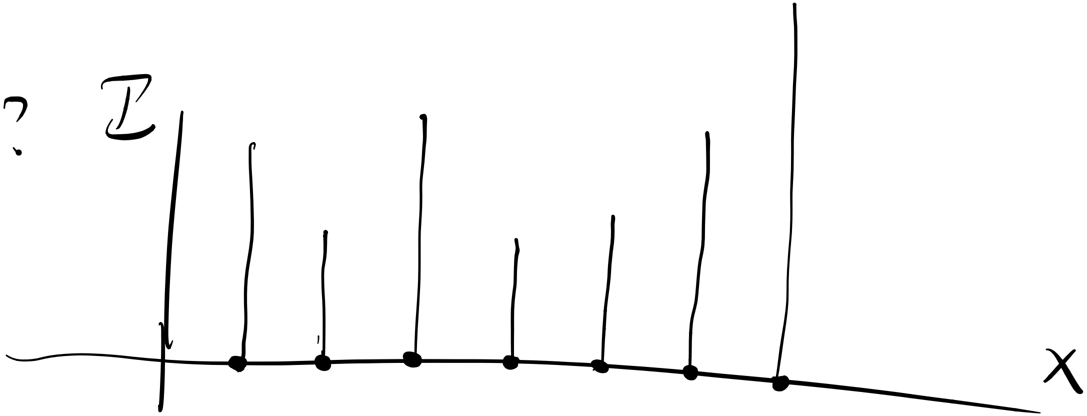
- Draw a rectangle on a canvas
- Demo colors

