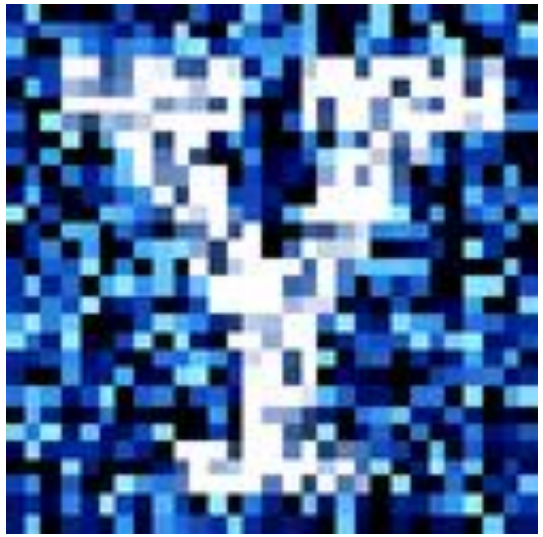
YData: Introduction to Data Science



Class 07: Array computation continued

Overview

Quick review of:

- NumPy arrays
- Numerical computations

More numpy:

- Boolean masking
- Higher dimensional numerical arrays
- Image manipulation

If there is time:

- Tuples and dictionaries
- Introduction to pandas Series and DataFrames

Announcement: practice session locations

Thursdays

- 5 pm to 6 pm
- 10 Hillhouse Avenue, Dunham Lab, Room 120

Fridays

- 2 pm to 3 pm
- 3 pm to 4 pm
- 4 pm to 5 pm
- 493 College Street, Room 106

Announcement: Homework 3

Homework 3 is due on Gradescope on Sunday September 22nd at 11pm

- **Be sure to mark each question on Gradescope!**

Notes:

- On problem 3, if the images are not showing up make sure to run the cells where the images are embedded
  - If you figure it out, help other people on Ed!

Quick review: ndarrays

The *NumPy package* efficiently stores and processes data that is all of the same type using ***ndarray***

```
import numpy as np

my_array = np.array([1, 2, 3])   # creating an ndarray
my_array[0]                      # accessing the 0th element

my_array.dtype             # get the type of elements
my_array.shape             # get the dimension
my_array.astype('str')     # convert to strings

sequential_nums = np.arange(1, 10)    # creates numbers 1 to 9
```

Quick review: functions on numerical arrays

The NumPy functions:

- np.sum()
- np.max(), np.min()
- np.mean(), np.median()
- np.diff() # takes the difference between elements
- np.cumsum() # cumulative sum

There are also "broadcast" functions that operate on all elements in an array

- my_array = np.array([12, 4, 6, 3, 4, 3, 7, 4])
- my_array * 2

- my_array2 = np.array([10, 9, 2, 8, 9, 3, 8, 5])
- my_array - my_array2

Warm up: Number journey!

Please download the class 6 Jupyter notebook

- import YData
- YData.download_class_code(6)

Please complete the following number journey in the class 6 notebook:

- **Step 1**: Create an ndarray called *my_array* that has the numbers: 12, 4, 6, 3, 4, 3, 7, 4
- **Step 2:** Create an array *my_array2* that consists of the values of *my_array* minus the mean value of *my_array*.
- **Step 3:** Create *my_array3* which is a Boolean array that has True values for the positive values in *my_array2*
- **Step 4:** Calculate and print the total number of True values in *my_array3*

Let's take a number journey now…

Boolean masking

Boolean masking

We can also use Boolean arrays to return values in another array

- This is called "Boolean masking", "Boolean subsetting" or "Boolean indexing"

```
my_array = np.array([12, 4, 6, 3])
boolean_mask = np.array([False, True, False, True, True])

smaller_array = my_array[boolean_mask]
```

This can be useful for calculating statistics on data that meet particular criteria:

- `np.mean(my_array[my_array < 5])  # what does this do?`

Boolean masking

Suppose you wanted to get the average movie revenue for movies that passed the Bechdel test

- domgross_2013: Movie revenue
- bechdel: whether a movie passed the Bechdel test

Can you do it?

Let's explore this in Jupyter!

