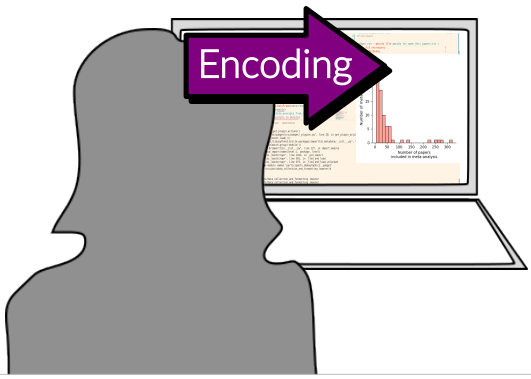
Introduction to Data Visualization

Part 2: Encoding

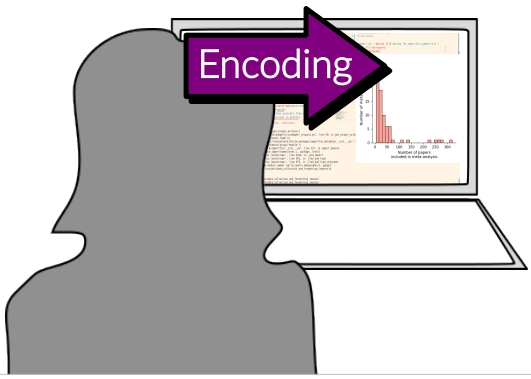


Kendra Oudyk

Welcome to introduction to data visualization, part 2: encoding, where we'll talk about programming data visualizations in Python.

Introduction to Data Visualization

Part 2: Encoding



Kendra Oudyk

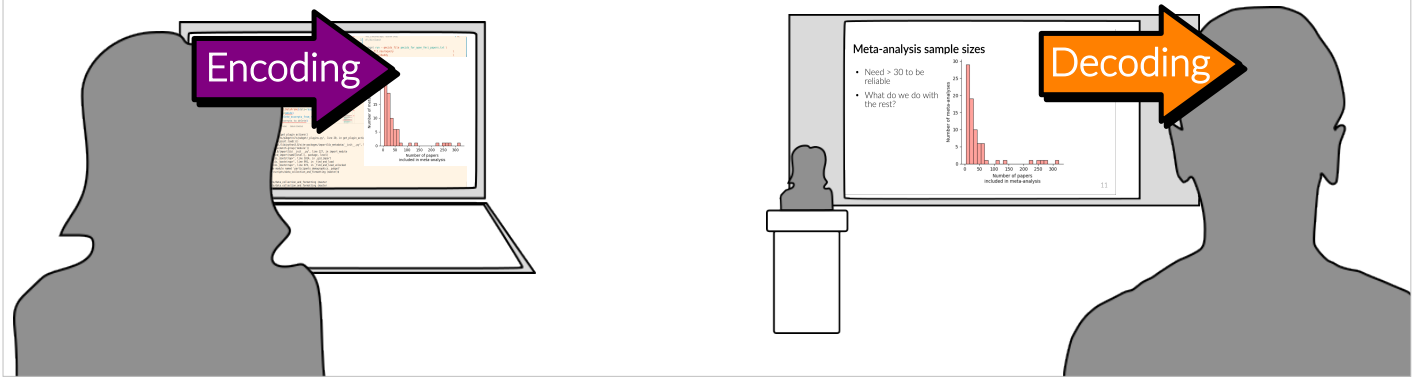
Welcome to introduction to data visualization, part 2: encoding, where we'll talk about programming data visualizations in Python.

Goal

Use principles of visual encoding and decoding

to efficiently create visualizations

that are effective and reproducible



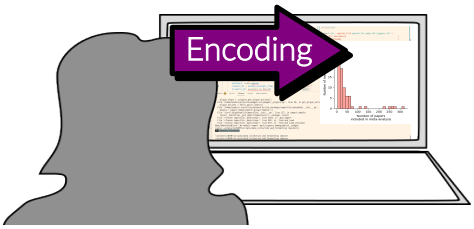
In part 1 of this lecture, we talked about Decoding, and I'll just go over the difference again here.

Decoding happens when someone sees your figure and understands something about your data.

Encoding happens when you write code to create the figure according to your plan.

In these lectures, I hope you will learn to
* use principles of visual encoding and decoding
To efficiently create visualizations
That are effective and reproducible.

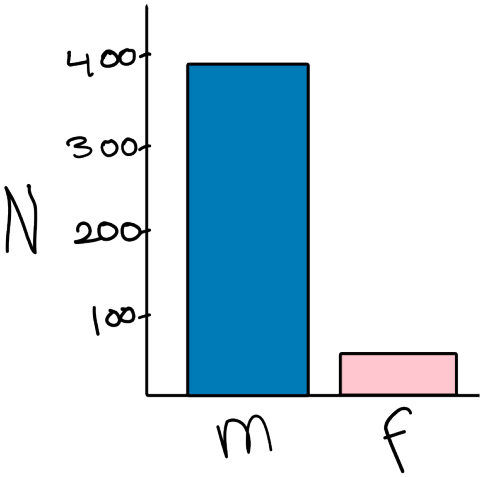
Understanding decoding will help you make effective figures
Understanding encoding will help you make figures more reproducibly and efficiently

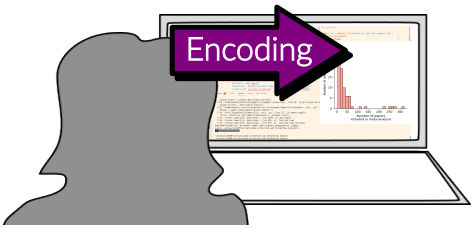


To program a figure efficiently and reproducibly, we should understand

- Some computer graphics
  - How the computer makes figure
- Matplotlib basics
  - What you and matplotlib need to do
- Higher-level libraries
  - More complex visualizations

In order to program a figure efficiently and reproducibly, it helps to understand...





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But before getting into these topics, we're going to start by making a really simple chart in matplotlib.

If you're completely new to matplotlib, don't expect to understand the code right away, as we'll continue to unpack it as we go through different topics.

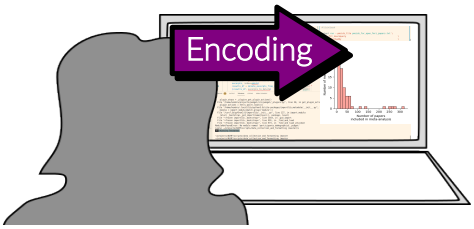
In the last lecture, we used principles of decoding to create this plan for a figure.

Now let's see how to encode this figure in python

go to Python

6

IN PYTHON



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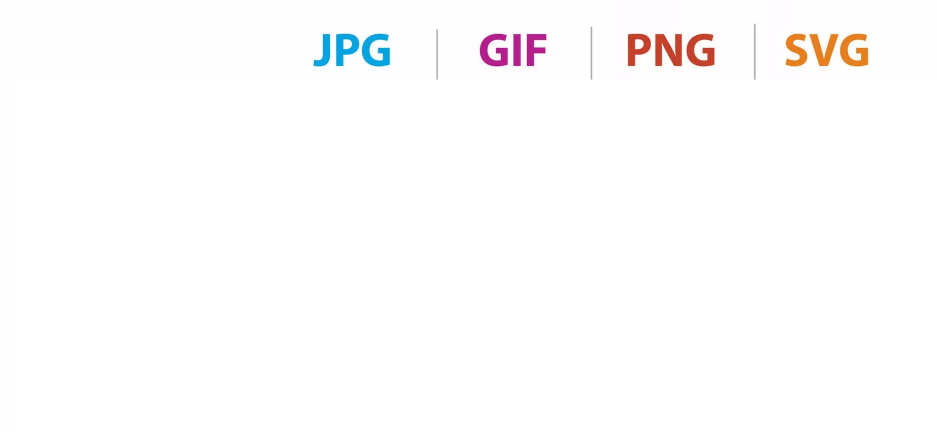
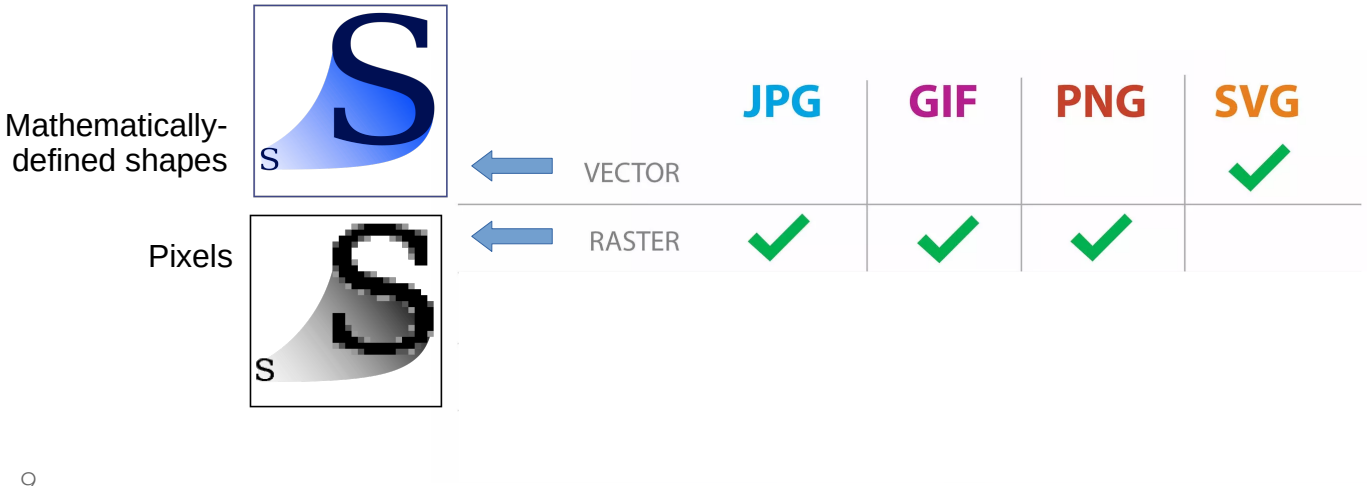
File formats



https://www.pagecloud.com/blog/web-images-png-vs-jpg-vs-gif-vs-svg

First, let’s start with something that’s probably familiar to most of us – some common file formats for images.

