Computer Graphics

Lecture 1

Logistics; Images

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

Announcements

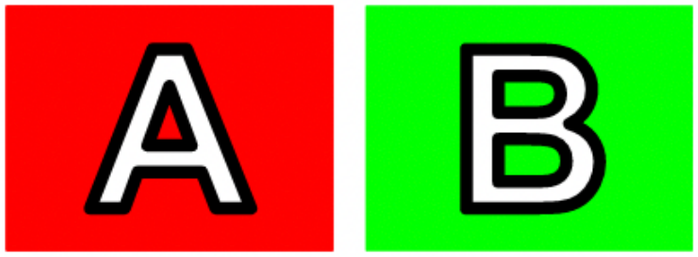
- Assignments out:
  - HW0 due next Friday
  - A0 due Monday, 10/3
- Please bring your name card to every class (or leave them with me and I'll bring them).
- Please fill out the About You survey if you haven't yet]

Logistics / Syllabus: Key Points

- Lectures occasionally flipped
- Book
- Slip days
- Math
- Julia, Javascript
- Feedback
- Q&A - Discord?

Syllabus/Logistics: Questions?

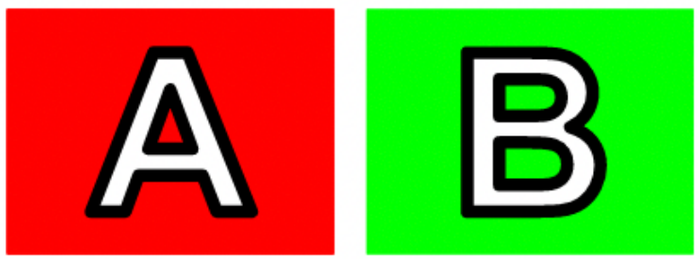
ABCD Cards



Some finer points on ABCD card use:

- Don’t show your answer until I say so
- Hold your card close
- Blank or unfolded: a valid (and underrated) way to say “I have no idea”

Syllabus



(False) (True)

1. You have 3 slip days that can applied to extend any deadline.

2. You **don't** need to email me to use a slip day.

3. The midterm is given in week 5 of the course.

4. Lecture slides, videos, etc. are posted on Canvas.

Goals (meta)

- A slide like this will (should) appear at the beginning of each lecture.
- This is my way of conveying what I expect you to be able to understand or do after the class.
- In aggregate, these goals form a study guide.

Goals

- Understand how images are represented mathematically (as a function) and computationally (as a 2D array sampled from a function)
- Know how to manipulate the pixel values of an image in Julia
- Know how color is represented using RGB values

How do we graphics?

Let's design a simple graphics system.

The goal: draw a triangle on the screen.

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(why a triangle? more on this next time...)

How do we graphics?

Let's design a simple graphics system.

The goal: draw a triangle on the screen.

(why a triangle? more on this next time...)

Pseudocode for graphics:

