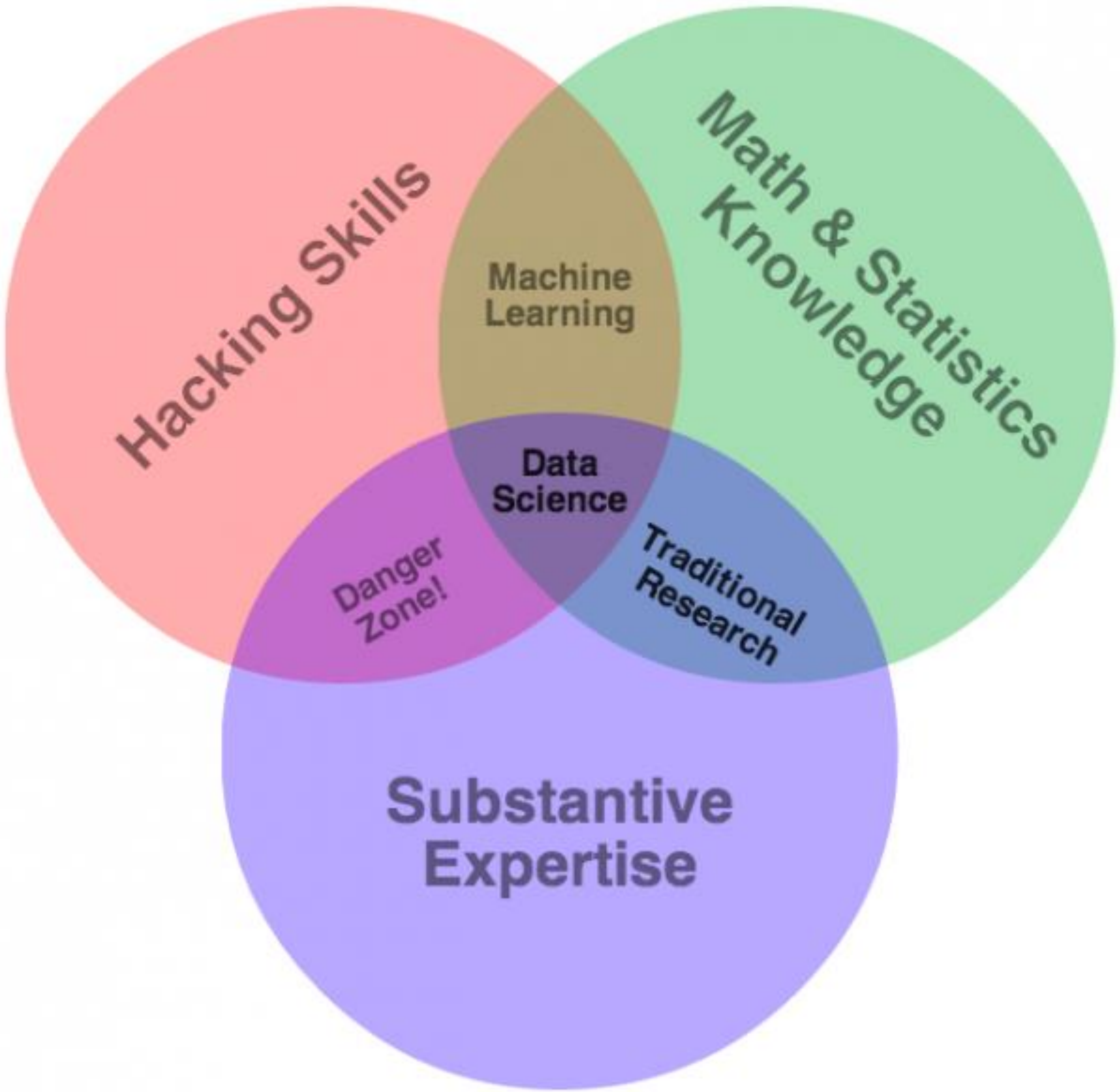
UNIVERSITY of WASHINGTON

Data Science UW Methods for Data Analysis

Introduction and Data Exploration
Lecture 1
Nick McClure


Hacking Skills
Math & Statistics Knowledge
Machine Learning
Data Science
Danger Zone!
Traditional Research
Substantive Expertise