File formats



https://www.pagecloud.com/blog/web-images-png-vs-jpg-vs-gif-vs-svg

One of the main defining features of each is whether they are constructed from mathematically-defined shapes or from pixels, that is, whether it's a vector or a raster-based image.

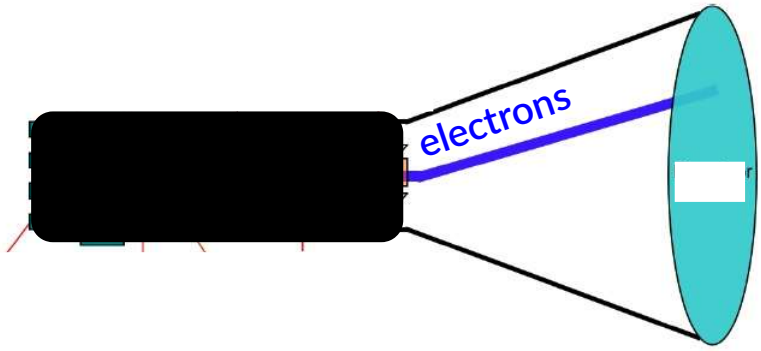
The obvious difference between these types of figures is that, when you zoom in on a raster-based image, it looks blurry.

But Vector images are just as clear no matter how zoomed in you are.

Generally, vector-based images are better if you want a good quality image in a paper, a slideshow, and a poster. It'll look just as clear.

But if the figure is very complicated, the file can become very big.

Cathode ray tube



10 https://www.tutorialspoint.com/computer_graphics/computer_graphics_quick_guide.htm

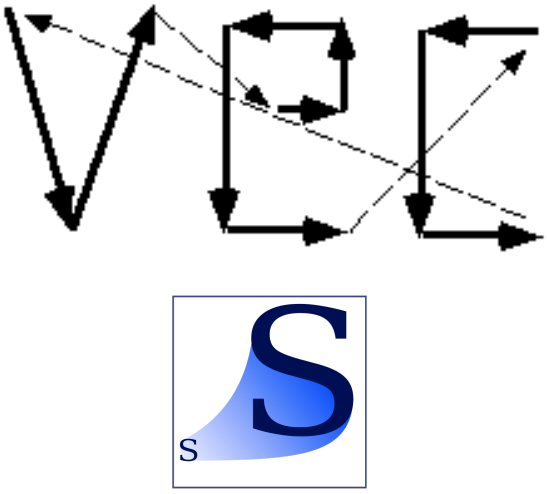
To understand why these types of files are different, we need to briefly think about how images are constructed on a screen.

This is a cathode ray tube.

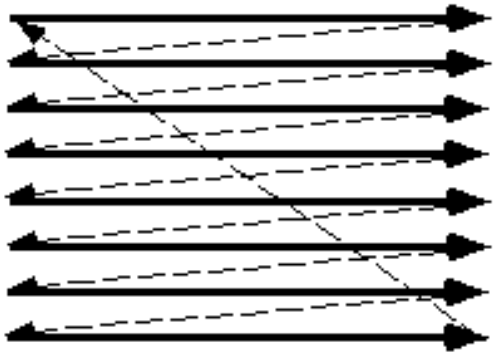
The complicated insides aren't important for our discussion.

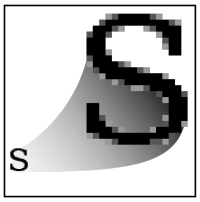
* the main thing to take away is that there are electrode guns in the tube that shoot electrons at the screen.

Vector scan



Raster scan

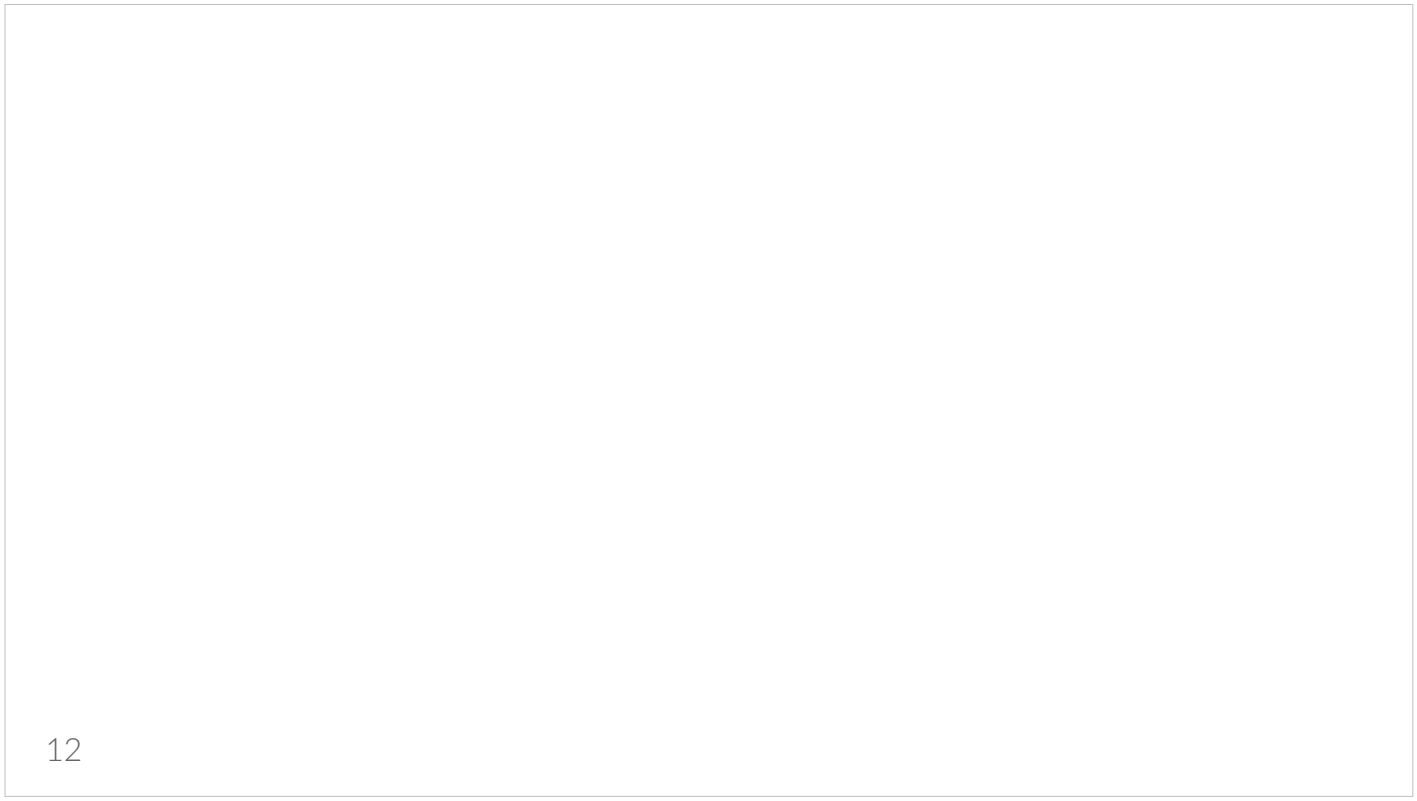




https://www.cs.uic.edu/~jbell/CourseNotes/ComputerGraphics/VectorVsRaster.html

For a vector graphic, the electron beam creates the image by tracing the vector equations.

For a raster image, the beam scans across each row of pixels on the screen.



VSC

Save image as .png and .svg

Open both figures, zoom it

INKSCAPE

Save basic bar chart moved slightly

Do git diff on svgs

Do git diff on pngs

File formats

	JPG	GIF	PNG	SVG
VECTOR				✓
RASTER	✓	✓	✓	
TRANSPARENCY			✓	✓
ANIMATION		✓	✓	✓
LOSSY	✓			

https://www.pagecloud.com/blog/web-images-png-vs-jpg-vs-gif-vs-svg

Here are a few more differences. We won't go into why, but it's good to know this so you can choose the best format for your data visualizations

Only PNG and SVG files allow for transparency.

And GIF, PNG< and SVG can be used to create animations

The JPG is lossy. Which means that you lose information when an image is stored in this format.

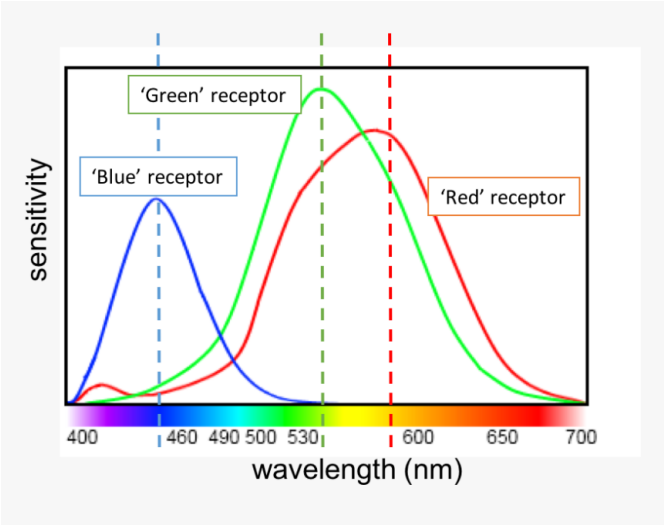
Color: salient but complicated

Now let’s talk about color again.

We’ve already discussed how color can be useful for encoding shapes, patterns, and groupings.

To round off that discussion, let’s see how computers make color.