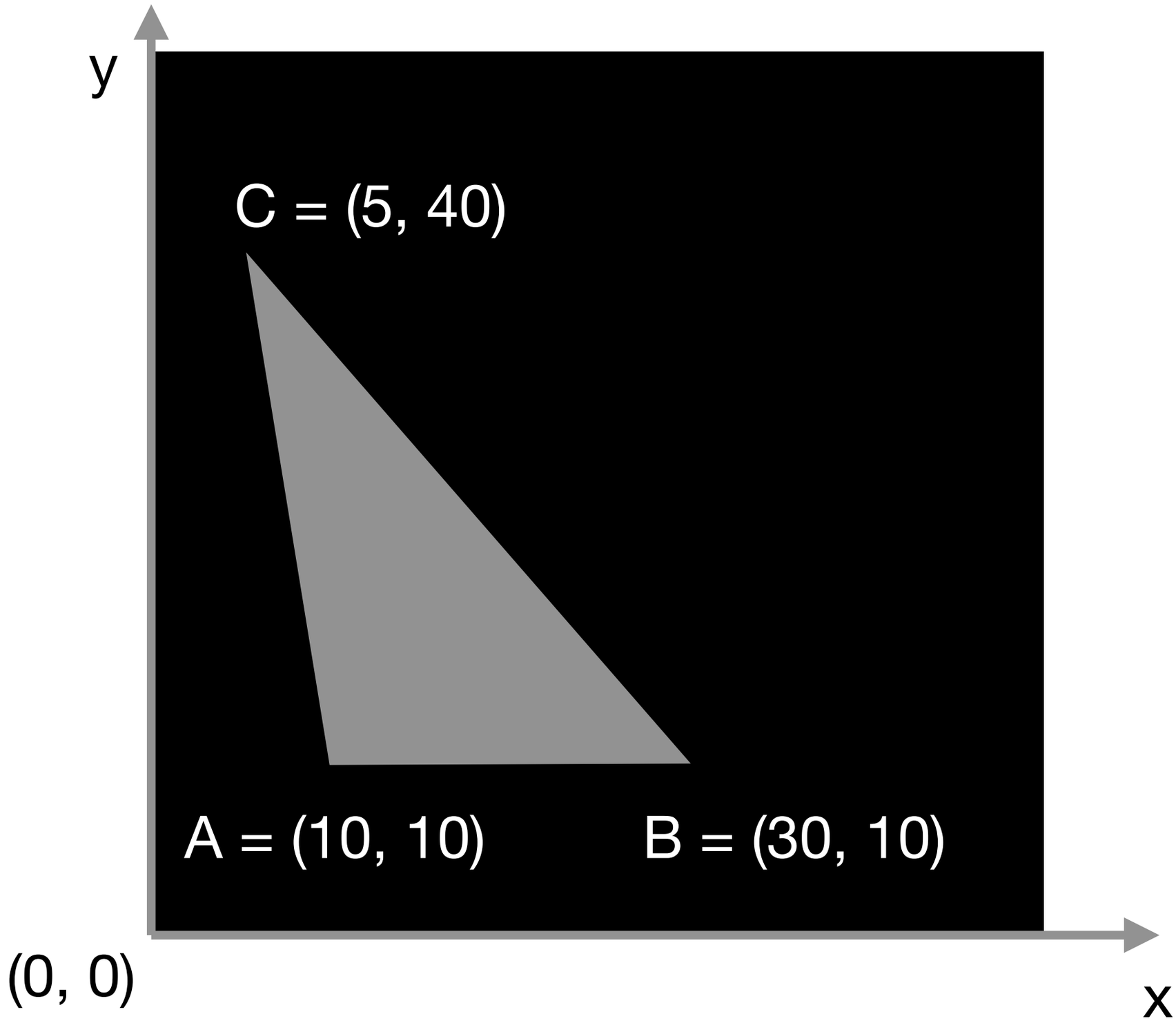
- Create a model of a scene

"Represent" the triangle

- Render an image of the scene

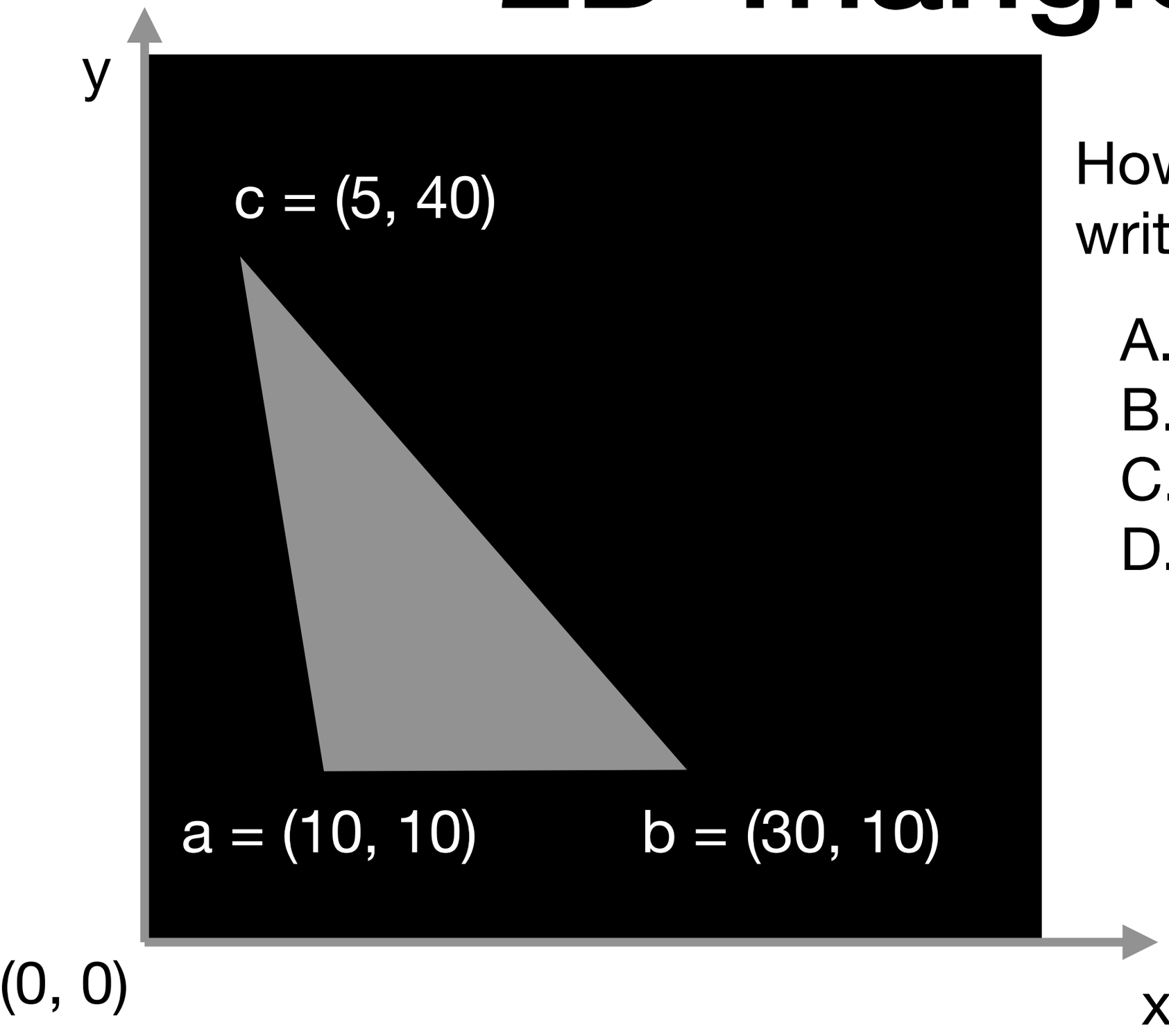
Turn on pixels inside the triangle

Create a model of the scene



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

2D Triangles

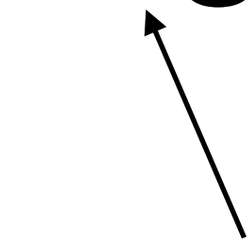


How many ways can I write down this triangle?

A. 1
B. 2
C. 3
D. 6

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?

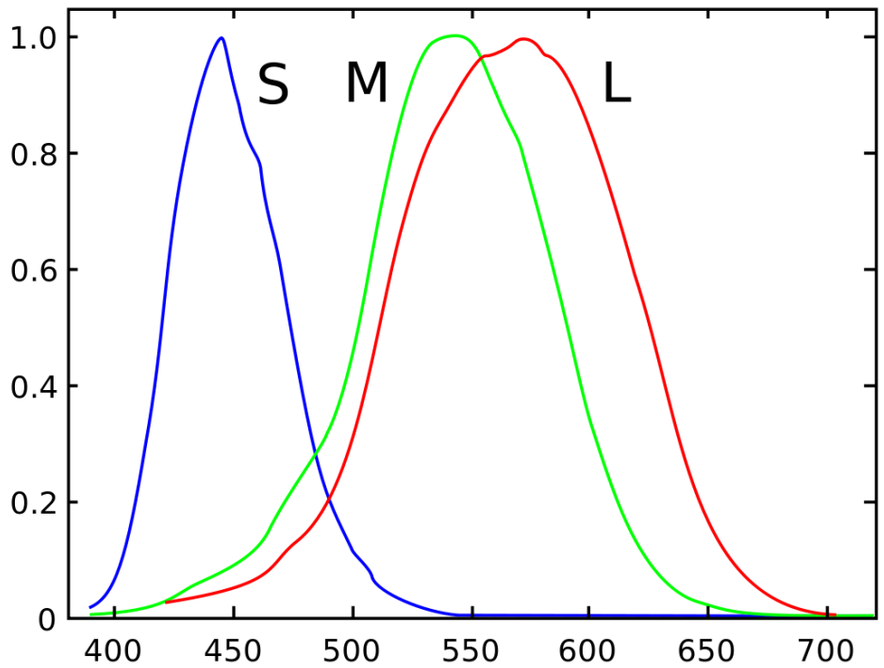
What is an image?

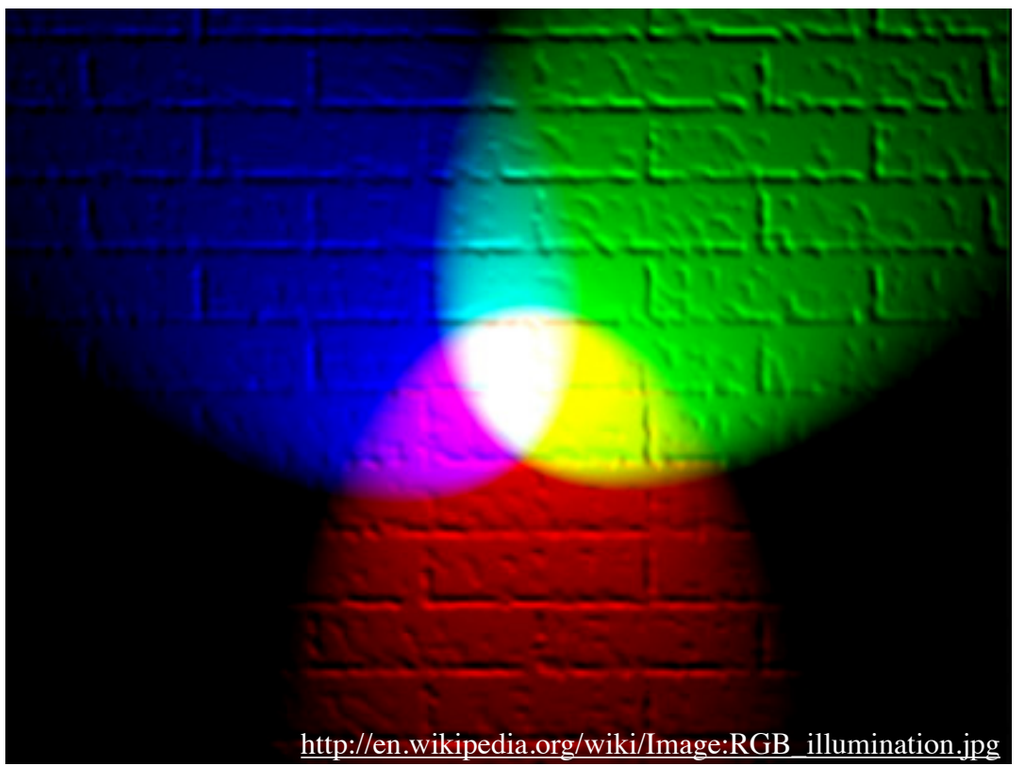
At its most formal and general: a **function** that maps *positions* in 2D to *distributions of radiant energy*

$$I : \mathbb{R}^2 \Rightarrow \; ??$$

What about color?

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

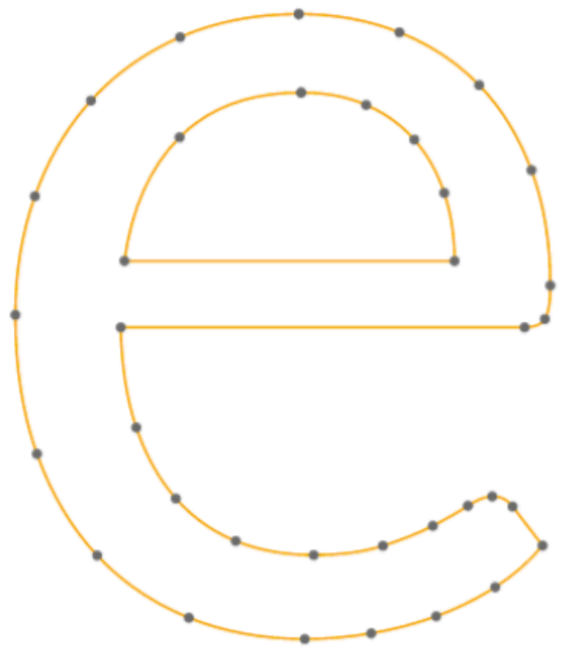




How do we represent images?