Percentiles

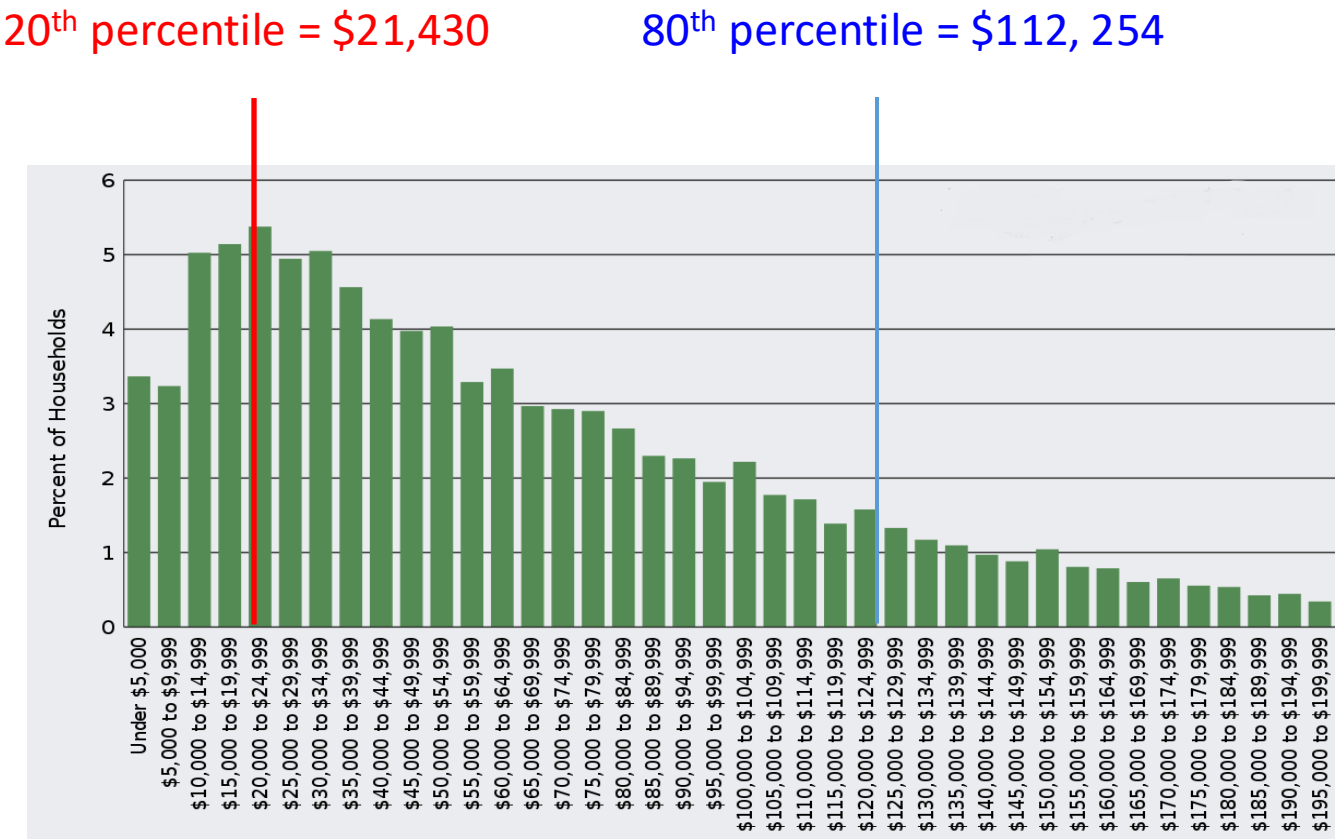
Percentiles

The **Pth percentile** is the value of a quantitative variable which is greater than P percent of the data

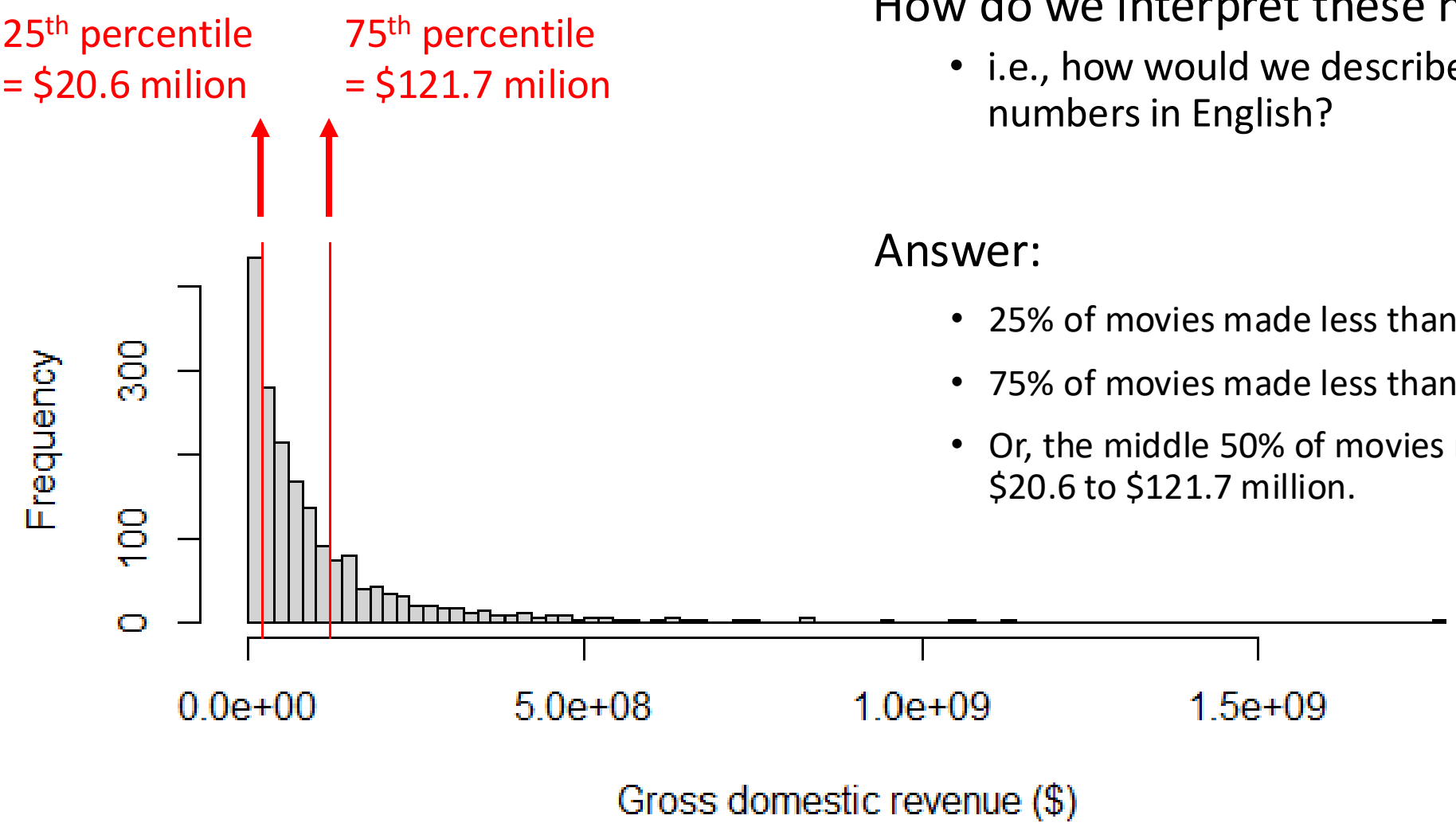
For the US income distribution what are the 20th and 80th percentiles?