A model of the scene



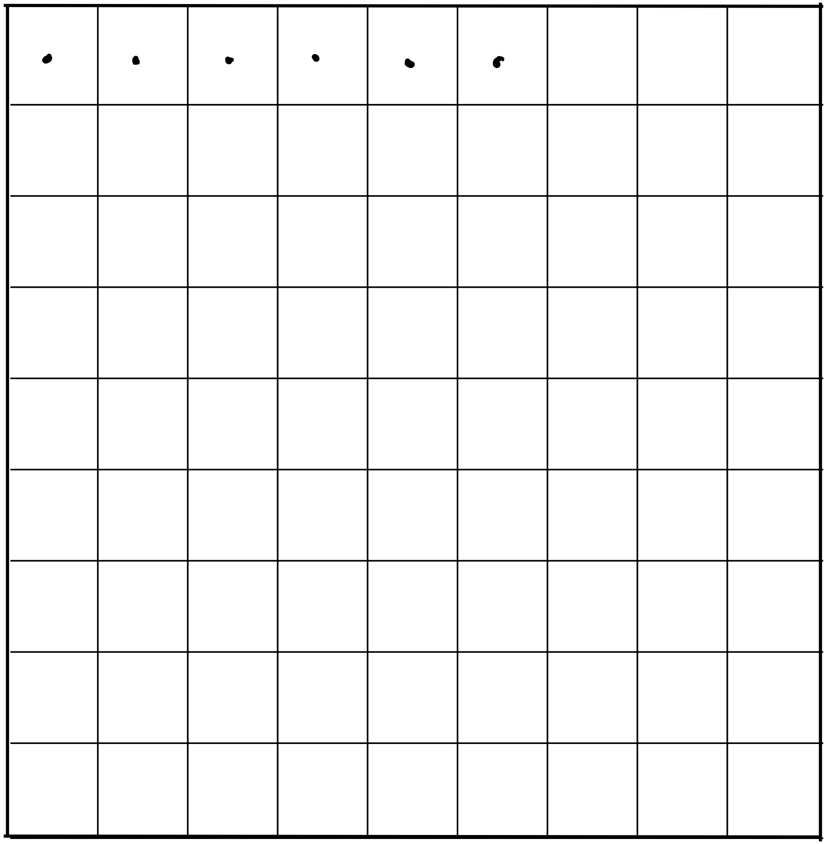
Raster images are *sampled*

$\mathcal{I}: \underset{\uparrow}{\mathbb{R}^2} \rightarrow ?$

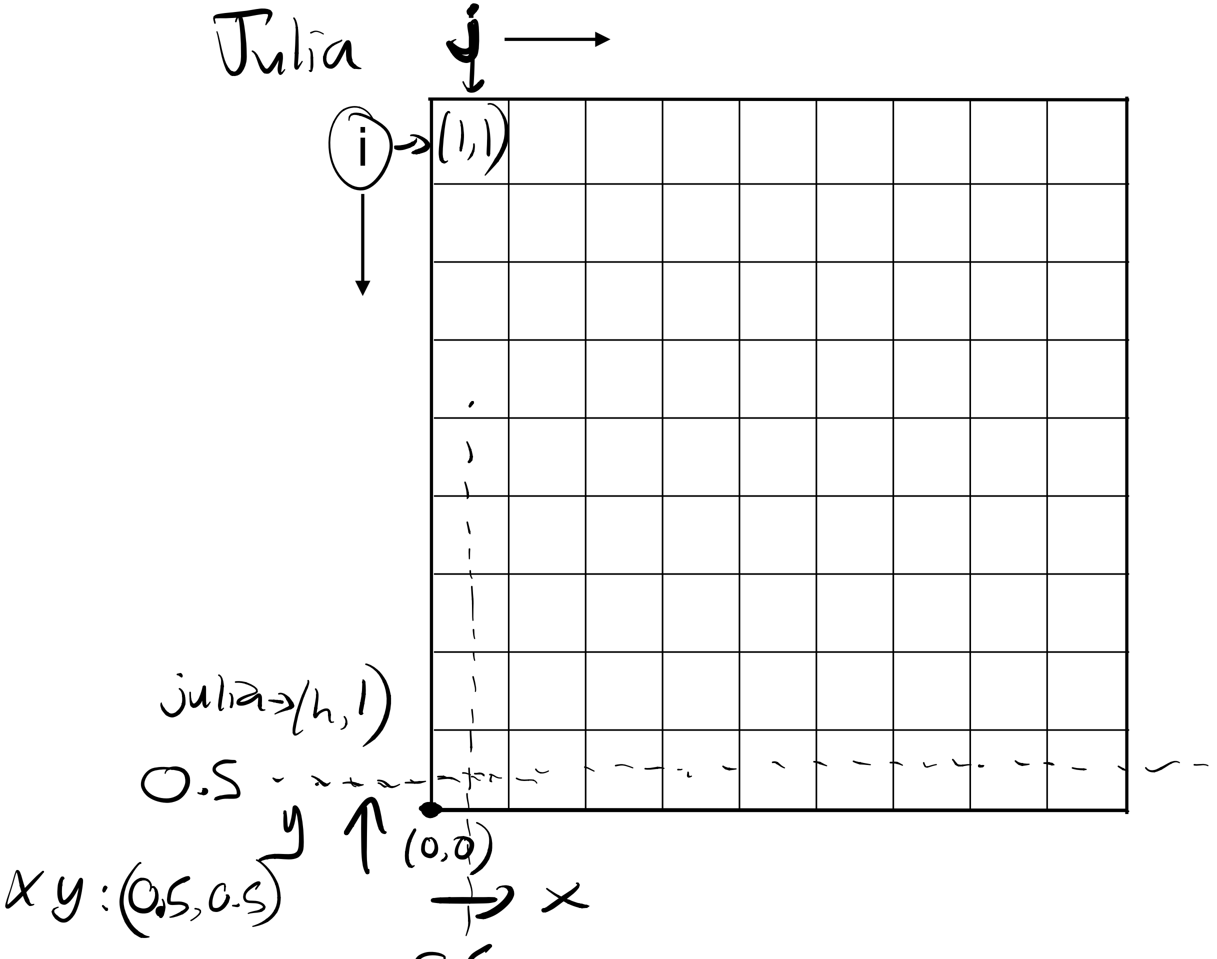


Representing Raster Images

What do pixels *mean*?