- Raster formats - a 2D array of numbers
- Vector formats - mathematical description

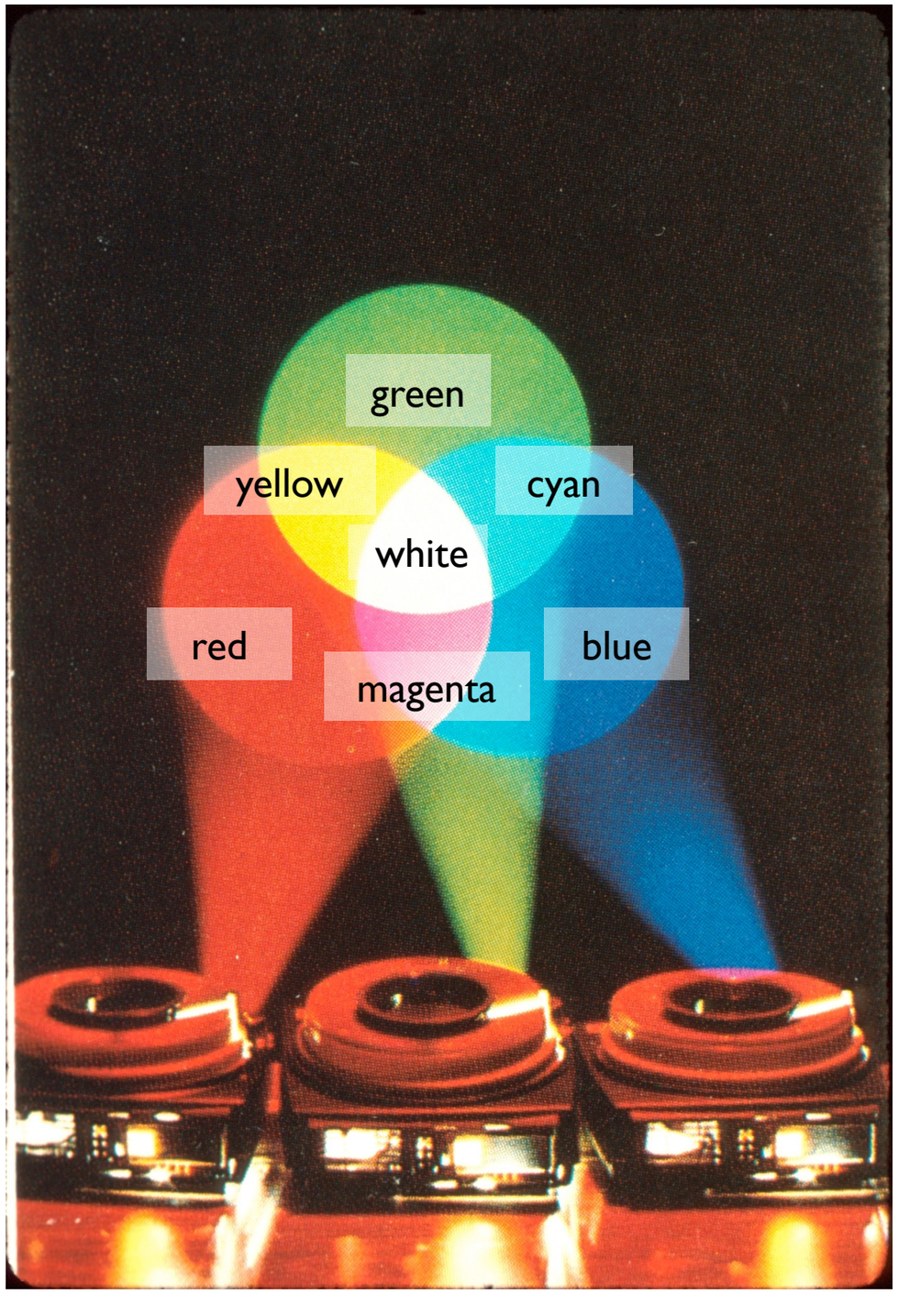
Raster Image



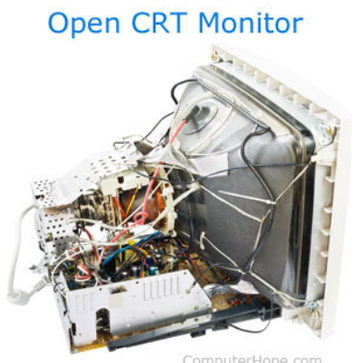
Vector Image

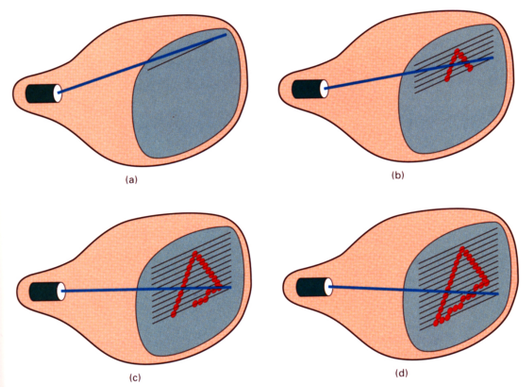
How do we display images?
Old School Edition