RGB: Types of photoreceptors in the retina

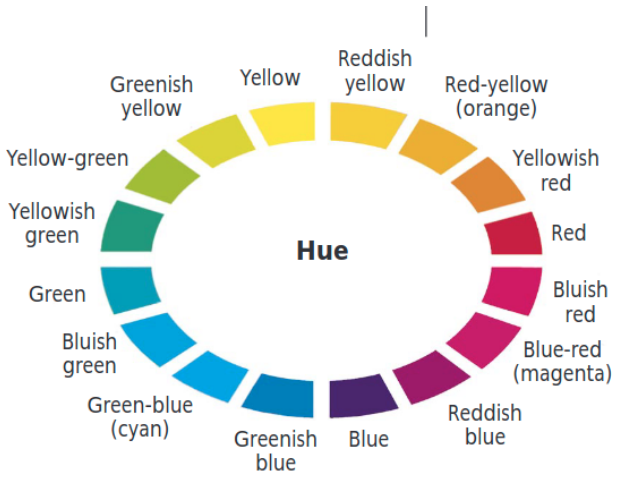


https://www.simplypsychology.org/what-is-the-trichromatic-theory-of-color-vision.html

I'm going back a bit further in the process of color perception, because I find it fascinating that both computers and our photoreceptors use red, green, and blue as the basis of color.

* In the back of our eyes are photoreceptors that respond preferentially to light of different wavelengths: red, blue, and green light.

Hue: how we casually talk about color

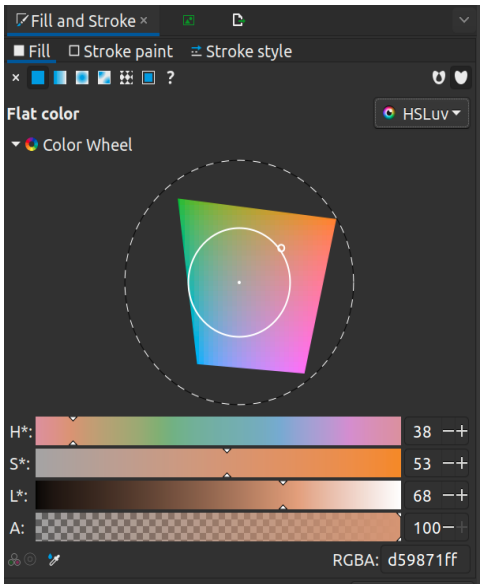


https://www.engr.colostate.edu/ECE666/Handouts/WritingPapers/UsingColorEffectively.pdf

Let’s move up to cognition.

We usually talk about colors as named hues.

HSLuv: how we talk about color perception



Hue
Saturation
Lightness / **L**uminance

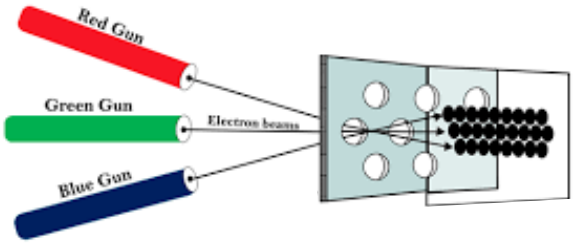
But to cover the full range of colors, we need to discuss saturation and lightness as well as Hue.

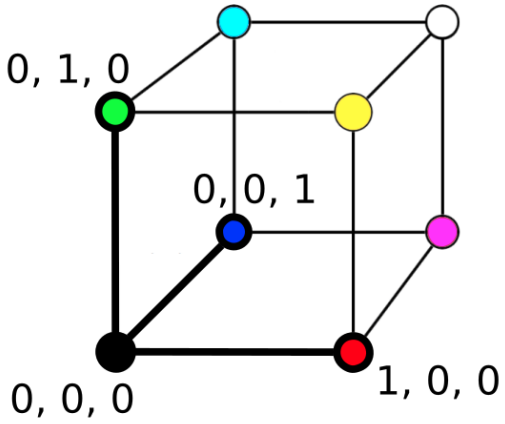
This is the HSL paletter.

In particular, here we see the HSLuv pallett, also known as H*S*L*..
It has been corrected for our uneven perception of lightness over the hue spectrum.

Our last lecture covered this more in depth.

RGB: How a computer produces color





https://www.javatpoint.com/computer-graphics-color-crt-monitors

But a computer goes fully back to the basics, producing color through beams of electrons with frequencies in the red, green, and blue ranges of the spectrum.

* Here is the cathode ray tube again, showing how there are electron guns for the three different wavelengths.

The RGB pallette can be thought of as a three-dimensional space, where each color (including its hue, saturation, and lightness) is made up of different amounts of these three frequencies.

* This can be visualized as a cube.

I find this fascinating. The three electron guns kind of match our three cone receptor types.

But the way colors are produced from mixing these three channels is very unintuitive. Let me demonstrate

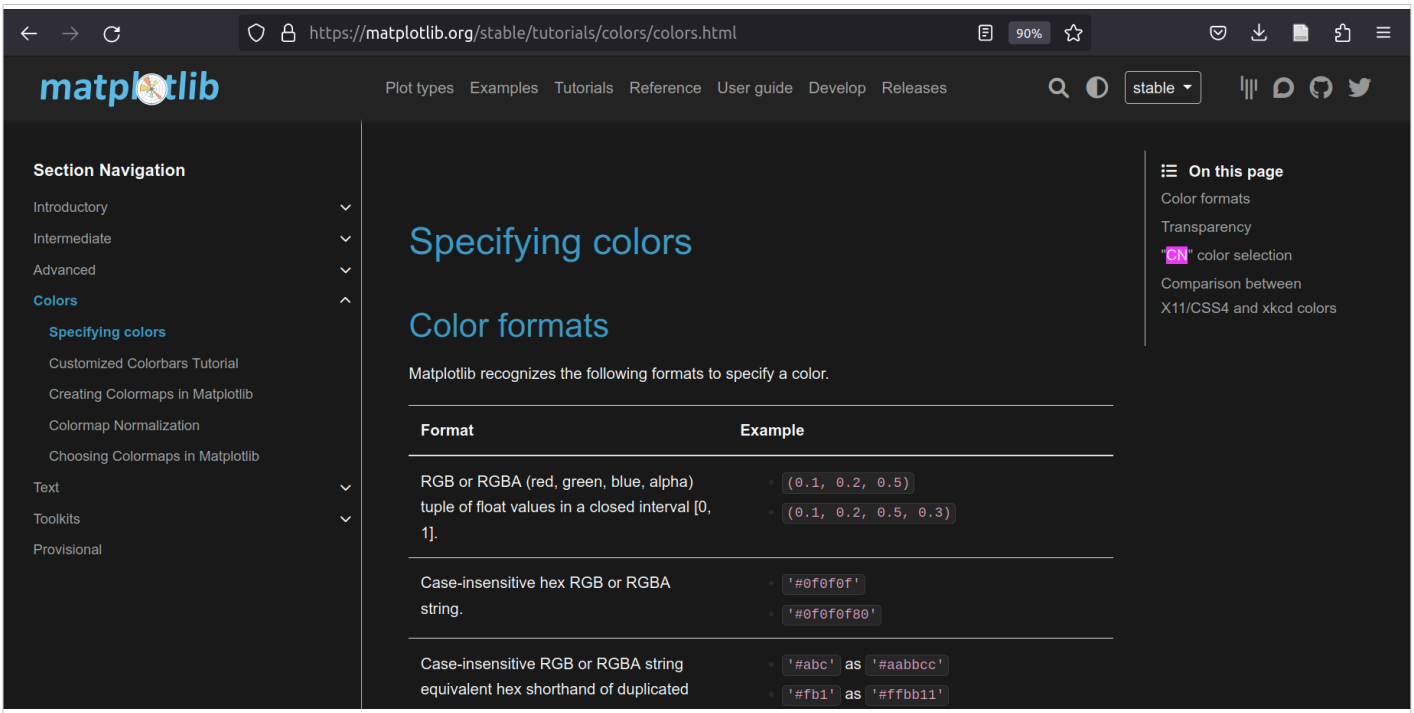
Go to inkscape

IN INKSCAPE

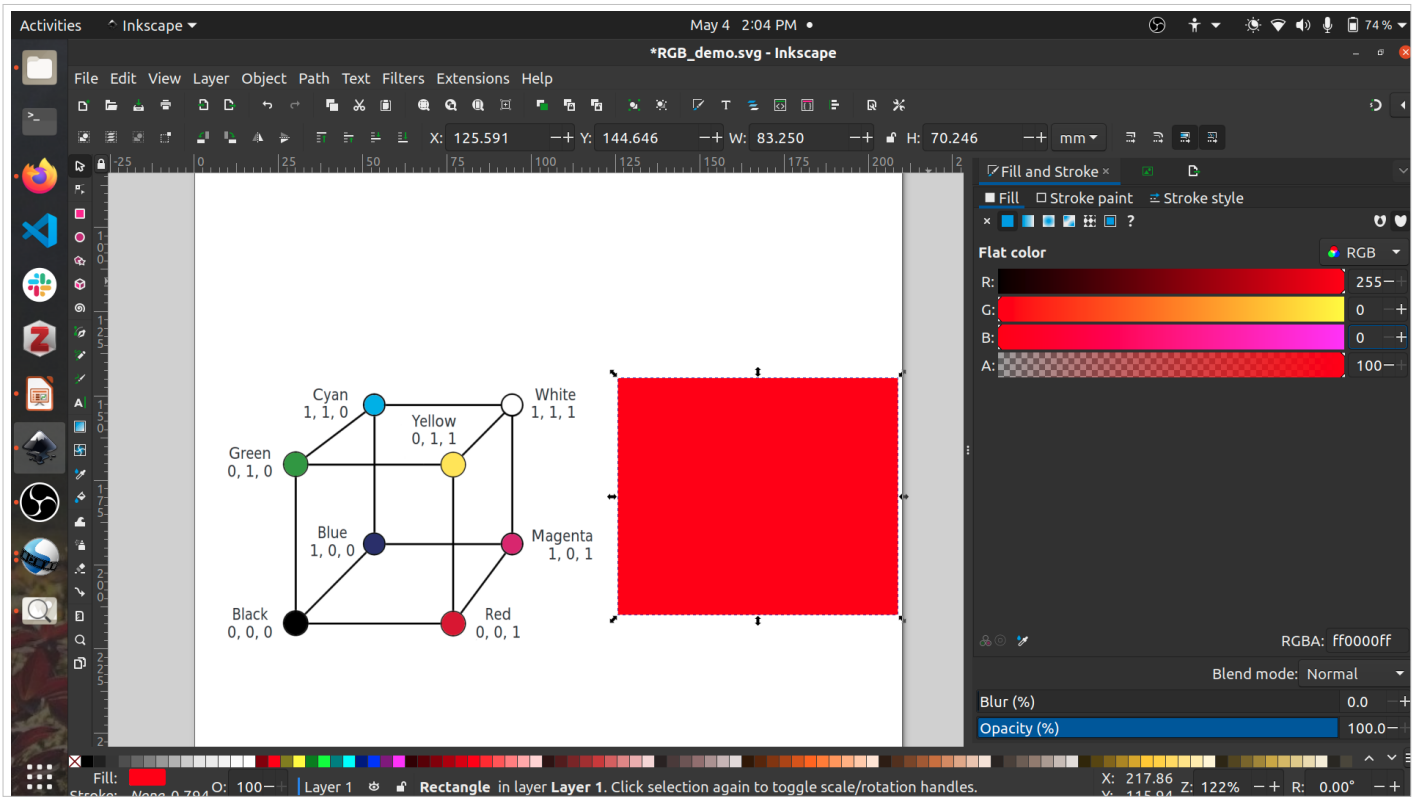
Let’s see how the RGB pallette maps onto this 3D cube.