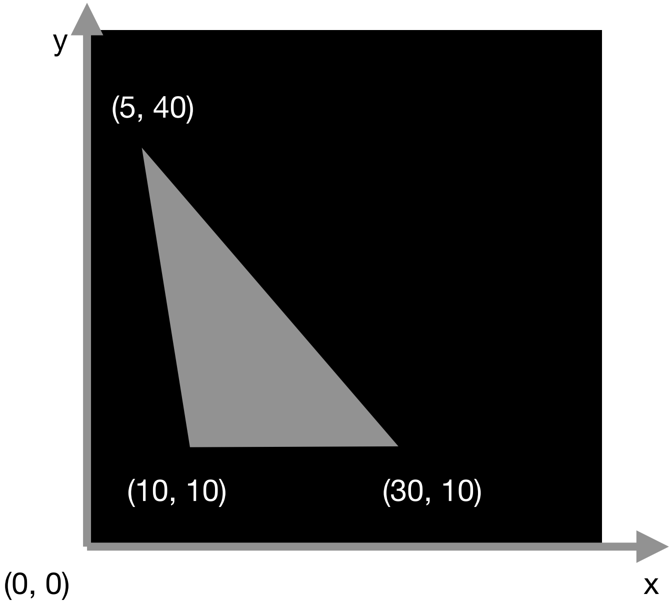


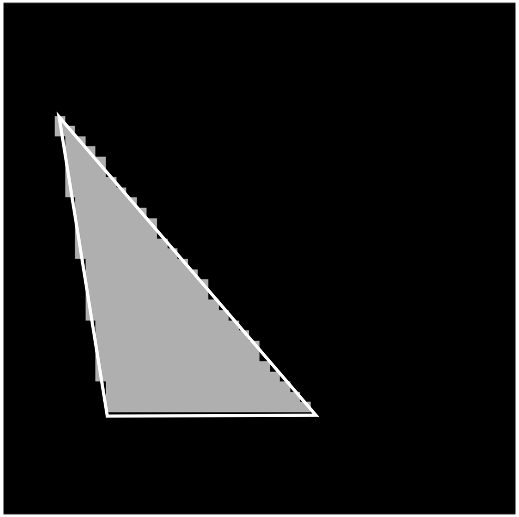
Raster Images: Coordinate Systems



0.5

A0: Rendering (*Rasterizing*) a Triangle

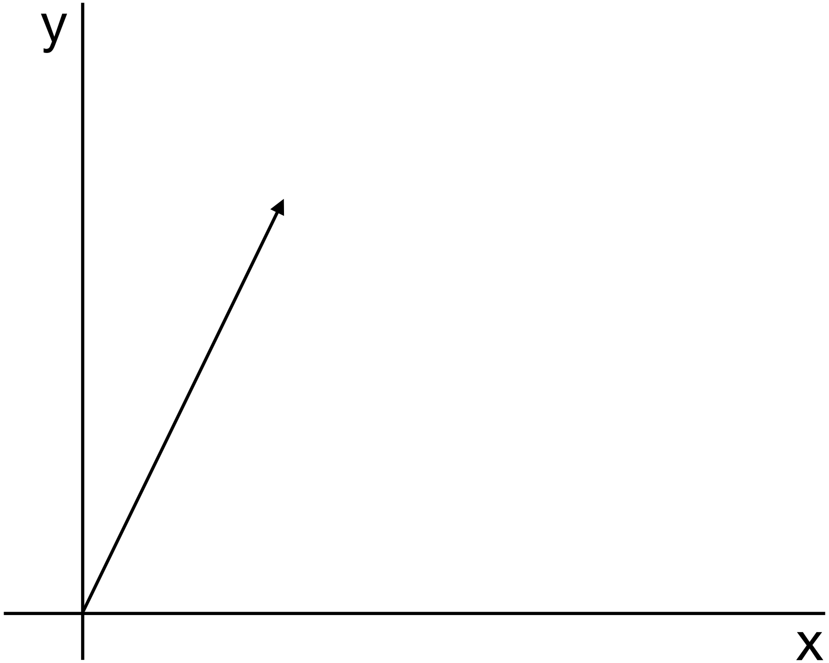




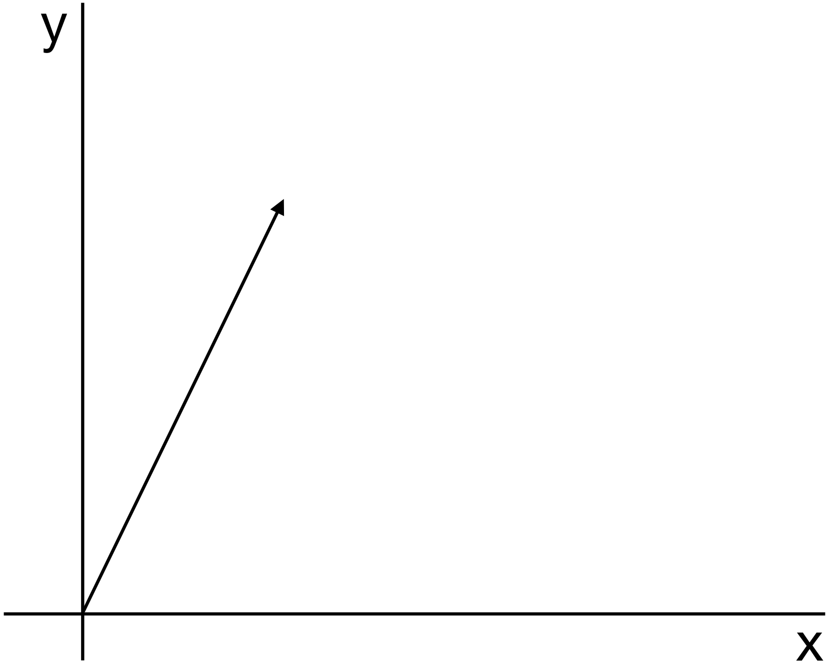
Pseudocode:

```
for each pixel
    if pixel is inside tri.
        color pixel
```