We can calculate percentiles using np.percentile()

np.percentile(data, [20, 80])



Movie revenue percentiles



How do we interpret these numbers?

- i.e., how would we describe these numbers in English?

Answer:

- 25% of movies made less than $20.6 million
- 75% of movies made less than $121.7 million
- Or, the middle 50% of movies made between $20.6 to $121.7 million.

Five Number Summary

Five Number Summary = (minimum, Q_1, median, Q_3, maximum)

Q_1 = 25^{th} percentile (also called 1^{st} quartile)

Q_3 = 75^{th} percentile (also called 3^{rd} quartile)

Roughly divides the data into fourths

Range and Interquartile Range

Range = maximum – minimum

Interquartile range (IQR) = $Q_3 - Q_1$

Let's calculate these statistics on Bechdel movie revenue data!

Box plots and outliers

Detecting of outliers

As a rule of thumb, we call a data value an **outlier** if it is:

Smaller than: Q_1 - 1.5 * IQR

Larger than: Q_3 + 1.5 * IQR

Box plots

A **box plot** is a graphical display of the five-number summary and consists of:

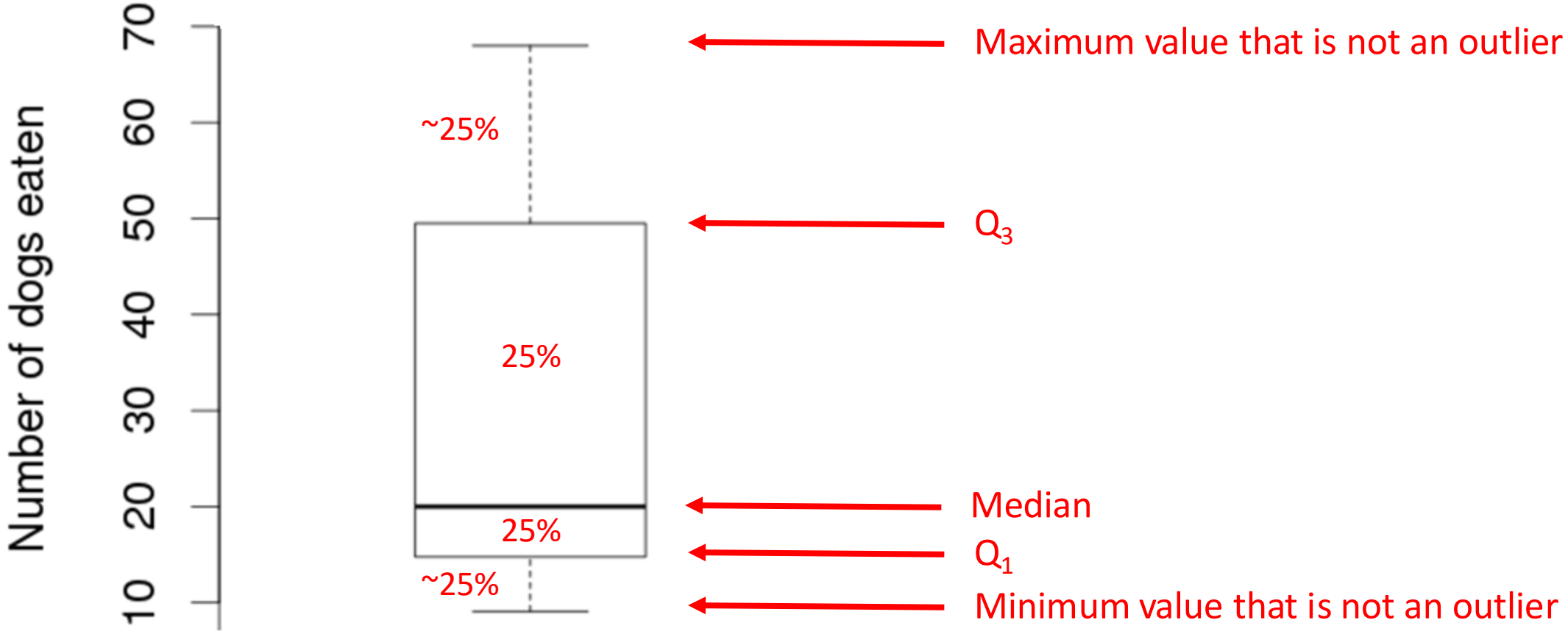
1. Drawing a box from Q_1 to Q_3

2. Dividing the box with a line (or dot) drawn at the median

3. Draw a line from each quartile to the most extreme data value that is not and outlier

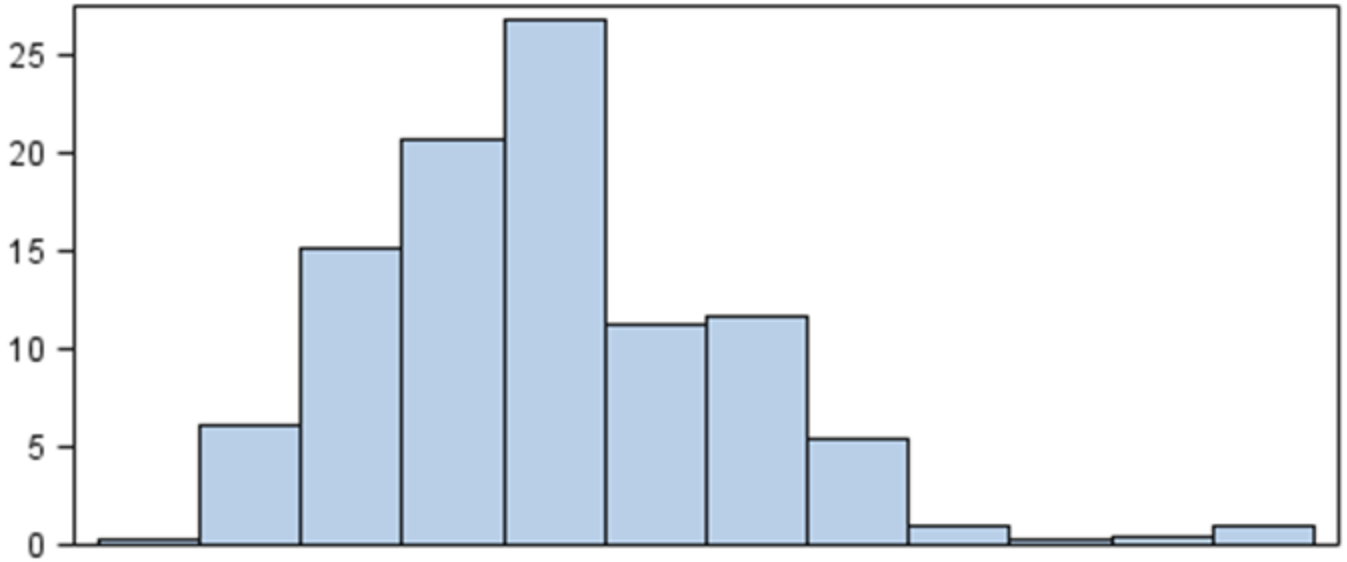
4. Draw a dot/asterisk for each outlier data point.

Box plot of the number of hot dogs eaten by the men's contest winners 1980 to 2010



Matplotlib: `plt.boxplot(data, labels)`

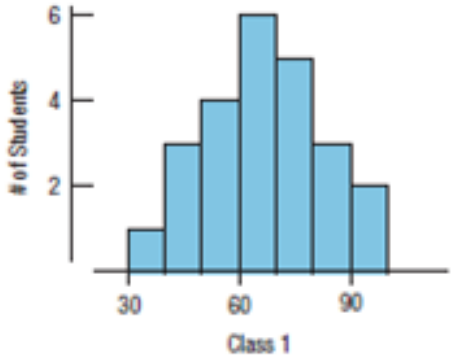
Box plots extract key statistics from histograms



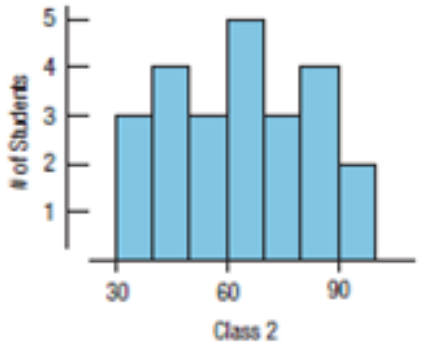
Box plots extract key statistics from histograms

Question: which Box plot goes with which histogram?