Try to notice how unintuitive it is, compared to the HSL pallette.

Demo color cube



If you go to the matplotlib documentation, you can see the different ways that it accepts color specifications.



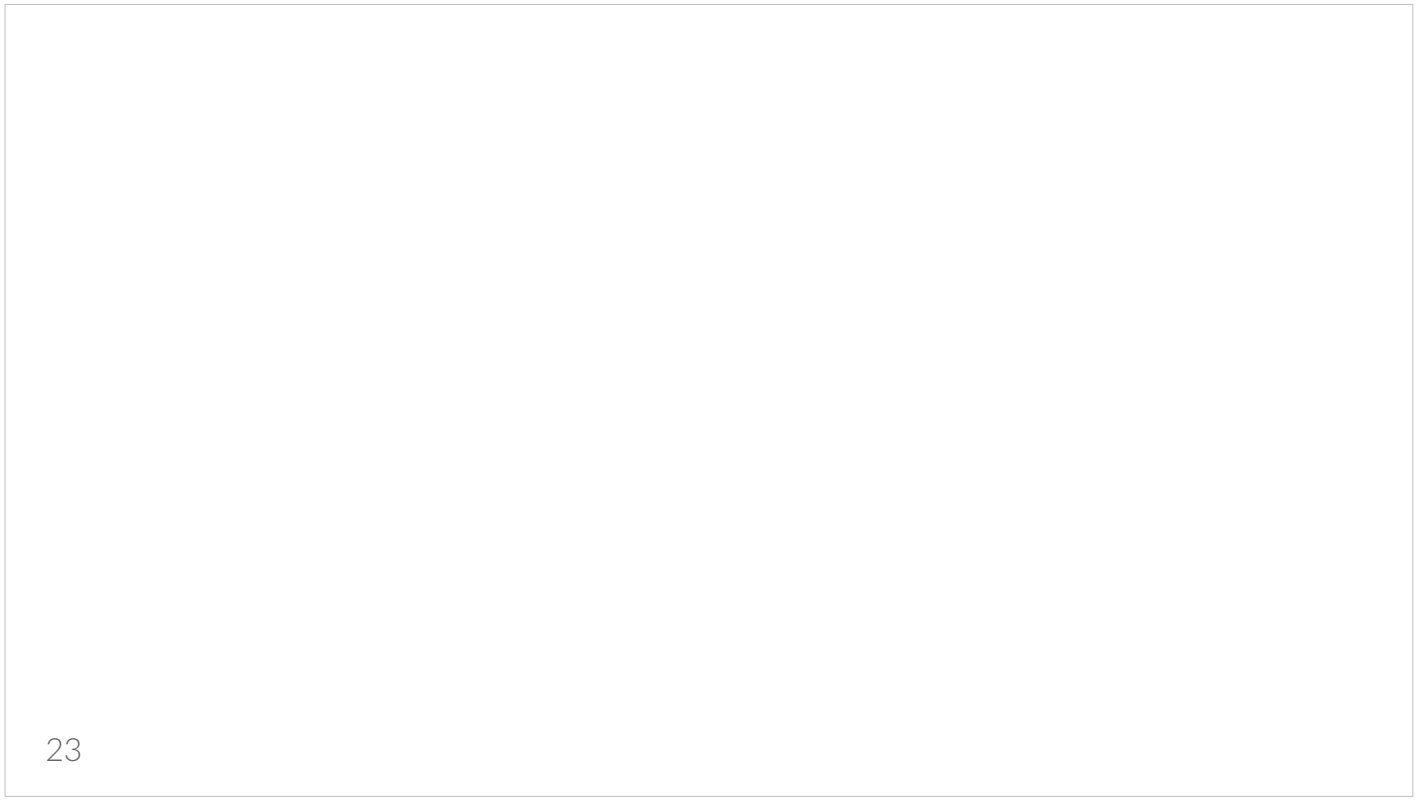
IN INKSCAPE

If you chose a color in HSL,
You could go to the RGB pallette and copy and paste its hex code.

Here's how the RGB scales map onto the hex code.

The first two characters are for red, the third and fourth for green, the fifth and 6th for blue, and the last two are for alpha, or the transparency.

When I change the red scale by one, the hexidecimal character for that scale changes by one.



If we enter colors by name in matplotlib,
It will still encode them as RGB behind the scenes.

SVC

Ax
Containers
0 bar container
0 rectangle
_facecolor

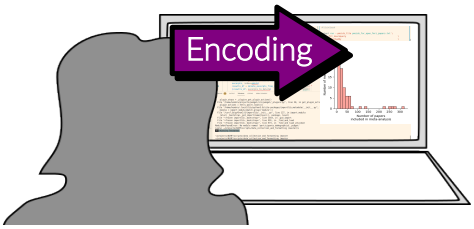
TL;DR

- Images have different properties/features because of **how they're made**
- The way a computer produces color (**RGB) is not intuitive**
  - You'll probably pick colors using named colors or an HSL tool

So, in summary of this very brief intro to computer graphics,

Images...

And the way...