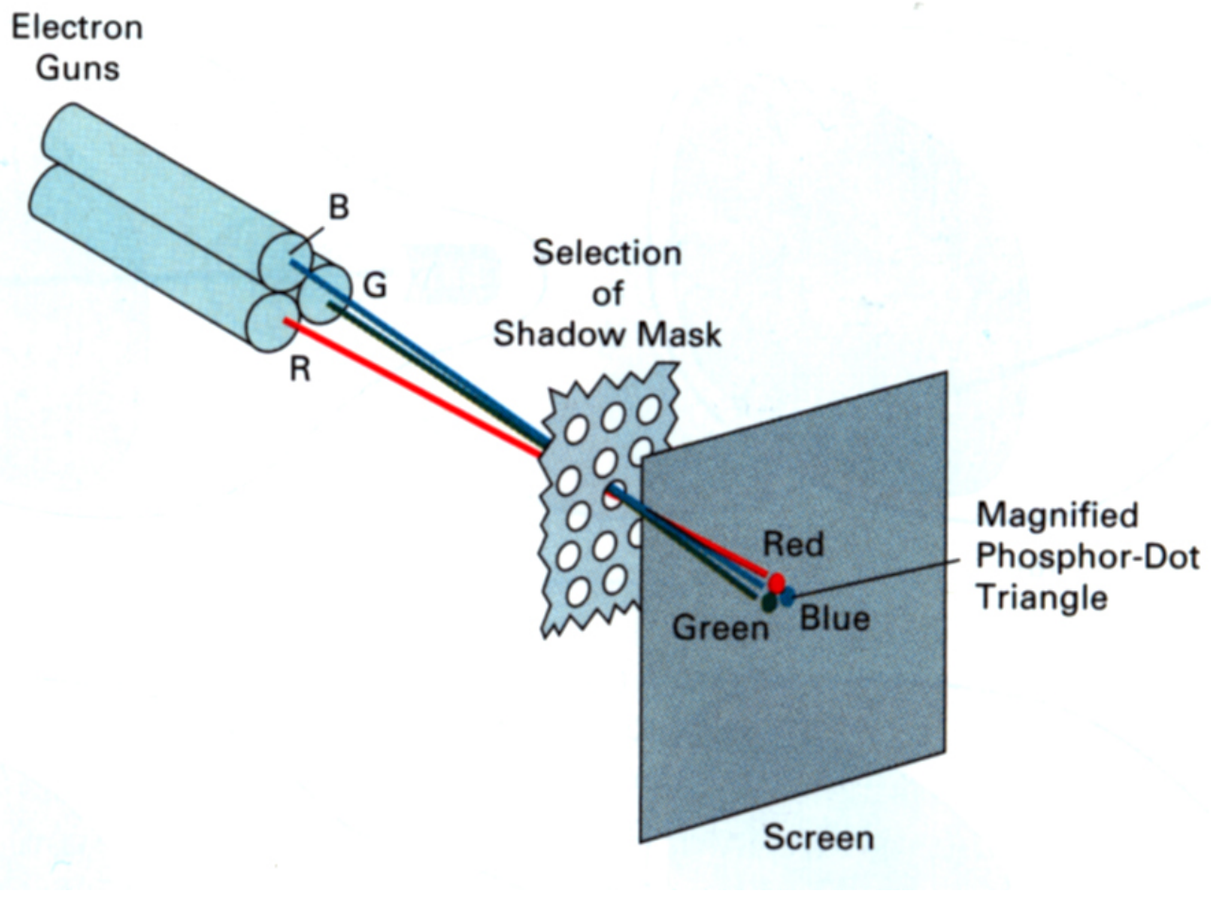
Color Projector



Cathode Ray Tube

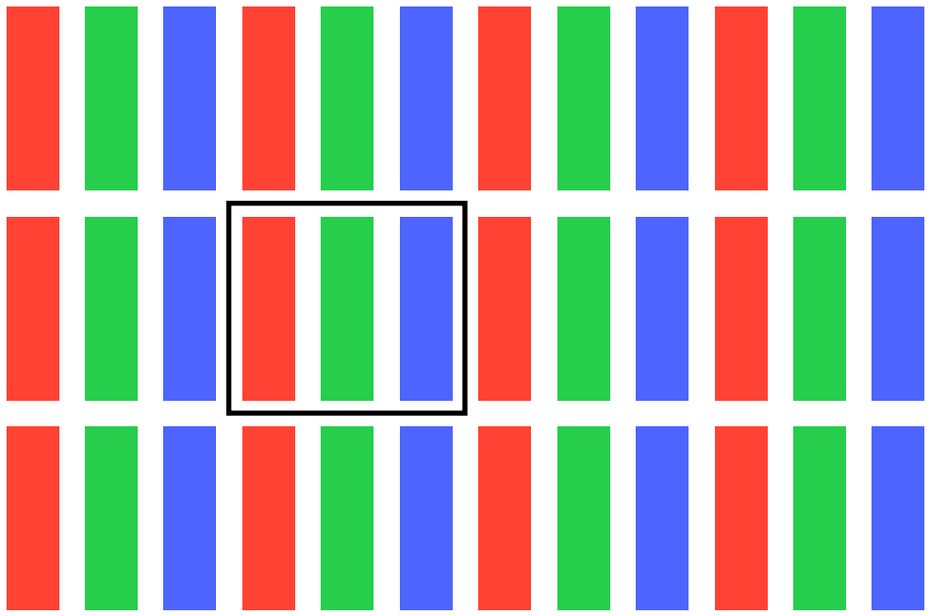




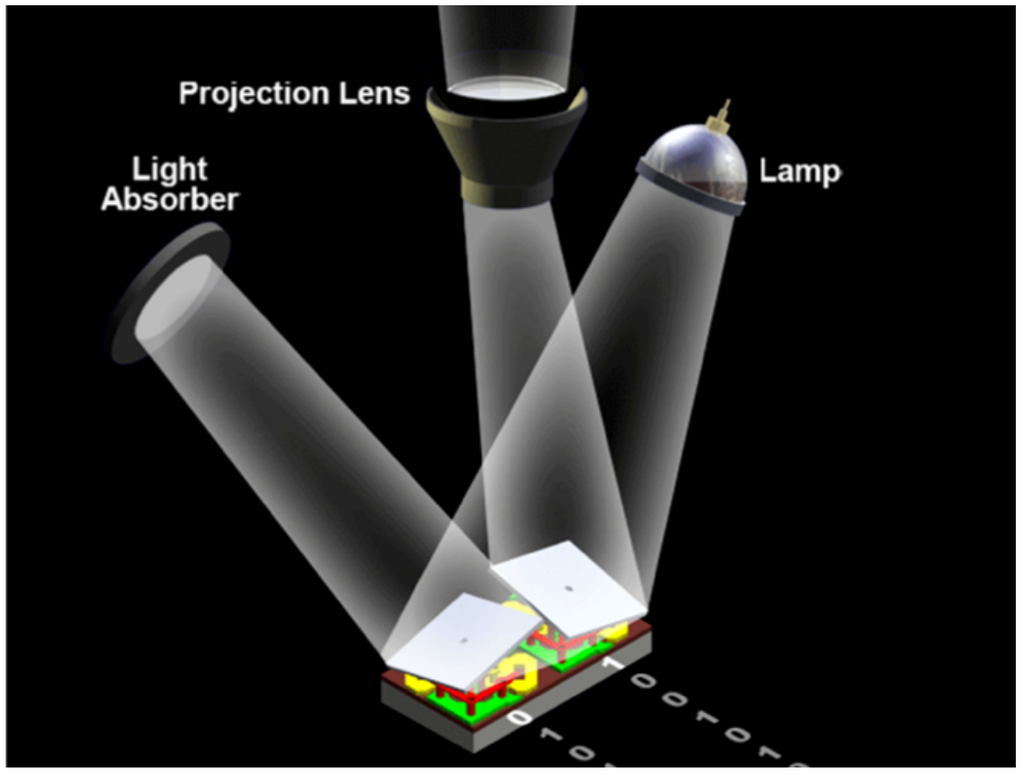


How do we display images?
Nowadays Edition

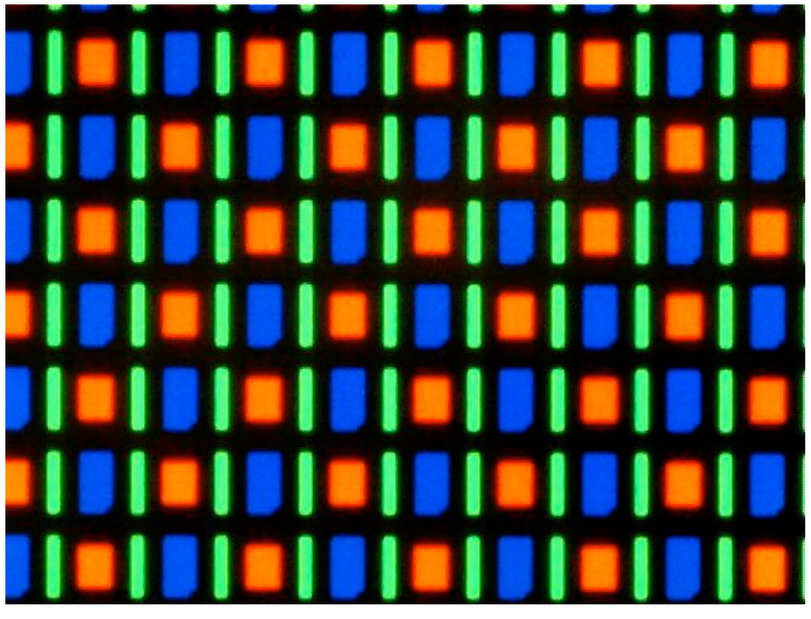
Liquid Crystal Display



Digital Light Processing



Light Emitting Diode Display



[Wikimedia Commons]

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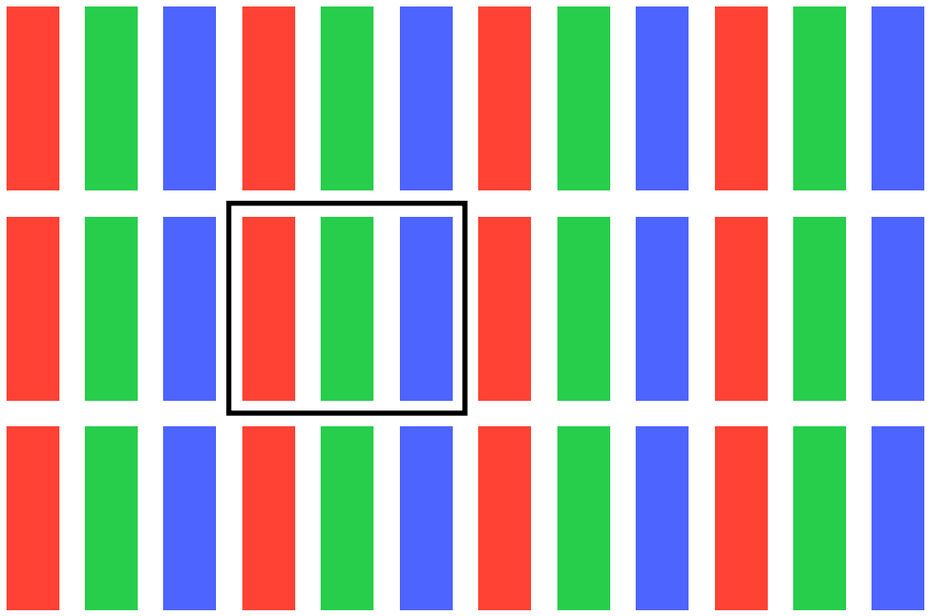