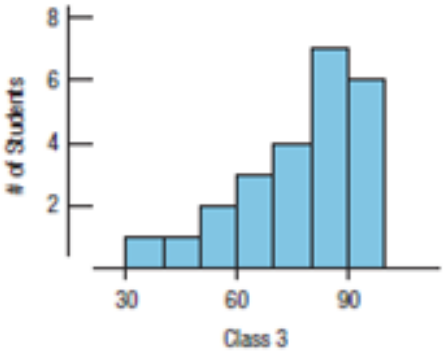
Histogram 1

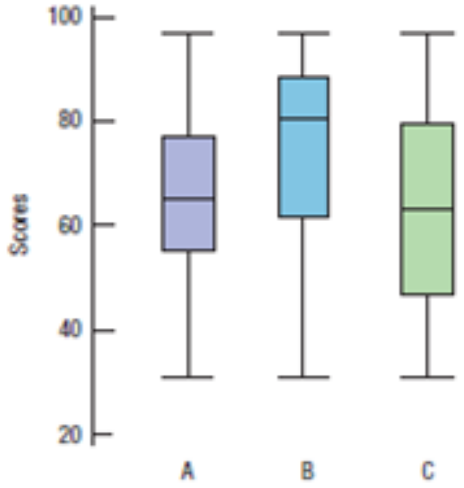


Histogram 2



Histogram 3





Box plots extract key statistics from histograms

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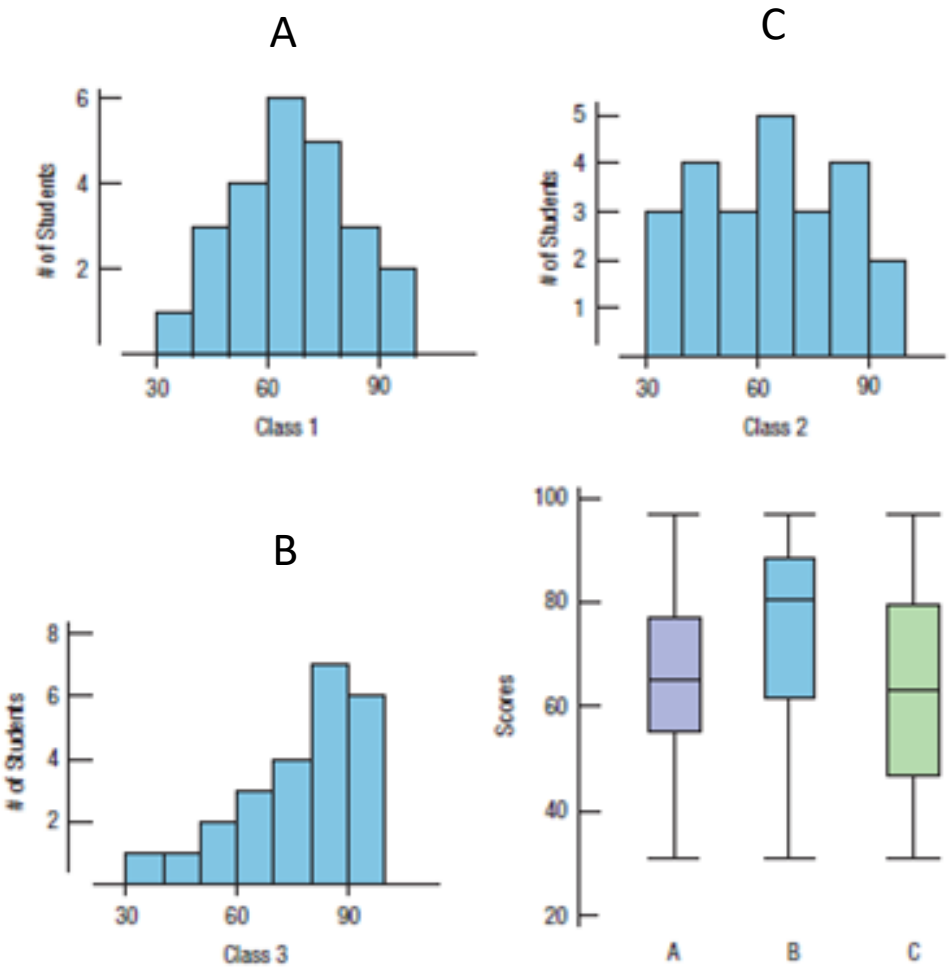
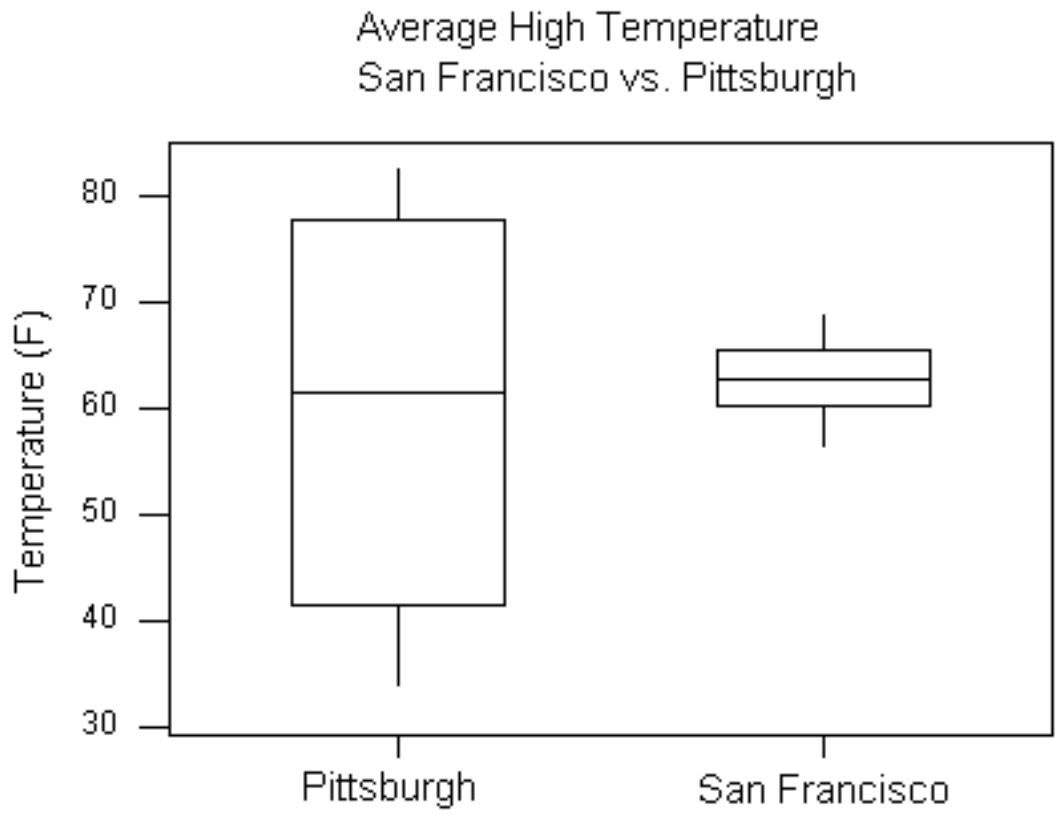