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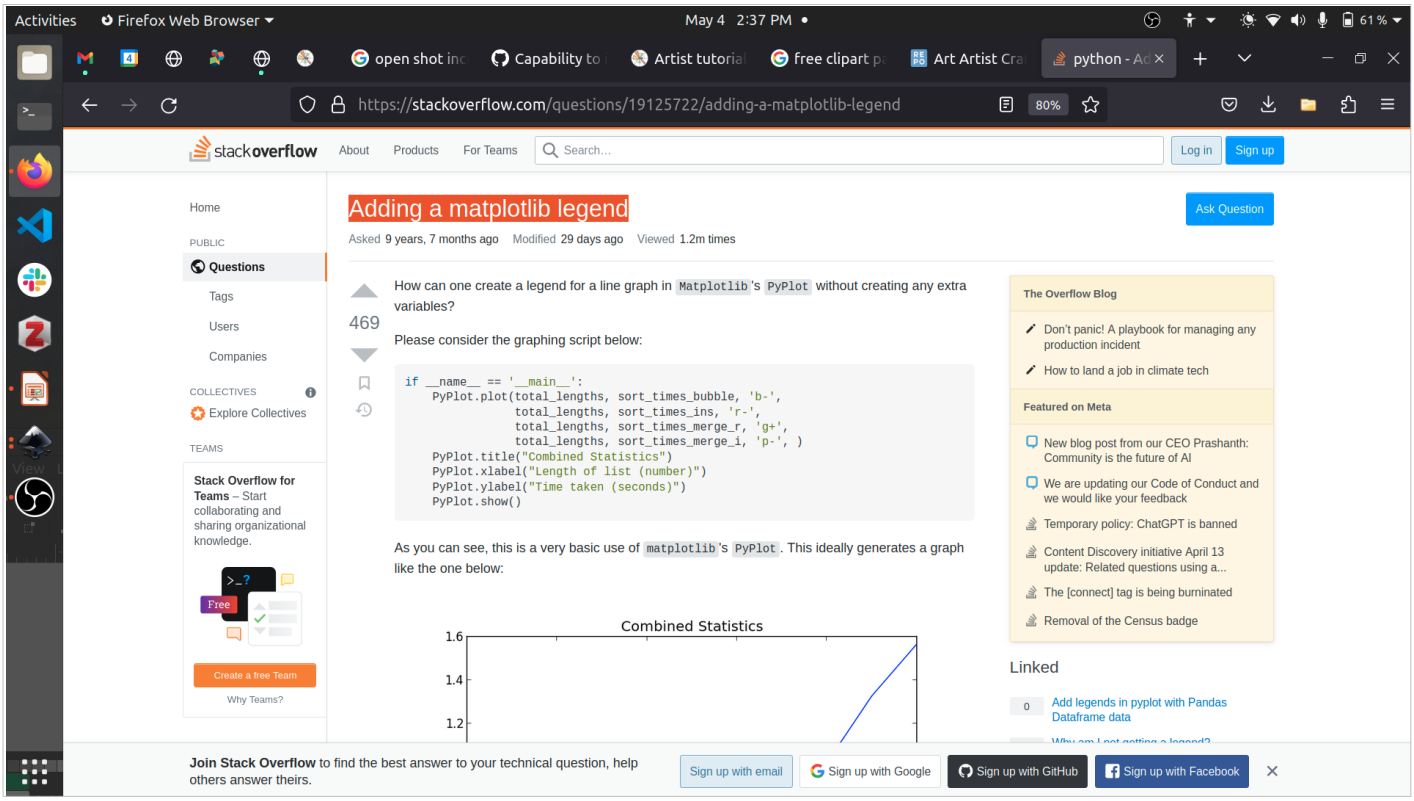
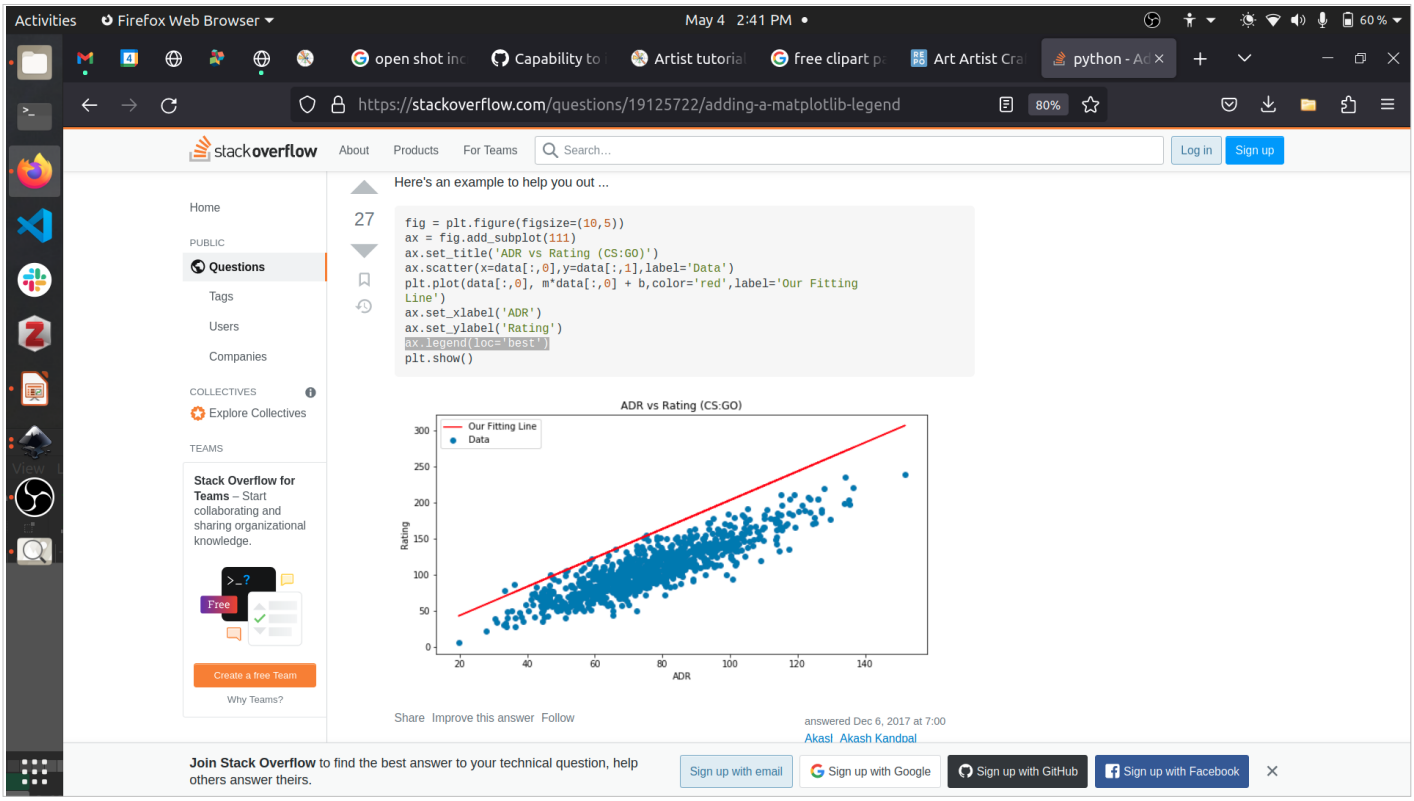
Now let's go over some matplotlib basics.
Matplotlib is a python library for creating visualizations.

We're going to go behind the scenes a bit to see how matplotlib works.
The important thing to remember is what you have to do.
But I hope it will be easier to remember what to do and which help to follow, if you understand a bit about what matplotlib is doing.

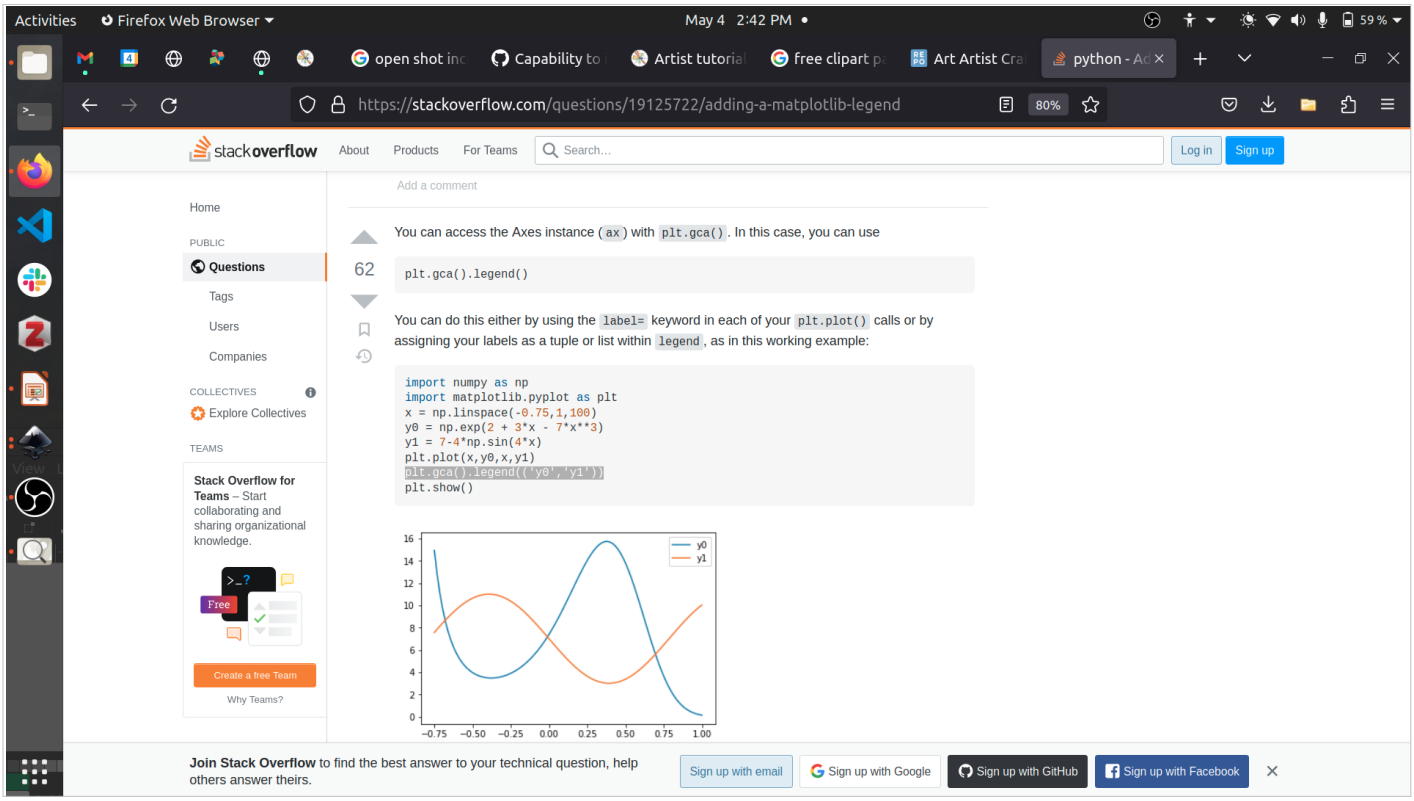


If you've ever used matplotlib, and ever looked up how to do something, you might have noticed that there's usually more than one way to accomplish something.

Here, someone is asking on Stack Overflow how to add a matplotlib legend.



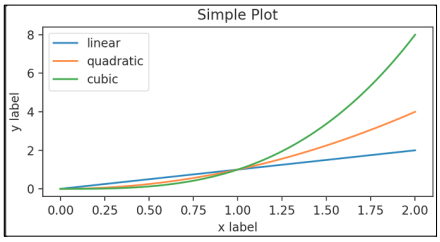
This person suggested using ax.legend()



Whereas this person suggested plt.gca().legend()

Both of these commands access the same objects behind the scenes, but they demonstrate different coding styles.

Coding styles



Explicit (object-oriented)

```
x = np.linspace(0, 2, 100)  # Sample data.

# Note that even in the OO-style, we use `.pyplot.figure` to create the Figure.
fig, ax = plt.subplots(figsize=(5, 2.7), layout='constrained')
ax.plot(x, x, label='linear')  # Plot some data on the axes.
ax.plot(x, x**2, label='quadratic')  # Plot more data on the axes...
ax.plot(x, x**3, label='cubic')  # ... and some more.
ax.set_xlabel('x label')  # Add an x-label to the axes.
ax.set_ylabel('y label')  # Add a y-label to the axes.
ax.set_title("Simple Plot")  # Add a title to the axes.
ax.legend()  # Add a legend.
```

Implicit

```
x = np.linspace(0, 2, 100)  # Sample data.

plt.figure(figsize=(5, 2.7), layout='constrained')
plt.plot(x, x, label='linear')  # Plot some data on the (implicit) axes.
plt.plot(x, x**2, label='quadratic')  # etc.
plt.plot(x, x**3, label='cubic')
plt.xlabel('x label')
plt.ylabel('y label')
plt.title("Simple Plot")
plt.legend()
```


https://matplotlib.org/stable/tutorials/introductory/quick_start.html

You can use explicit or implicit coding styles in matplotlib.

The explicit style is object-oriented and is most transparent because you're directly, or explicitly, interacting with the objects.

The implicit style is more similar to matlab.
It can do the same things, in most cases, but you don't interact directly with the objects.