Course Purpose

- This course isn’t designed to make you an expert
- This course is designed to point you in the right direction
- Course Objectives:
  - Statistical tools for data exploration
  - The use of R to apply these tools to real data
  - Using inferential statistics to interrogate data
  - Testing and experimental design
  - Bayesian and classical statistics
- See syllabus for more information:
  - http://nfmcclure.github.io/DataScience350/

Course Requirements and Grading

This course will be graded by attendance, homework, and an individual project.

- Attendance: You MUST attend at least 8 out of 10 classes. This is non-negotiable, a UW requirement.
- Homework must be completed by the start of the next class. (Assigned weeks 1-8).
  - Returned as a 0,1, or 2.
    - 0 = Not done or a major part wrong/missing.
    - 1 = Completed, but missing or got wrong 1 or 2 parts.
    - 2 = Completed with at most minor issues. Demonstrates full understanding of subject.
- Individual Project: Due at the start of the last class.
  - Counts as 8 points.

Course Requirements and Grading

There is a total of 24 possible points. (16 pts for hmk + 8 project)

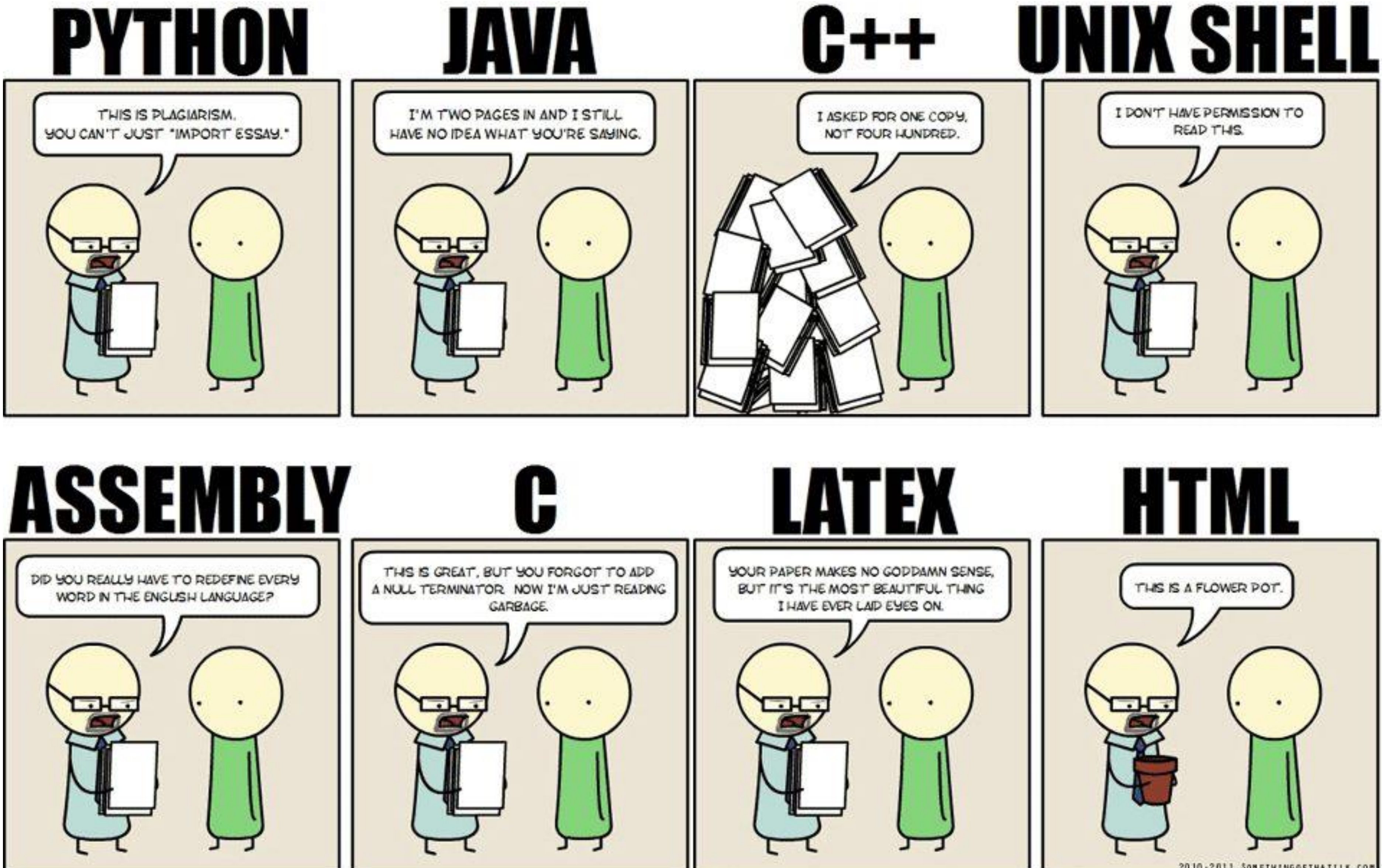
- Must get 18 total points to pass.
- 4 homework assignments must be made in a production level script (every other one = 2,3,5,7).
- 4 homework assignments are regular script writing (every other one = 1,4,6,8).
- The individual project must be production level code.