Comparing quantitative variables across categories

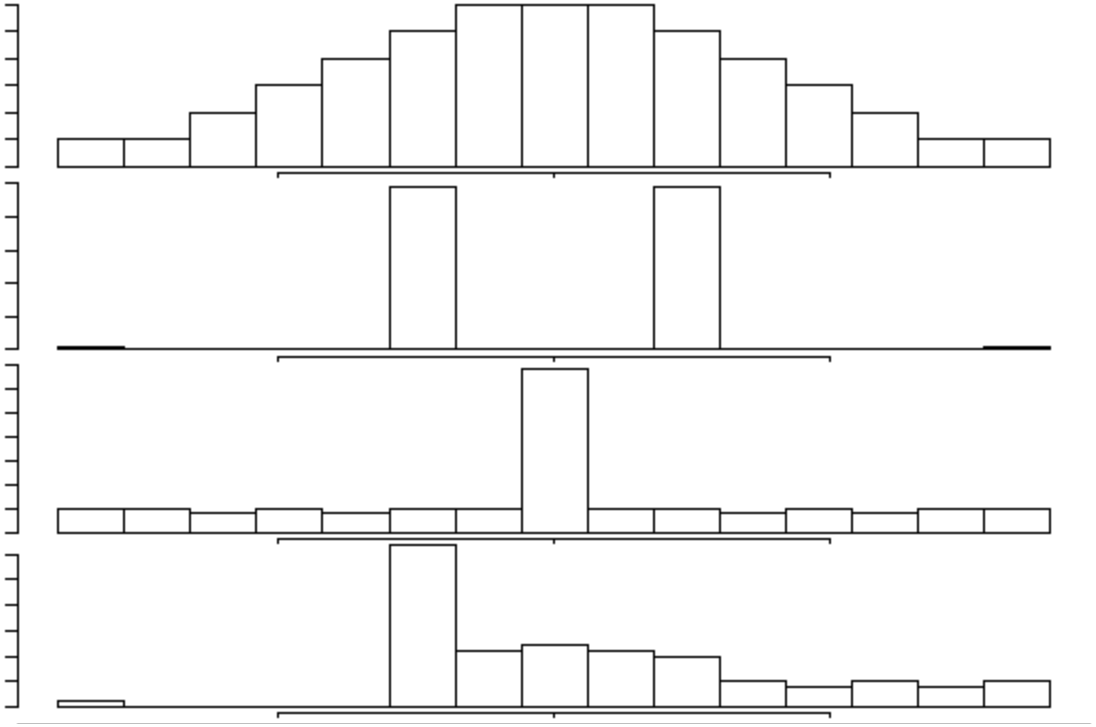
Often one wants to compare quantitative variables across categories

Side-by-Side graphs are a way to visually compare quantitative variables across different categories




```
plt.boxplot([data1, data2],   labels = ["name 1", "name 2"])
```

Box plots don’t capture everything



Do you think the box plots for these distributions look similar?

Let's explore side-by side boxplots on the Bechdel data to try to see if movies that pass the Bechdel test make a larger profit!