**Here are two pieces of code that create the same figure.

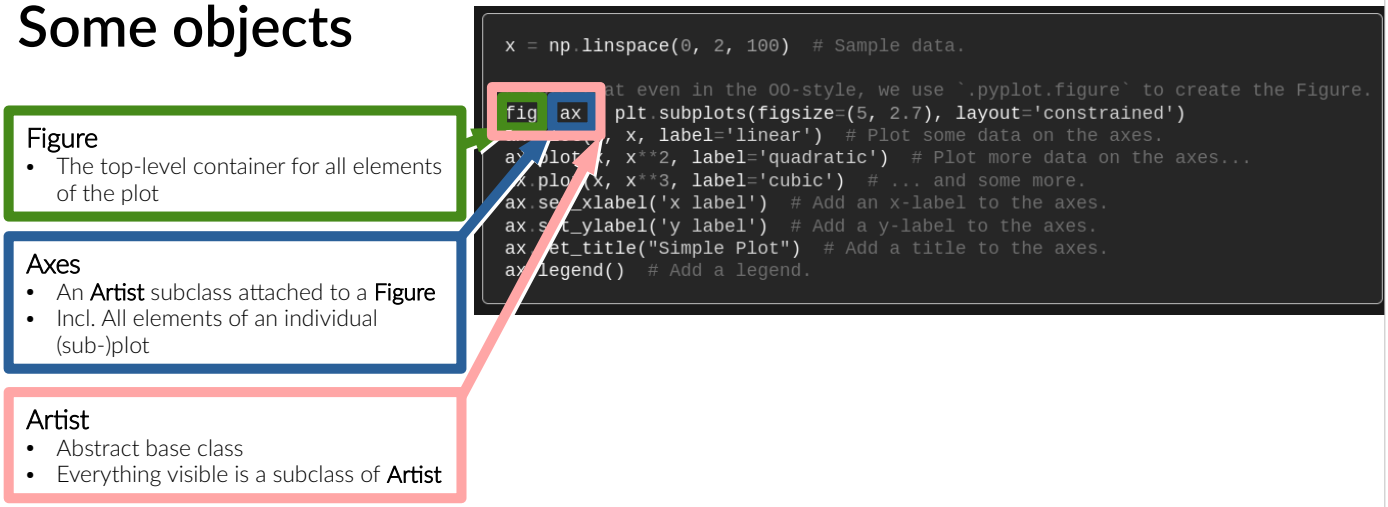
* We can see the differences if we focus on the beginnings of the line.

In the explicit style, they define an object called ax and then adjust it explicitly.

In the implicit style, they continue to call the pyplot sublibrary, which tracks the object for the axis behind the scenes.

Some objects

Explicit (**object**-oriented)



Let's take a closer look at the important objects.

*The fig variable is an instance of the Figure object. It is the top-level container for all elements of a plot.

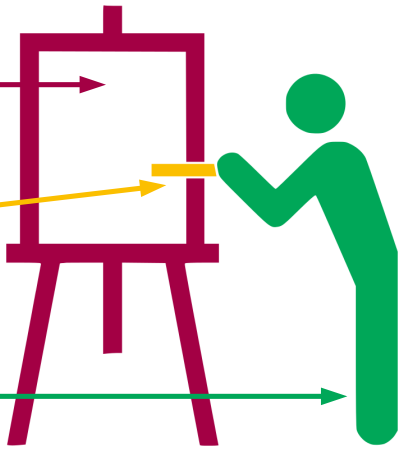
*The ax variable is an instance of the Axes object. It is a subclass attached to a figure, and it includes all elements of an individual plot.

* Both the Figure and Axes objects are from the Artist base class.

Remember, an artist is something that uses a renderer to draw on a canvas.

3 layers of matplotlib

- "matplotlib.backend_bases.FigureCanvas is the area onto which the figure is drawn
  - matplotlib.backend_bases.Renderer is the object which knows how to draw on the FigureCanvas
    - matplotlib.artist.Artist is the object that knows how to use a renderer to paint onto the canvas."



What you'll be working with 95% of the time

33 https://matplotlib.org/stable/tutorials/intermediate/artists.html

https://www.svgrepo.com/svg/307645/art-artist-craft-canvas

Stepping back a bit, there are three main layers of the matplotlib API.

The figureCanvas is the area onto which the figure is drawn

The Renderer is the object that knows how to draw on the figure canvas

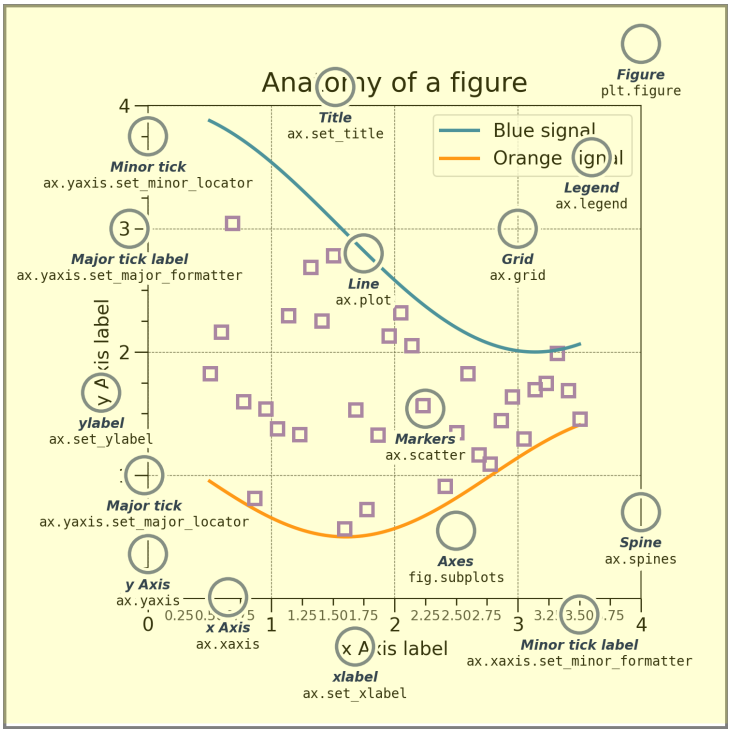
The artist is the object that knows how to use a renderer to paint on the canvas

You'll be interacting with Artist objects 95% of the time, and won't have to worry too much about what goes on behind the scenes.

But let's take a look, just so you know what's there

2 types of artists

1) Primatives: things to draw
   - Line2D
   - Rectangle
   - Text
   - AxesImage
2) Containers: where to draw them
   - Figure
   - Axes
   - Axis



There are two main types of artists: primatives and containers.

Primatives are basic graphical objects
* like lines, rectangles, text, and images

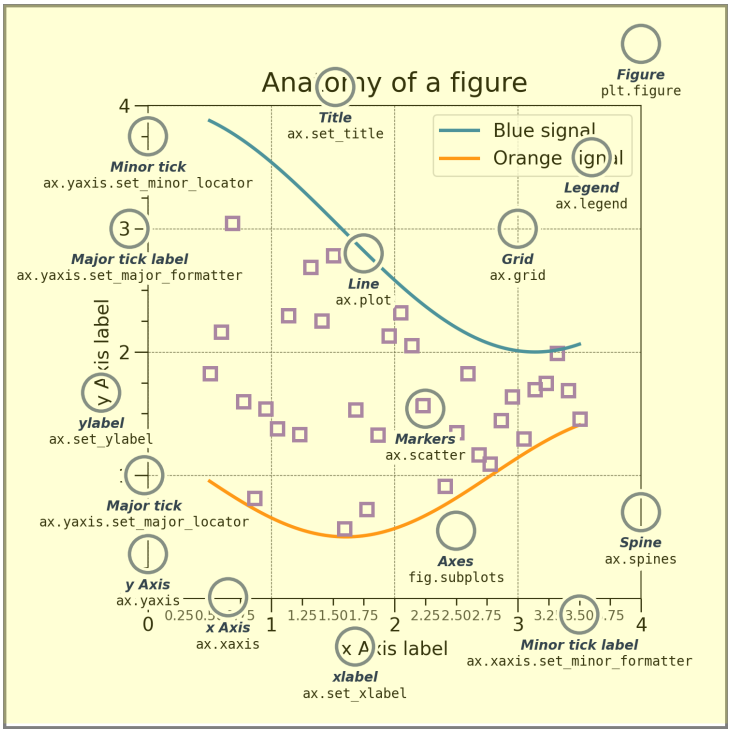
Containers define where to draw the rectangles, etc.

The Figure includes the entire figure area

2 types of artists

1) Primatives: things to draw
   - Line2D
   - Rectangle
   - Text
   - AxesImage

2) Containers: where to draw them
   - Figure
   - Axes
   - Axis



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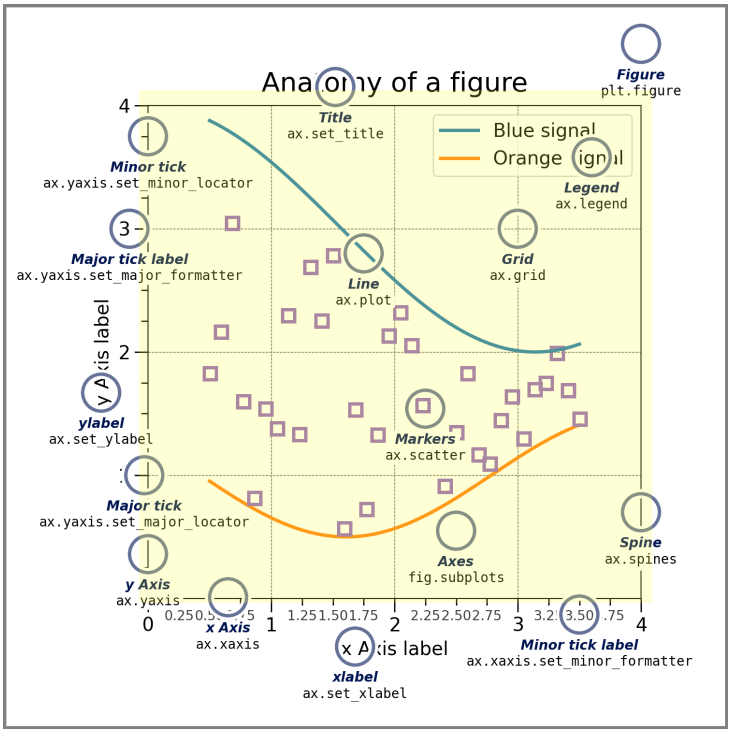
Primatives are basic graphical objects
* like lines, rectangles, text, and images

Containers define where to draw the rectangles, etc.