Office Hours and Contact Information

- List of ways to contact me:
  - nickmc@uw.edu
- When I’m *usually* available:
  - Off/on for simple things during work. (M-F 8am-5pm PST)
  - Mon-Wed 7pm-10pm.
  - Sunday various afternoon/evening times.

Emergency contact: 402-980-3192

Review


PYTHON
THIS IS PLAGIARISM. YOU CAN'T JUST "IMPORT ESSAY."
JAVA
I'M TWO PAGES IN AND I STILL HAVE NO IDEA WHAT YOU'RE SAYING.
C++
I ASKED FOR ONE COPY, NOT FOUR HUNDRED.
UNIX SHELL
I DON'T HAVE PERMISSION TO READ THIS.
ASSEMBLY
DID YOU REALLY HAVE TO REDEFINE EVERY WORD IN THE ENGLISH LANGUAGE?
C
THIS IS GREAT, BUT YOU FORGOT TO ADD A NULL TERMINATOR. NOW I'M JUST READING GARBAGE.
LATEX
YOUR PAPER MAKES NO GODDAMN SENSE, BUT IT'S THE MOST BEAUTIFUL THING I HAVE EVER LAID EYES ON.
HTML
THIS IS A FLOWER POT.
2010-2011 SOMETHINGOFTHATILK.COM

R Review

- R resources:
  - R page:
    - http://www.r-project.org/other-docs.html
  - Stackoverflow:
    - http://www.stackoverflow.com
  - 'Little' R intro:
    - http://cran.r-project.org/doc/contrib/Rossiter-RIntro-ITC.pdf
  - Quick R:
    - http://statmethods.net/
  - There are many tutorials available online, e.g.,
    - http://cyclismo.org/tutorial/R/
  - Notes from a two day course at UW:
    - http://faculty.washington.edu/tlumley/Rcourse/
  - Google's Style Guide:
    - http://google-styleguide.googlecode.com/svn/trunk/google-r style.html

Statistics Review

- Familiar Concepts:
  - Discrete vs. Continuous Distributions
  - Probability
  - y = mx + b vs $\bar{Y} = \mathbf{M} \cdot \bar{X} + \mathbf{B}$
- This area is the emphasis of the course.

SQL Review

- SQL (to know):
  - Create tables
  - Drop tables
  - Joins (Inner, outer, right, left)
  - Temp tables
  - Coalesce, Cast, Case

Counting Review

- Factorials
  - Count # ways to order N things = N!
- Permutations
  - Count # of ways to **order** R things from N things = N!/(N-R)!
  - Ordering matters
  - P(N,R)
- Combinations
  - Count # of ways to **group** R things from N things = N!/(R!(N-R!))
  - Ordering doesn't matter
  - C(N,R) or $\binom{N}{R}$
- We will talk about this in depth next class.