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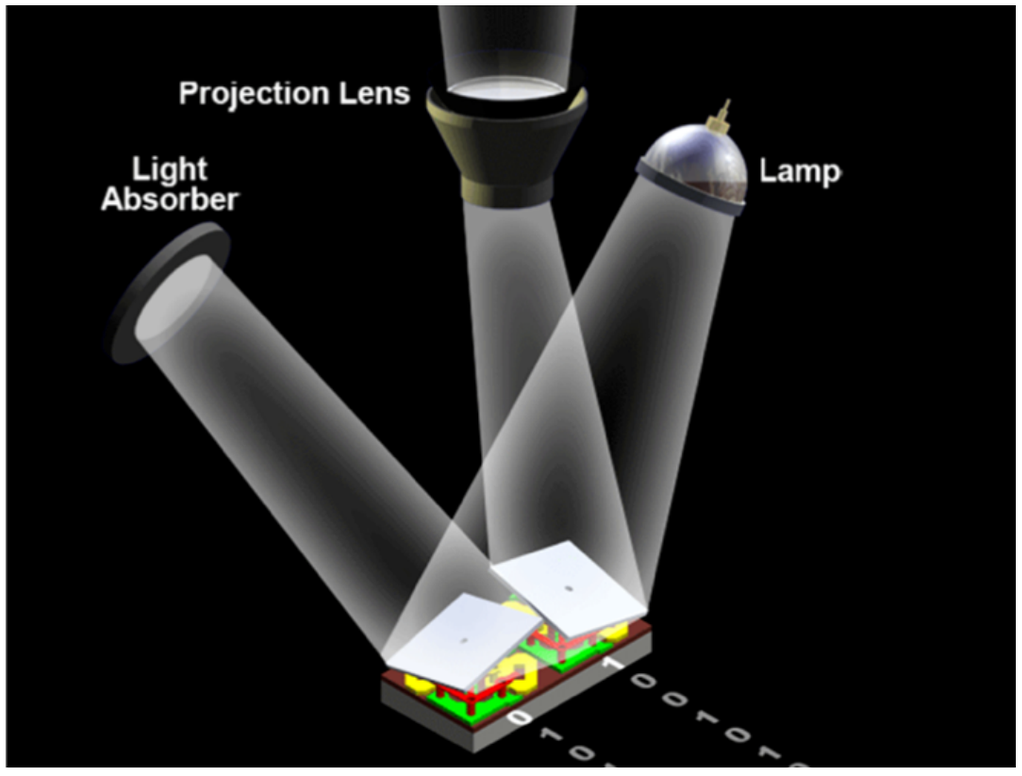

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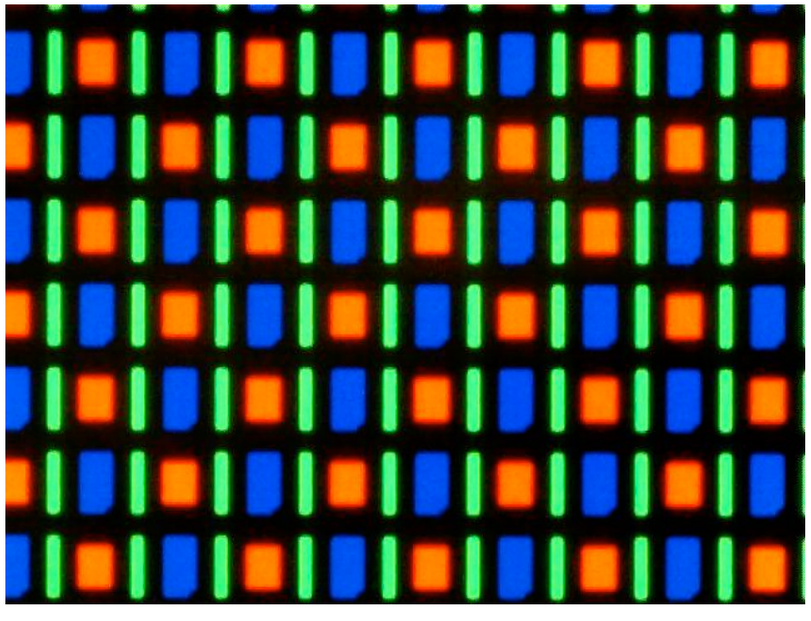
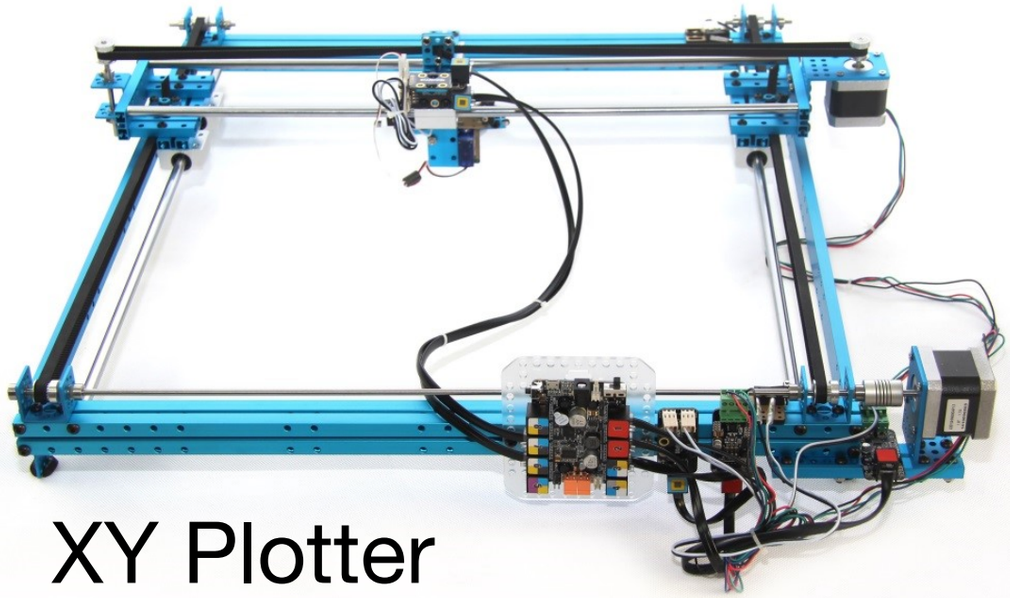


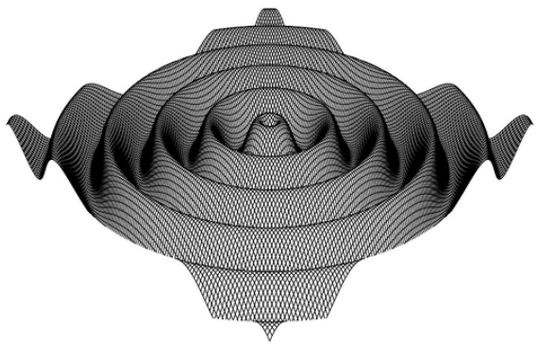
[Wikimedia Commons]

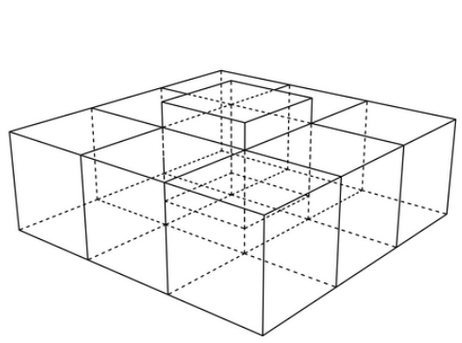
these are all examples of **raster displays**

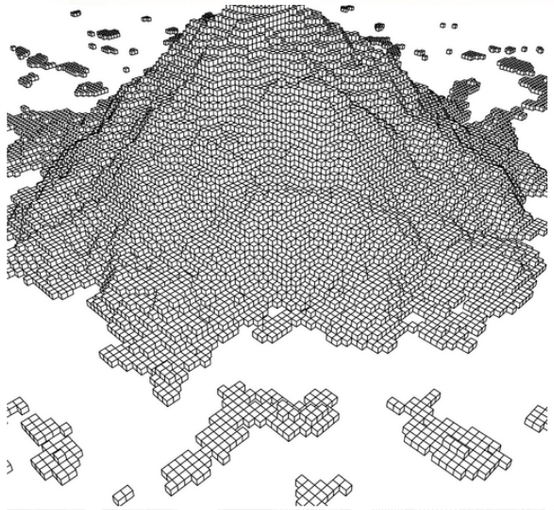
Aside: It doesn't have to be this way...