The Figure includes the entire figure area

2 types of artists

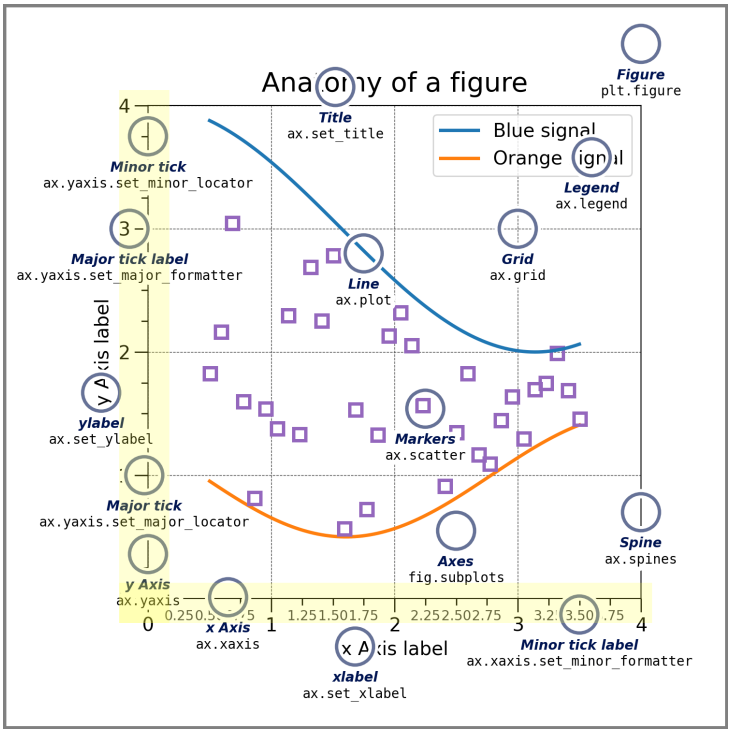
1) Primatives: things to draw
   - Line2D
   - Rectangle
   - Text
   - AxesImage
2) Containers: where to draw them
   - Figure
   - Axes
   - Axis



The Axes (with an es) includes all the individual axes and the main plotting area

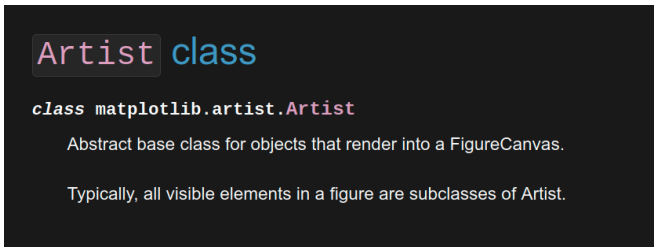
2 types of artists

1) Primatives: things to draw
   - Line2D
   - Rectangle
   - Text
   - AxesImage
2) Containers: where to draw them
   - Figure
   - Axes
   - Axis



The Axis (with an is) is one individual axis, like the x axis

What actually is an Artist??



So, what actually is an artist?

In the docs, Matplotlib describes it as an...

What actually is an Artist??

`Artist` class

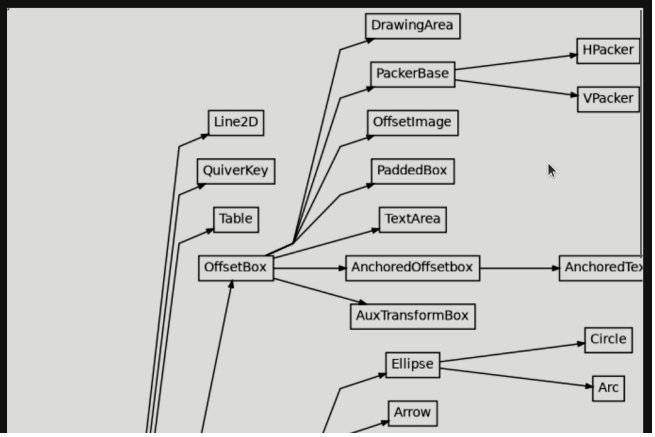
class **matplotlib.artist.Artist**

Abstract base class for objects that render into a FigureCanvas.

Typically, all visible elements in a figure are subclasses of Artist.

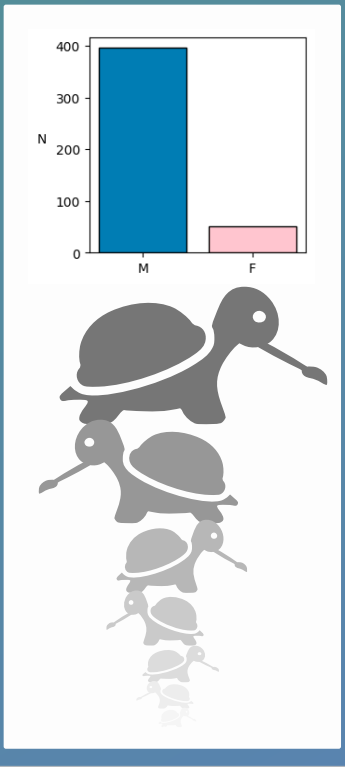
`matplotlib.artist`

Inheritance Diagrams



TL;DR for our purposes,

it’s Artists all the way down



But basically, for our purposes, it’s artists all the way down.

We’ll usually be interacting with artists.

Axes helper methods for plot types

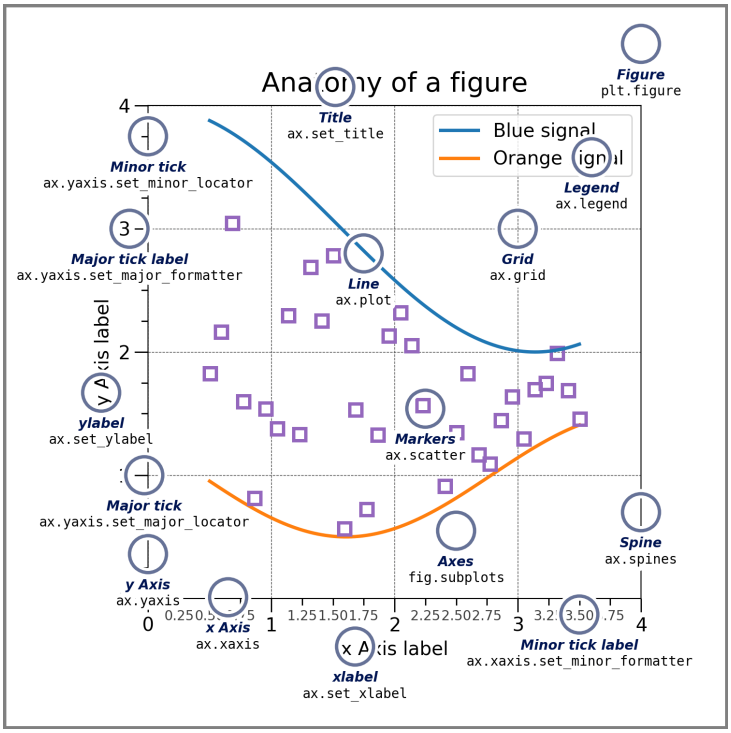
- ax.plot() # line graph
- ax.bar() # bar graph
- ax.imshow() # image

So you don’t have to construct figures from shapes

On the Axes artis, there are helper methods for different plot types, for example, the line and bar graphs, or showing an image or heatmap.

This is very helpful – hence the name helper method - so you don’t have to construct figures from basic lines and shapes.