Data Distributions (Discrete)

- Discrete Distribution Properties
  - Sum of all events must equal 1.
  - Probability of event equal to value of distribution at point.
  - No Negative values or values greater than 1.

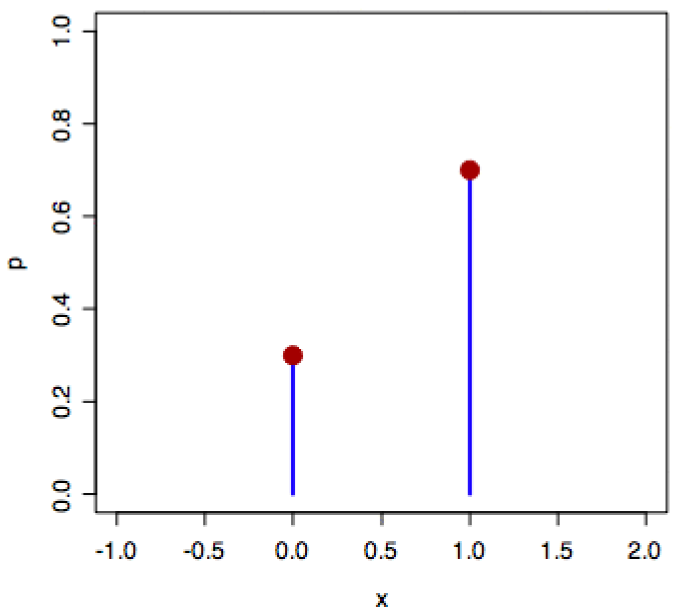
Data Distributions (Discrete)

> Bernoulli (1 event, e.g.: coin flip)

$$P(x) = \begin{cases} p \; if \; x = 1 \\ (1-p) \; if \; x = 0 \end{cases}$$

$$P(x) = p^x (1-p)^{(1-x)} \quad x \in \{0,1\}$$

- Mean = p
- Variance = p(1-p)



Data Distributions (Discrete)

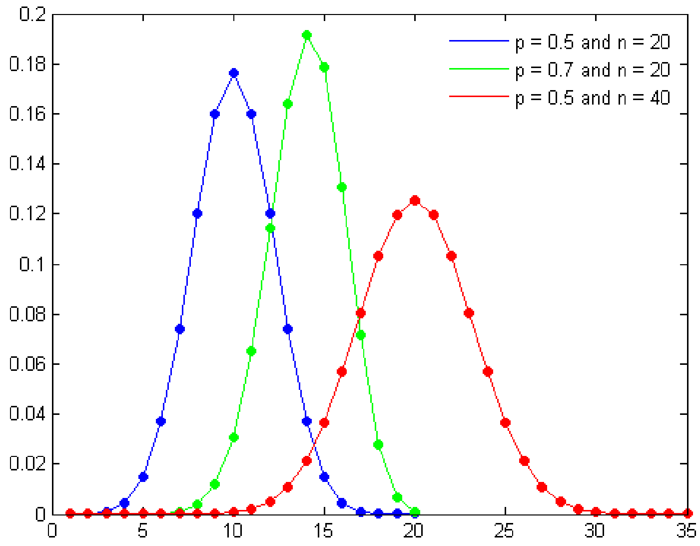
> Binomial (Multiple Bernoulli's Events)

- Multiple Independent events = Product of Bernoulli Probabilities

$$P(x|N,p) = \binom{N}{x} p^x (1-p)^{(N-x)}$$

- Mean = np
- Variance = np(1-p)

Note: for larger n, we approximate this by a normal distribution.