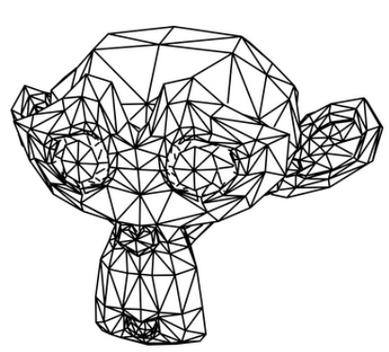


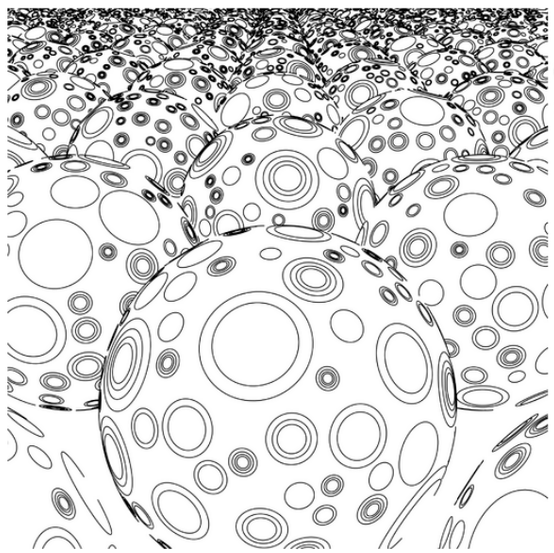
XY Plotter

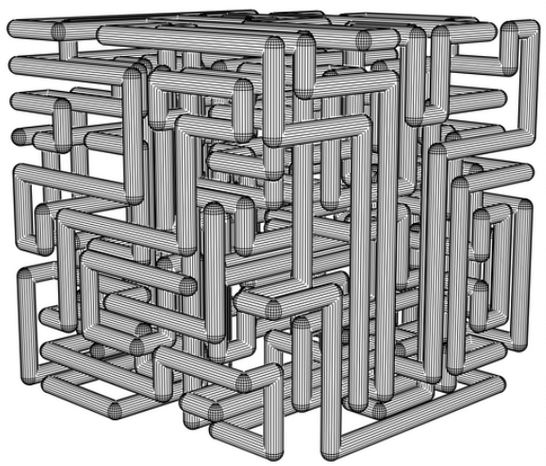


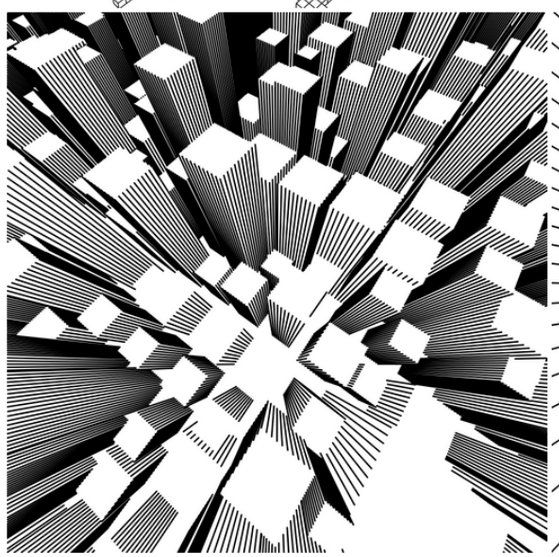


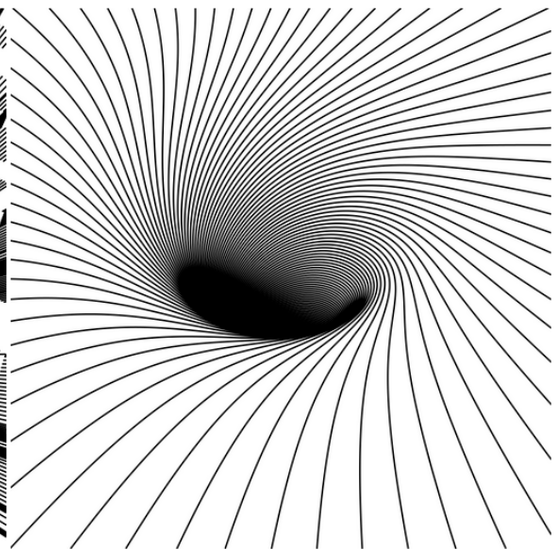










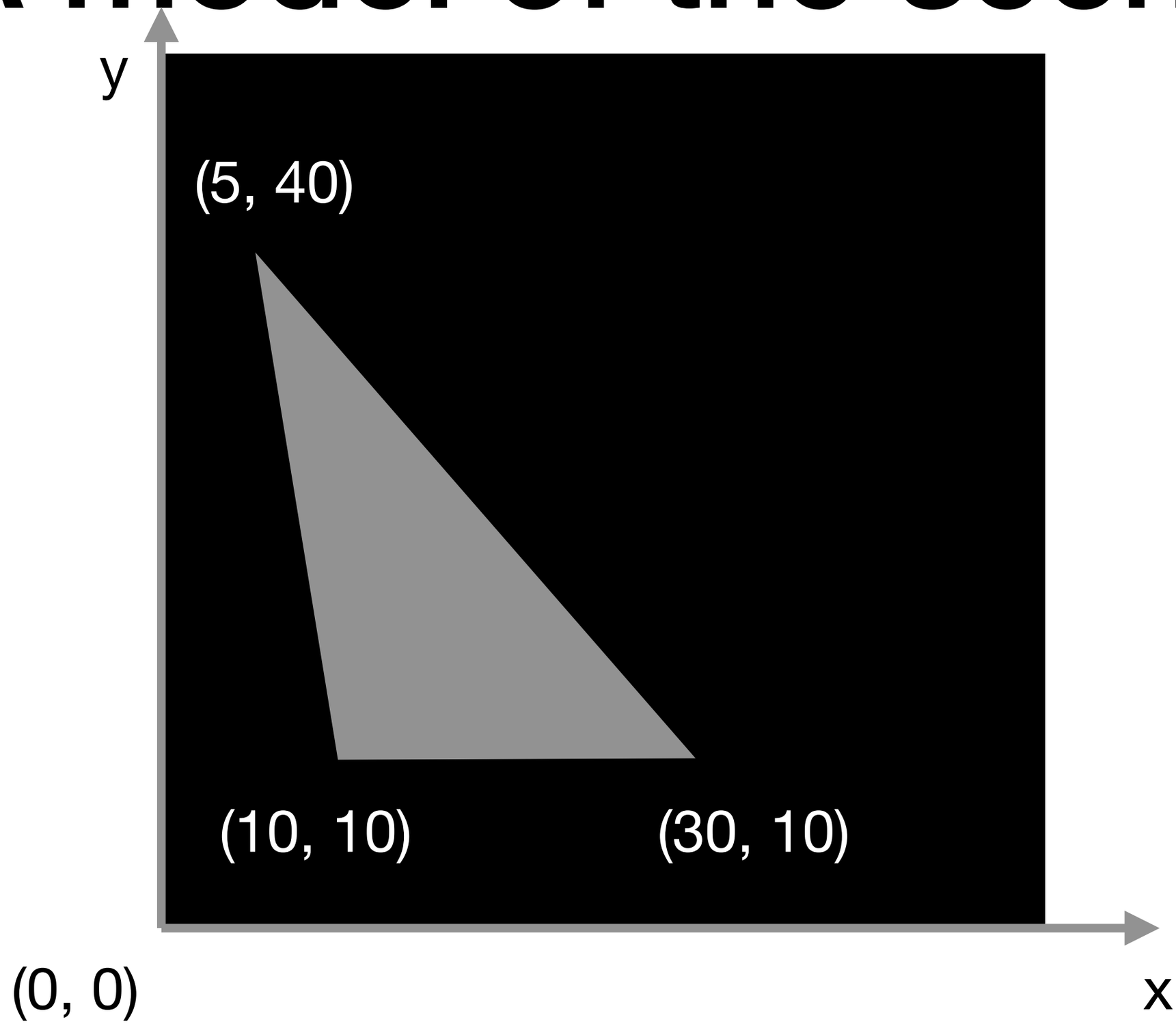


images: https://github.com/fogleman/ln

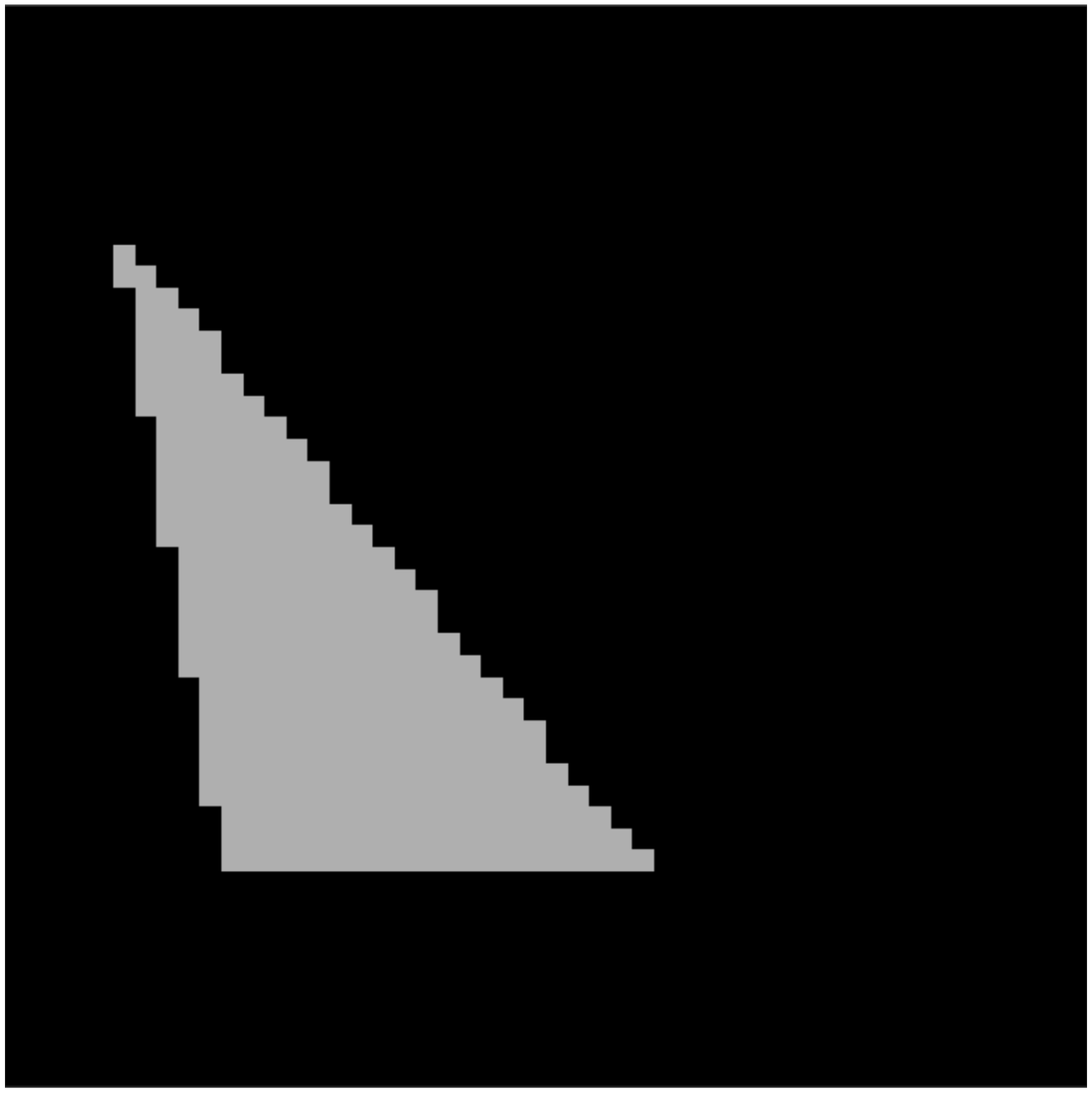
Raster Images

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

A model of the scene



A Raster Image of the Scene



Representing Raster Images: 2D Arrays of Numbers

- Bitmap (1 bit per pixel) $I : \mathbb{R}^2 \Rightarrow$
- Grayscale (usually 8 bpp) $I : \mathbb{R}^2 \Rightarrow$