Helper methods for customization

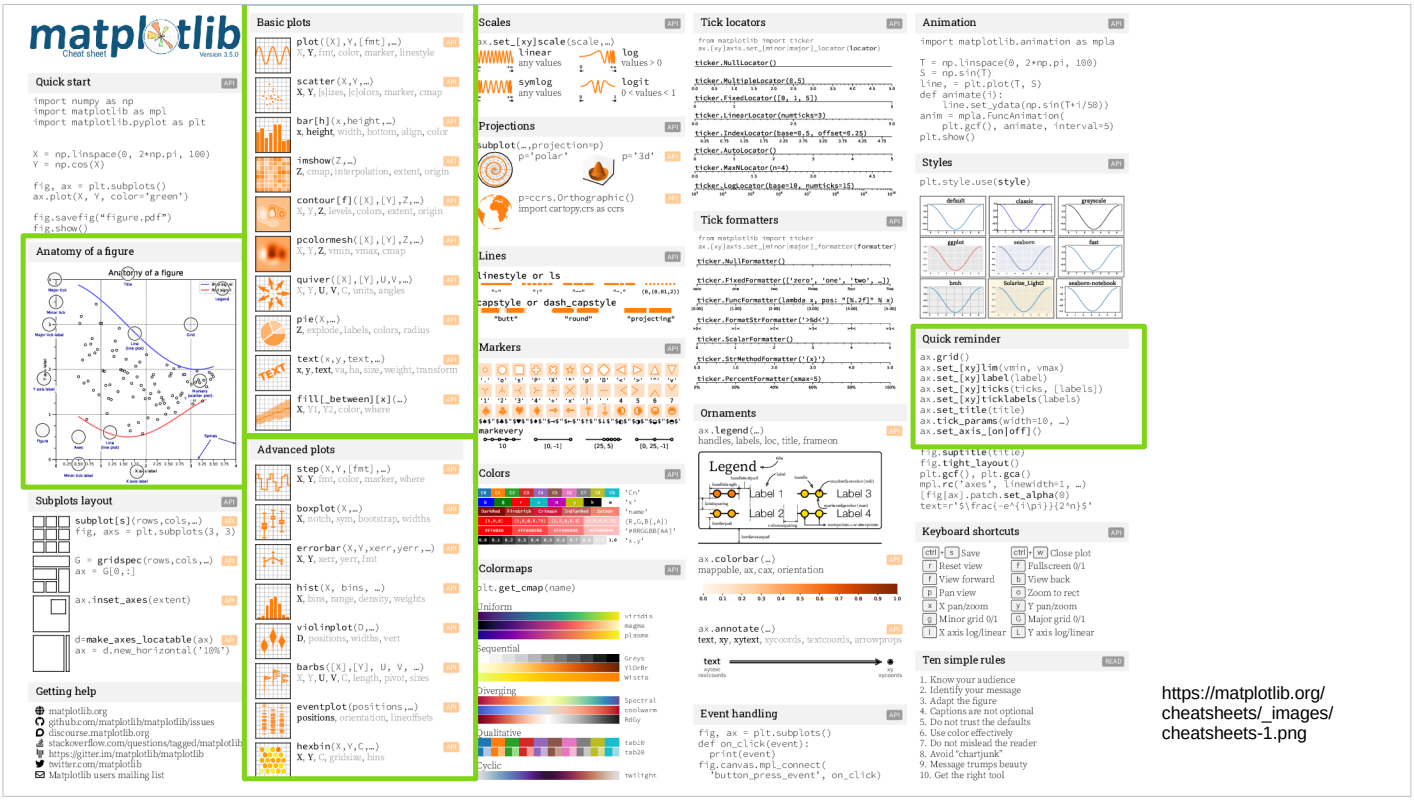


https://matplotlib.org/stable/tutorials/introductory/quick_start.html#sphx-glr-tutorials-introductory-quick-start-py

There are also helper methods for customizing charts.

Here, you can see all the anatomy of a figure, with the labels being the helper methods for editing different aspects of the figure.

Remember, this is the explicit way of coding, where you're interacting directly with the Axes artists objects



https://matplotlib.org/cheatsheets/_images/cheatsheets-1.png

Here we see a matplotlib cheatcheet, which can be found in their documentation

*I've highlighted where to find the helper methods for different basic plot types

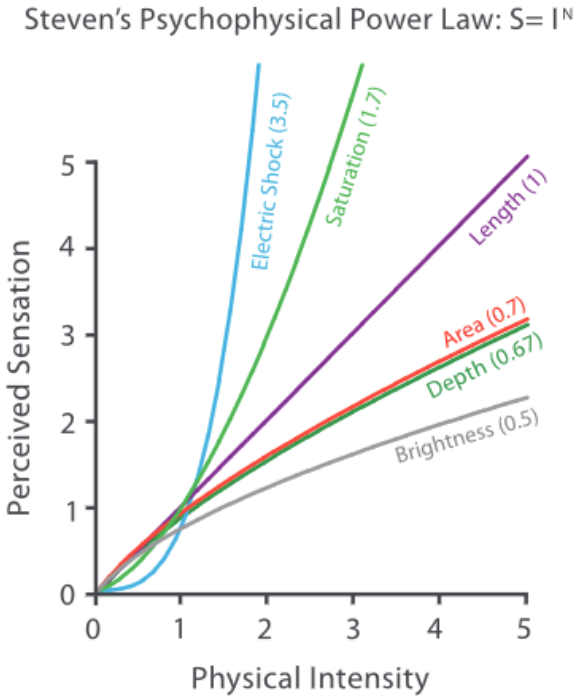
*And the more advanced plots.

*Here we have the anatomy of a figure again, but they label parts with the names instead of the commands for changing them.

But you can find the commands here *, and they're fairly intuitive from their names.

Live coding

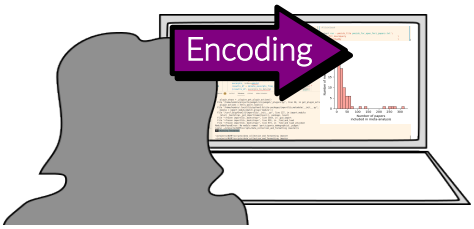
- Replicating this figure



Munzner, T. (2014). Visualization analysis and design. CRC press.

MATPLOTLIB DEMO

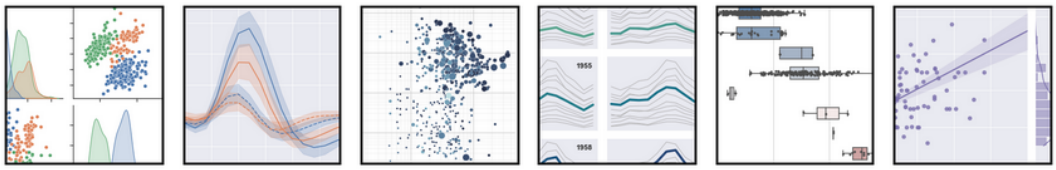
Re-create line graph from last lecture



To program a figure efficiently and reproducibly, we should understand

- Some computer graphics
  - How the computer makes figure
- Matplotlib basics
  - What you and matplotlib need to do
- Higher-level libraries
  - More complex visualizations

seaborn: statistical data visualization

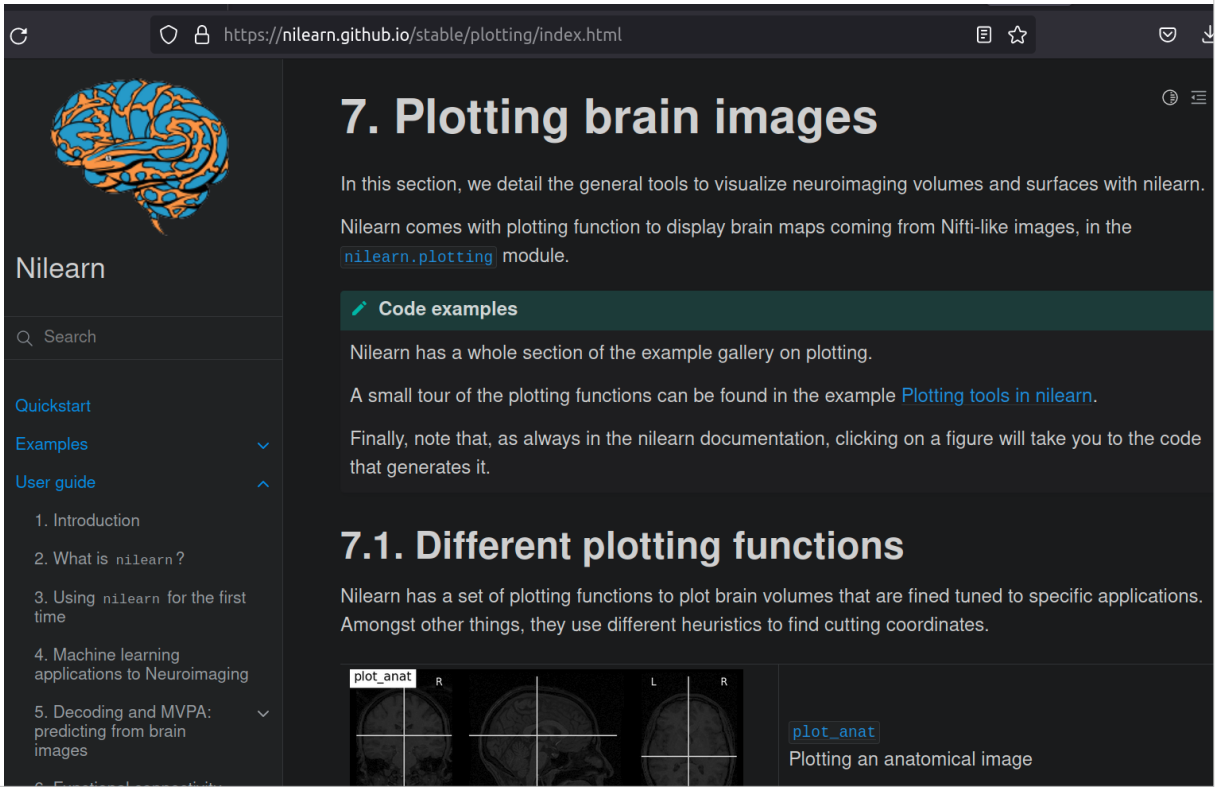


Seaborn is a Python data visualization library based on matplotlib. It provides a high-level interface for drawing attractive and informative statistical graphics.

Features of Seaborn

- Works well with **pandas.DataFrame()** objects
- Default colors are from **perceptually uniform** pallettes
- Can **calculate stats** as well as visualize
- More easily visualize **complex data** (e.g, multivariate)

Nilearn


https://nilearn.github.io/stable/plotting/index.html
Nilearn
Search
Quickstart
Examples
User guide
1. Introduction
2. What is nilearn?
3. Using nilearn for the first time
4. Machine learning applications to Neuroimaging
5. Decoding and MVPA: predicting from brain images
7. Plotting brain images
In this section, we detail the general tools to visualize neuroimaging volumes and surfaces with nilearn.
Nilearn comes with plotting function to display brain maps coming from Nifti-like images, in the nilearn.plotting module.
Code examples
Nilearn has a whole section of the example gallery on plotting.
A small tour of the plotting functions can be found in the example Plotting tools in nilearn.
Finally, note that, as always in the nilearn documentation, clicking on a figure will take you to the code that generates it.
7.1. Different plotting functions
Nilearn has a set of plotting functions to plot brain volumes that are fined tuned to specific applications. Amongst other things, they use different heuristics to find cutting coordinates.
plot_anat
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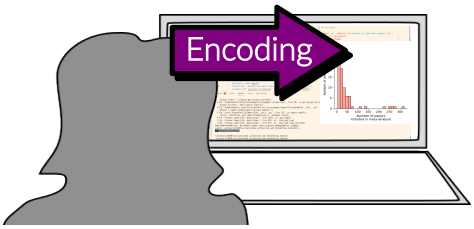
plot_anat
Plotting an anatomical image



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