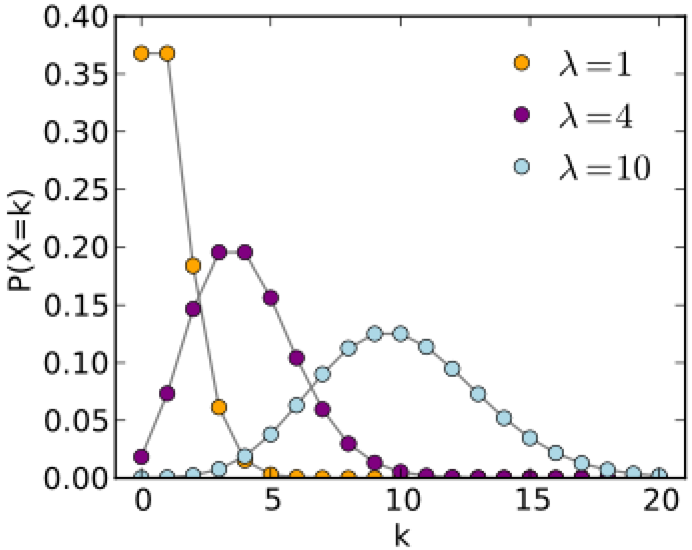
Data Distributions (Discrete)

> Poisson (Count of number of events in a time span)

$$P(x|\lambda) = \frac{\lambda^x}{x!} e^{-\lambda}$$

- Mean = λ
- Variance = λ

Interpret as the rate of occurrence of an event is equal to lambda in a finite period of time.



Data Distributions (Continuous)

> Continuous Distribution Properties
  - Area under the curve must be equal to 1.
  - Probability of event equal to AREA under curve.
  - No negative values.
  - Probability of a single, exact value is 0.

Data Distributions (Continuous)

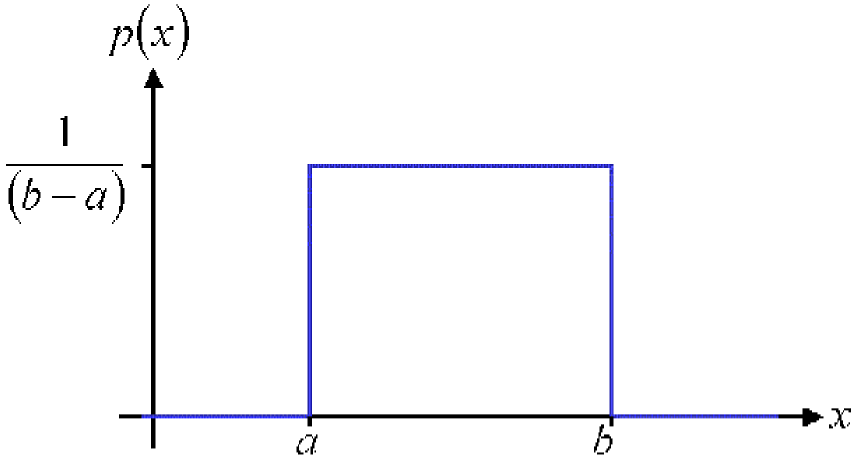
> Uniform (flat, bounded)

$$P(x) = \begin{cases} \dfrac{1}{(b-a)} \; if \; a \leq x \leq b \\ 0 \; if \; x < a \; or \; x > b \end{cases}$$

> Very useful for parameter priors. (future discussion)