- Color (usually 24 bpp) $I : \mathbb{R}^2 \Rightarrow$
- Floating-point (gray or color) $I : \mathbb{R}^2 \Rightarrow$
  - 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.

Consequence: creating a 1 megapixel image requires making 2^{20} decisions.

Implication: performance matters.

2D Arrays in Julia

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

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

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

Make an array of zeros…

…of type RGB{Float32}…

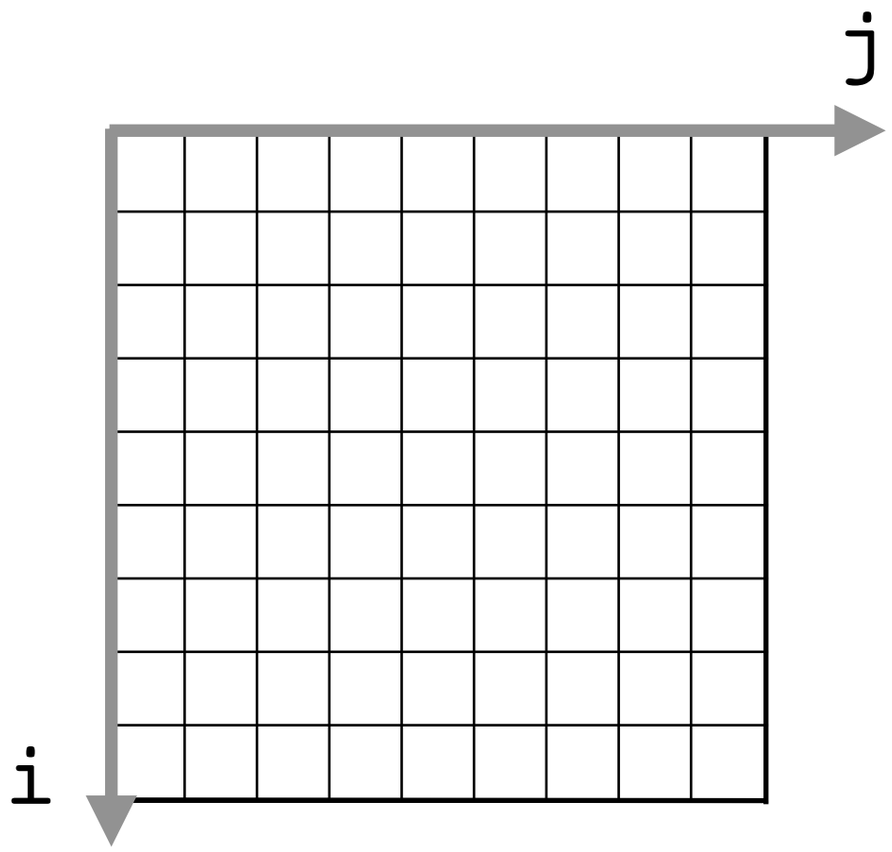
…with dimensions (height x width)