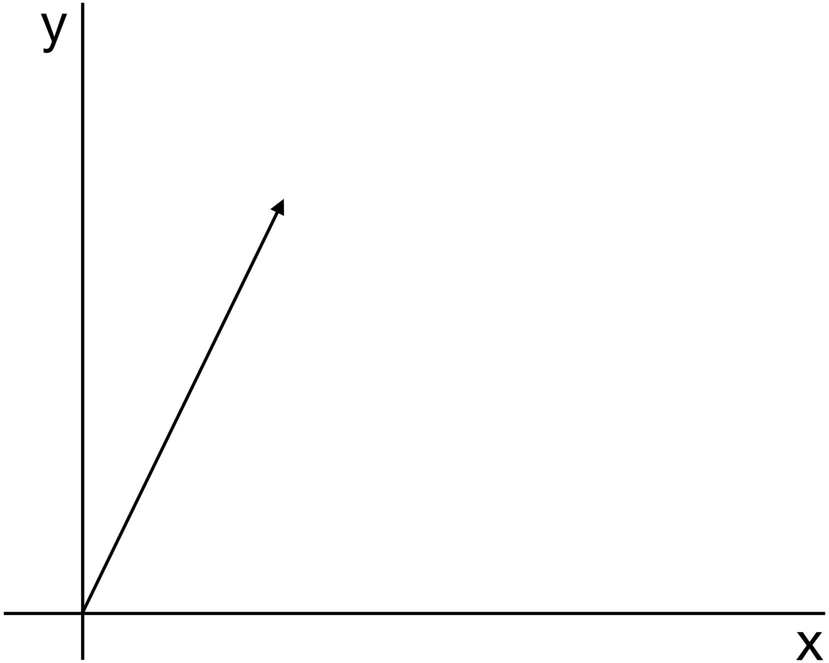
Vectors



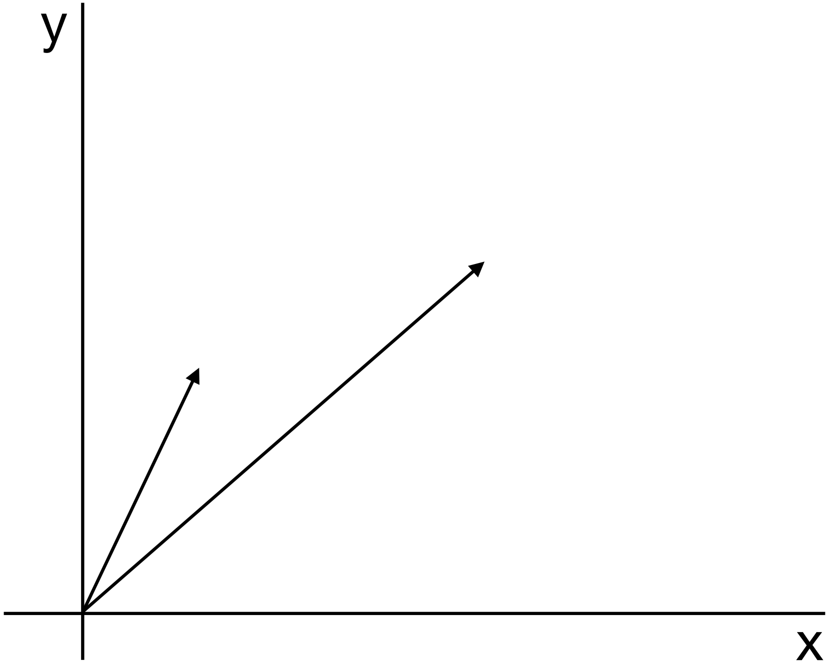
The Canonical Basis



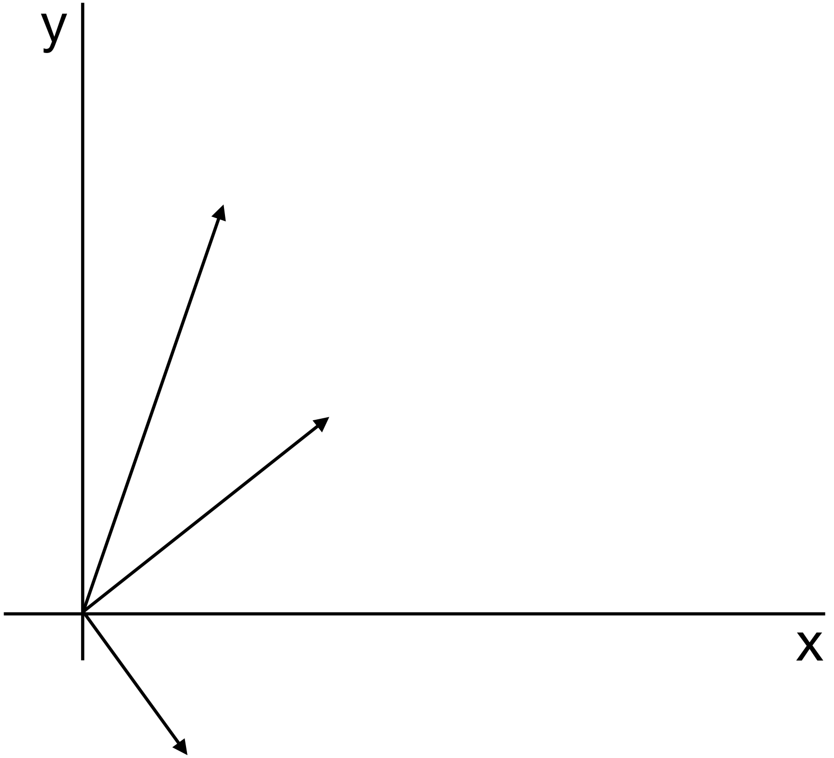
Magnitude (length)



The vector between two points



The dot product



Point-in-Triangle