– Mean=(a+b)/2

– Variance=(1/12)(b-a)^2

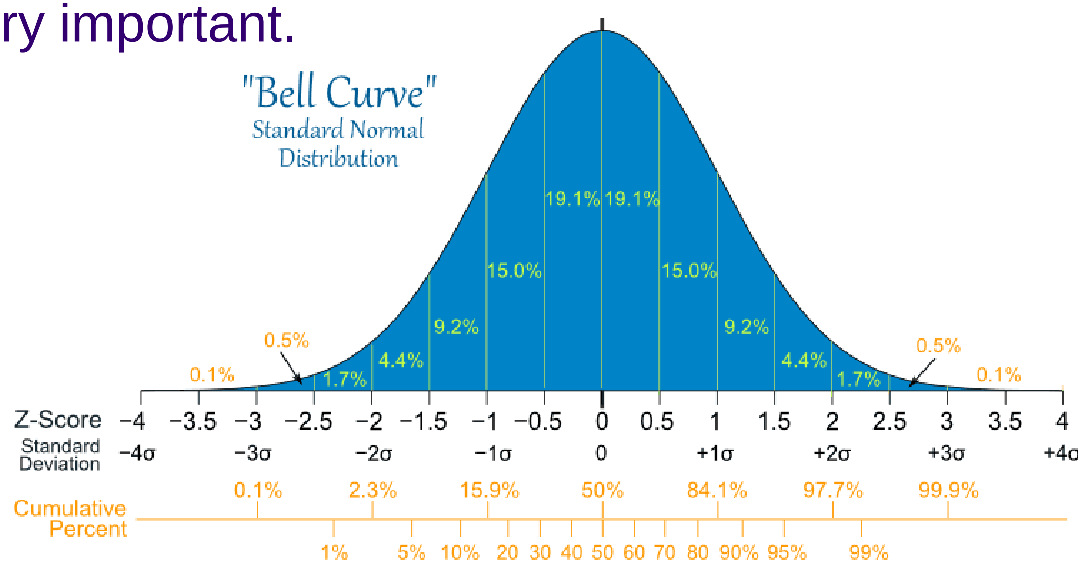


Data Distributions (Continuous)

> Normal (Gaussian) distribution
  - Most common and occurs naturally.
  - Defined by a mean and variance only. (standard = N(0,1))

$$P(x) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{\frac{-(x-\mu)^2}{2\sigma^2}}$$

  - Has very nice properties.
  - Tests for normality are very important.



Data Distributions (Continuous)

- Student's T (normal for small samples)
  - Important for hypothesis testing smaller sample sizes.
  - Used for:
    - Testing of mean value when st. dev. is unknown.
    - Testing difference between two distribution means.
  - Looks very similar to the normal distribution.

Data Exploration (Descriptive Statistics)

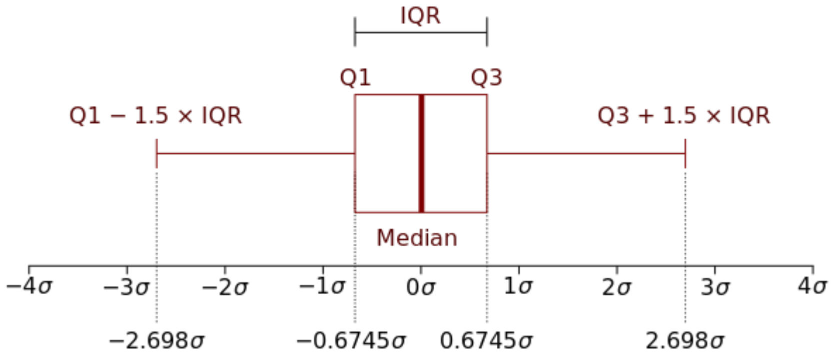
- Purpose: To gain a clear understanding of your data.
  - How large is it?
  - What columns are of interest?
  - Missing data?
  - Outliers?

Numerical Exploration

- str(): structure of the data frame
- summary(): summary of each of the columns
- head() / tail(): top / bottom of data frame
- table(): frequency table