2D Arrays in Julia

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

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

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



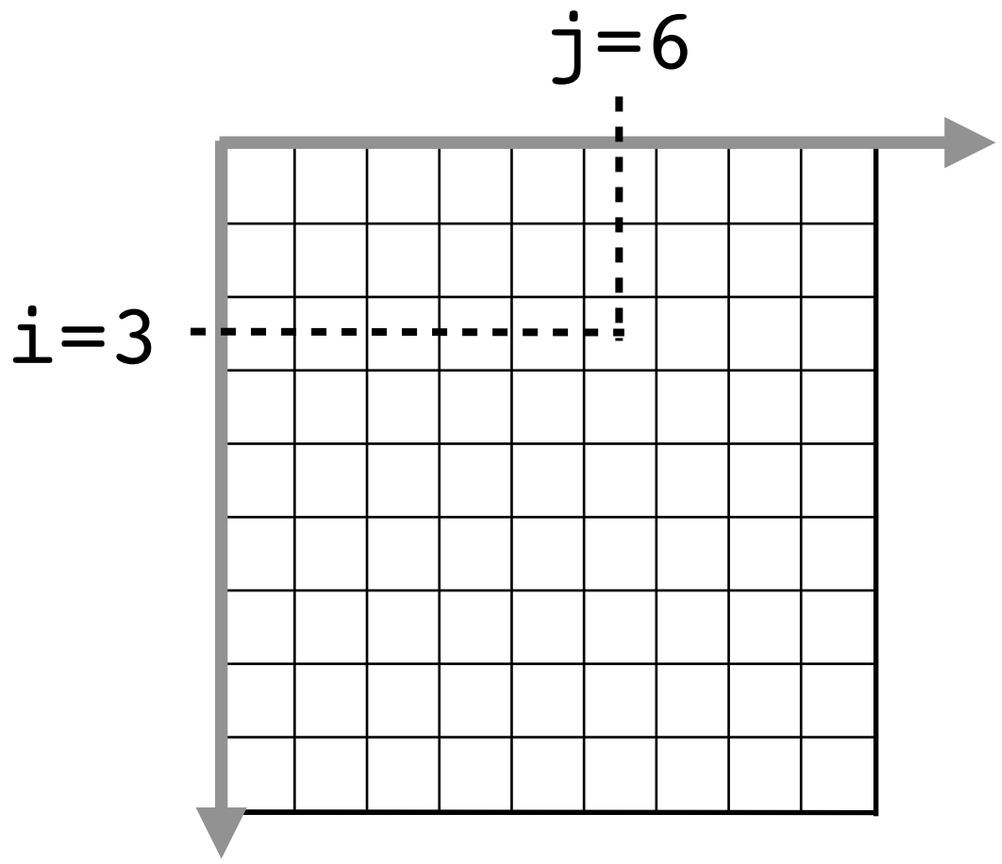
2D Arrays in Julia

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

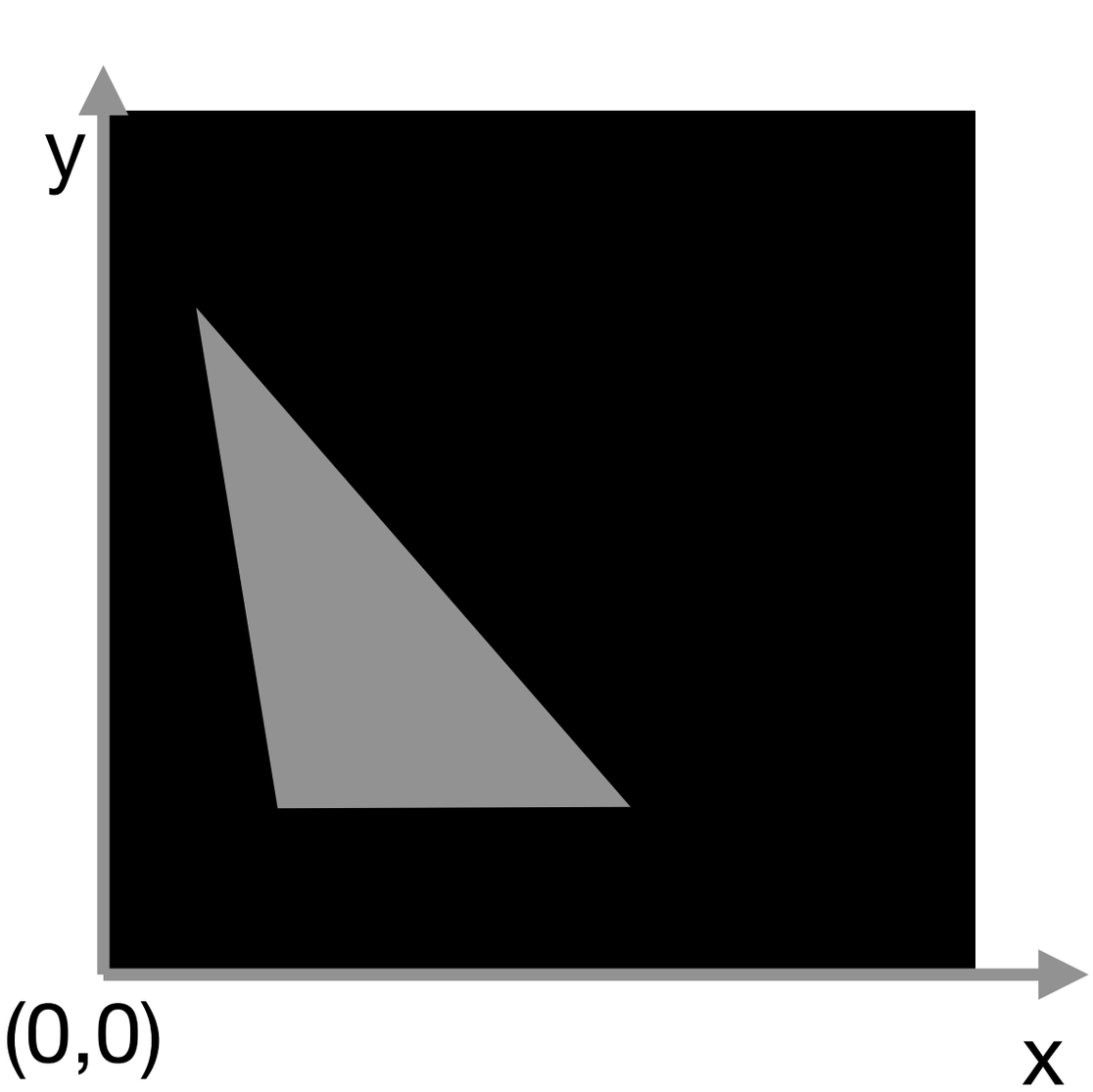
Matrix-style **1-based** indexing (row, column):

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

```
canvas[3, 6]
```



Raster Images: Coordinate Systems



Model coordinates

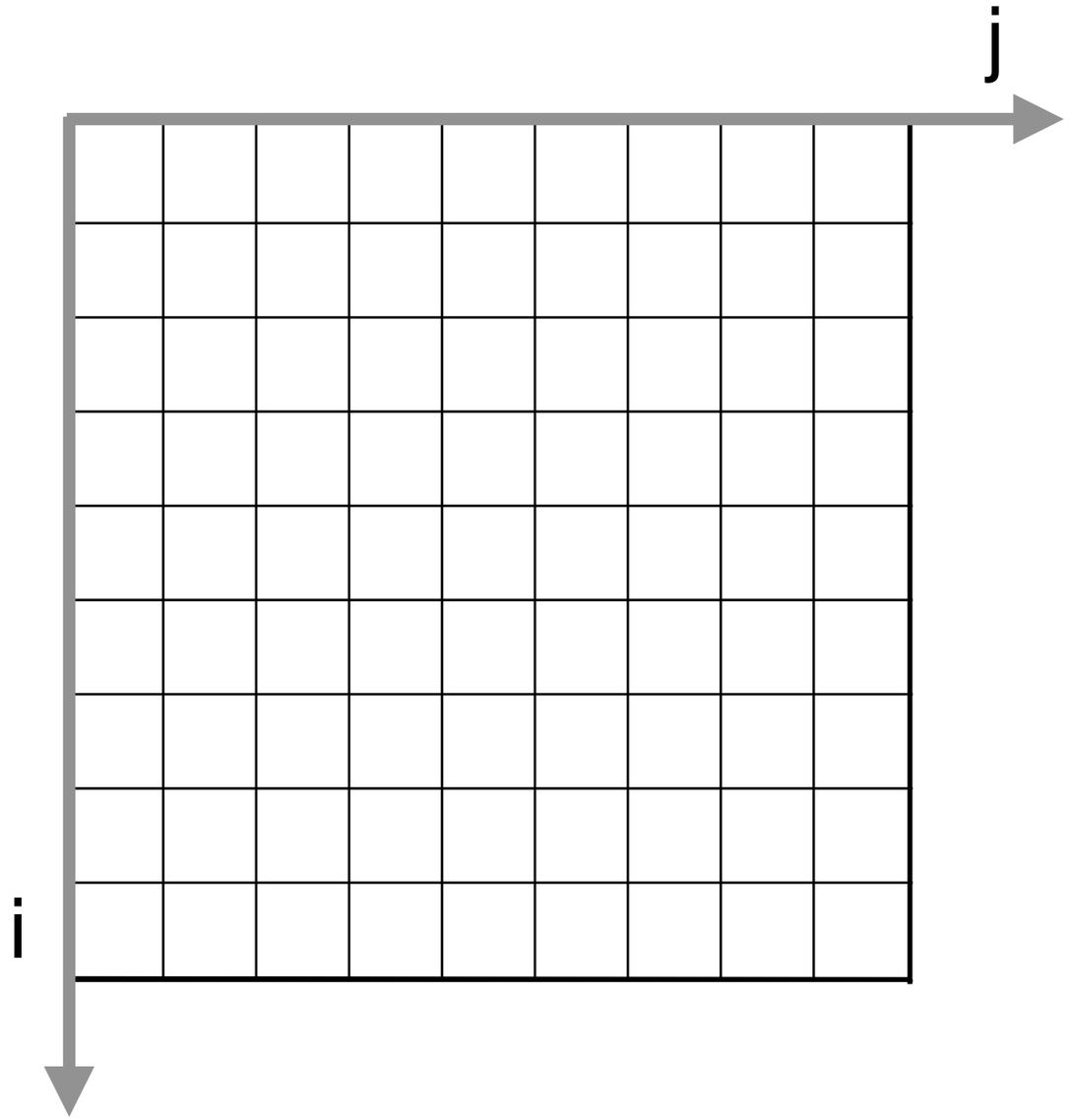


Image coordinates

We'll be working a lot with coordinate transformations!