Boolean arrays

It is often to compare all values in an ndarray to a particular value

- my_array = np.array([12, 4, 6, 3, 4, 3, 7, 4])
- my_array < 5
  - array([False, True, False, True, True, True, False, True])

This can be useful for calculating proportions

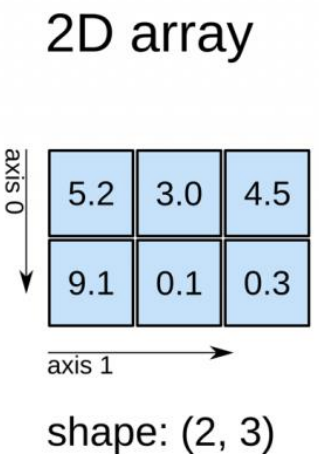
- True == 1 and False == 0
- Taking the sum of a Boolean array gives the total number of True values
- The number of True 's divided by the length is the proportion
  - Or we can use the np.mean() function

Categorical Variable

PLAYER	POSITION	TEAM	SALARY
str	str	str	f64
"Paul Millsap"	"PF"	"Atlanta Hawks"	18.671659
"Al Horford"	"C"	"Atlanta Hawks"	12.0
"Tiago Splitter..."	"C"	"Atlanta Hawks"	9.75625
"Jeff Teague"	"PG"	"Atlanta Hawks"	8.0
"Kyle Korver"	"SG"	"Atlanta Hawks"	5.746479

$$\text{Proportion centers} = \frac{\text{number of centers}}{\text{total number}}$$

Higher dimensional arrays



We can make higher dimensional arrays

- (matrices and tensors)

```
my_matrix = np.array([[1, 2, 3], [4, 5, 6], [7, 8, 9]])
my_matrix
```

We can slice higher dimensional array

- my_matrix[0:2, 0:2]

We can apply operations to rows, columns, etc.

- np.sum(my_matrix, axis = 0) # sum the values down rows

Let's explore this in Jupyter!

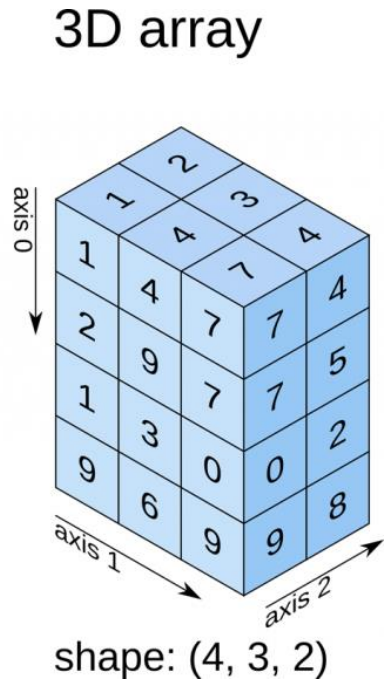


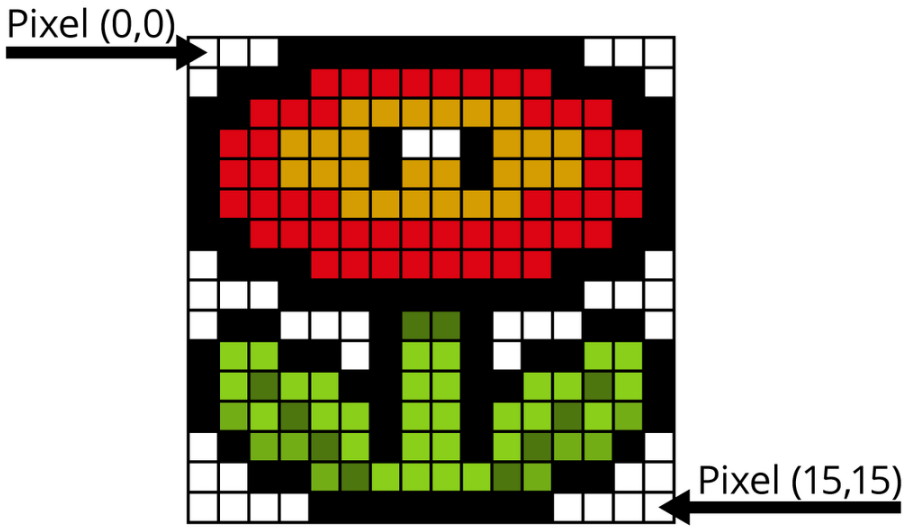
Image processing

We can use higher dimensional numpy arrays to store and manipulate images

Digital images are made up of pixels

Each pixel consists of a red (R), green (G), and Blue (B) color channel

- i.e., we have an “RGB image”



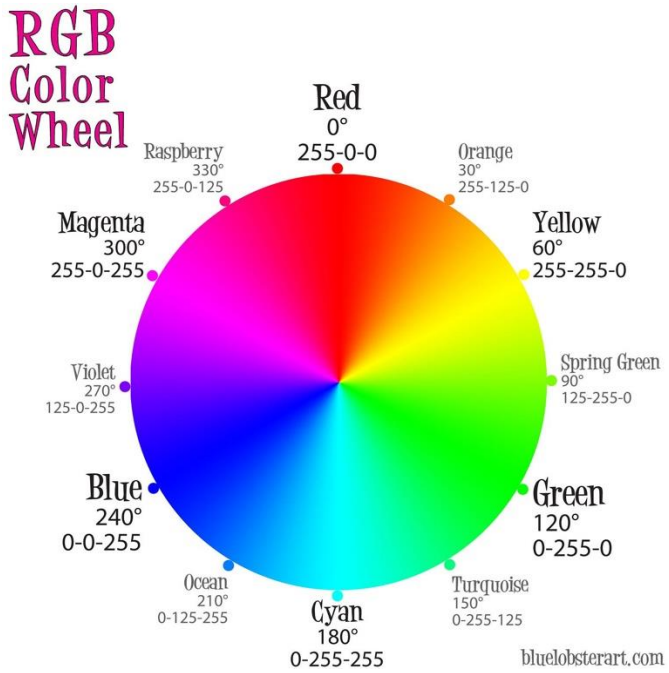
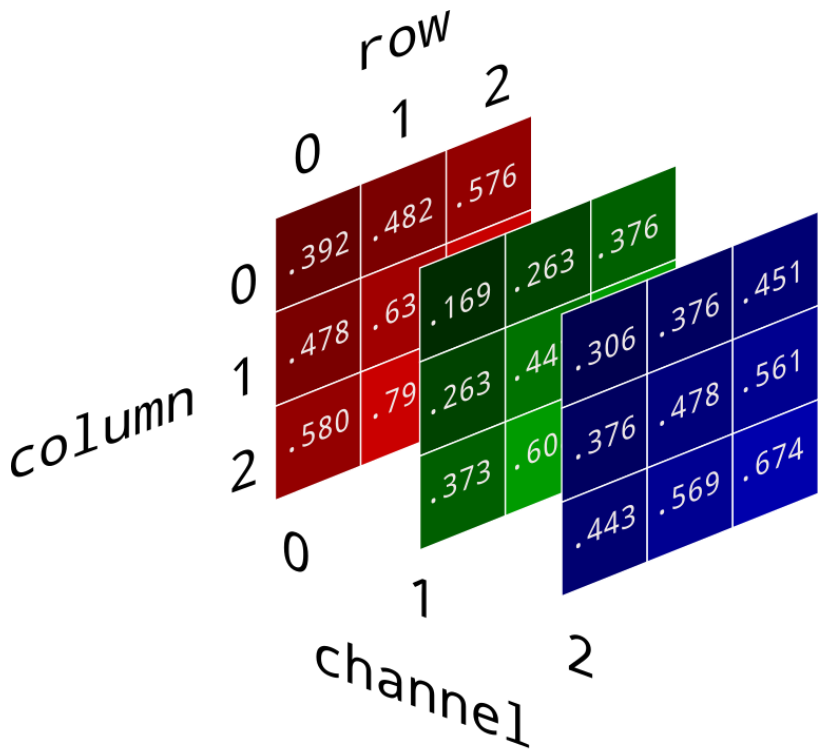


Image processing

We can use 3-dimemsional numerical arrays to store digital RGB images

We can use masking and other array operations to process images



Let's explore this in Jupyter!

Tuples and Dictionaries

Tuples

Tuples are like lists but they are immutable; i.e., once they are created we can't change the values in a tuple.

We can create a tuple using:

- my_tuple = (10, 20, 30)

Like lists, we can access elements of tuples using square brackets

- my_tuple[1]

We can't change values in tuples:

- my_tuple[1] = 50 # Error!!!

Tuples

We can assign values in tuples into regular names using “tuple unpacking”

- my_tuple = (10, 20, 30)
- val1, val2, val3 = my_tuple
- val3

Let's explore this in Jupyter!

Dictionaries

Dictionaries allow you to look up ***values*** based on a ***key***

- i.e., you supply a “key” and the dictionary returns the stored value

We can create dictionaries using the syntax:

- my_dict = { 'key1': 5, 'key2': 20}

We can retrieve dictionary values by supplying a key using square brackets []

- my_dict['key2']

Let's explore this in Jupyter!

Series and Tables

Pandas: Series and DataFrames

"pandas is an open source, BSD-licensed library providing high-performance, easy-to-use data structures and data analysis tools for the Python programming language."

There are two main data structures in pandas:

- **Series**: represent one-dimensional data
- **DataFrames**: represent data tables
  - i.e., relational data

pandas Series

pandas Series are: One-dimensional ndarray with axis labels

- (including time series)

Example: egg _prices

DATE	
1980-01-01	0.879
1980-02-01	0.774
1980-03-01	0.812

Index

values

pandas Series

We can access row elements by Index ***name*** using **.loc**

- egg_prices.loc["1980-01-01"]

We can access row elements by Index ***number*** using **.iloc**

- egg_prices.iloc[0]

Let's explore this in Jupyter!

pandas DataFrames

Pandas DataFrame hold Table data

This is one of the most useful formats to extract insights from datasets

Often we read data into a DataFrame using:

- pd.read_csv("file.csv")

Variables

Cases

PLAYER	POSITION	TEAM	SALARY
str	str	str	f64
"Paul Millsap"	"PF"	"Atlanta Hawks"	18.671659
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