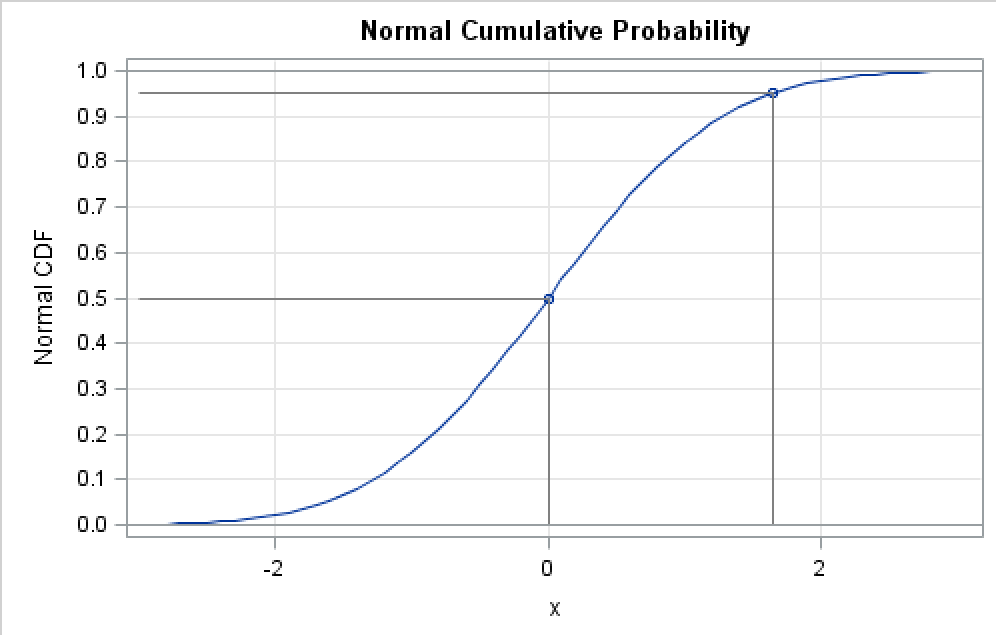
Numerical Exploration

> IQR(): inner quartile range (Q3 – Q1)



Numerical Exploration

> quantile(): quantiles of numerical vectors
  - Quantiles are inverse values of the CDF (cumulative distribution function).
  - Standard Normal: (shown in figure)
    > Quantile(0.5) = 0, means at x=0, 50% of the distribution lies to the left. (This is also the median)
    > Quantile(0.95) = 1.65



Numerical Exploration

> Relationships:

- cov(): covariances

$$cov(x, y) = E\big((x - \mu_x)(y - \mu_y)\big)$$

- Interpretation: Expected value of the differences between x and y and their corresponding mean.

- E.g. if x is above it's mean when y is also above it's mean, then they will have a high covariance.

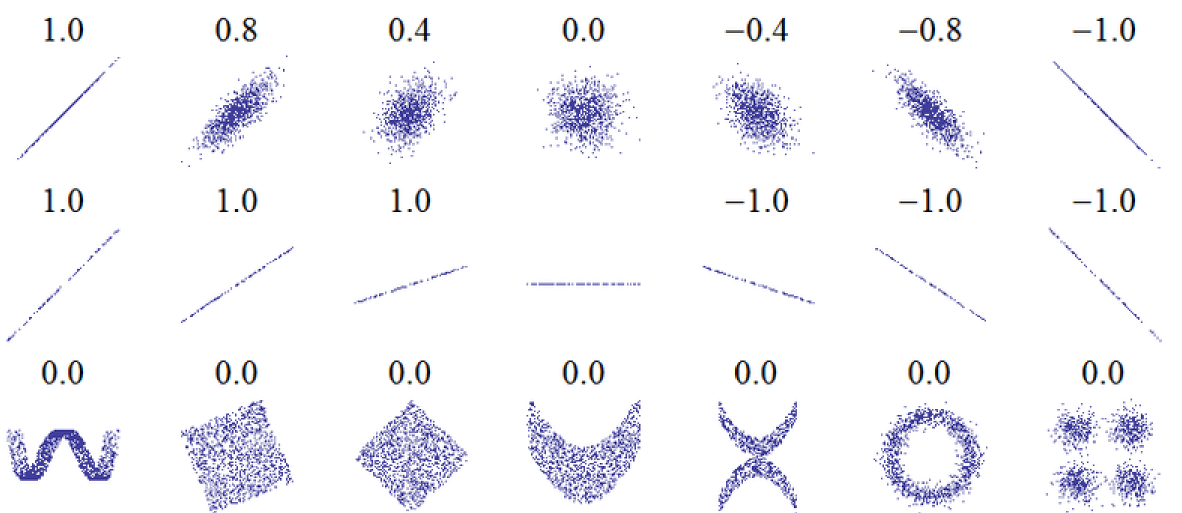
- Highly interpretable, but not bounded.

Numerical Exploration

> Relationships:
  - cor(): correlations (pearsons)

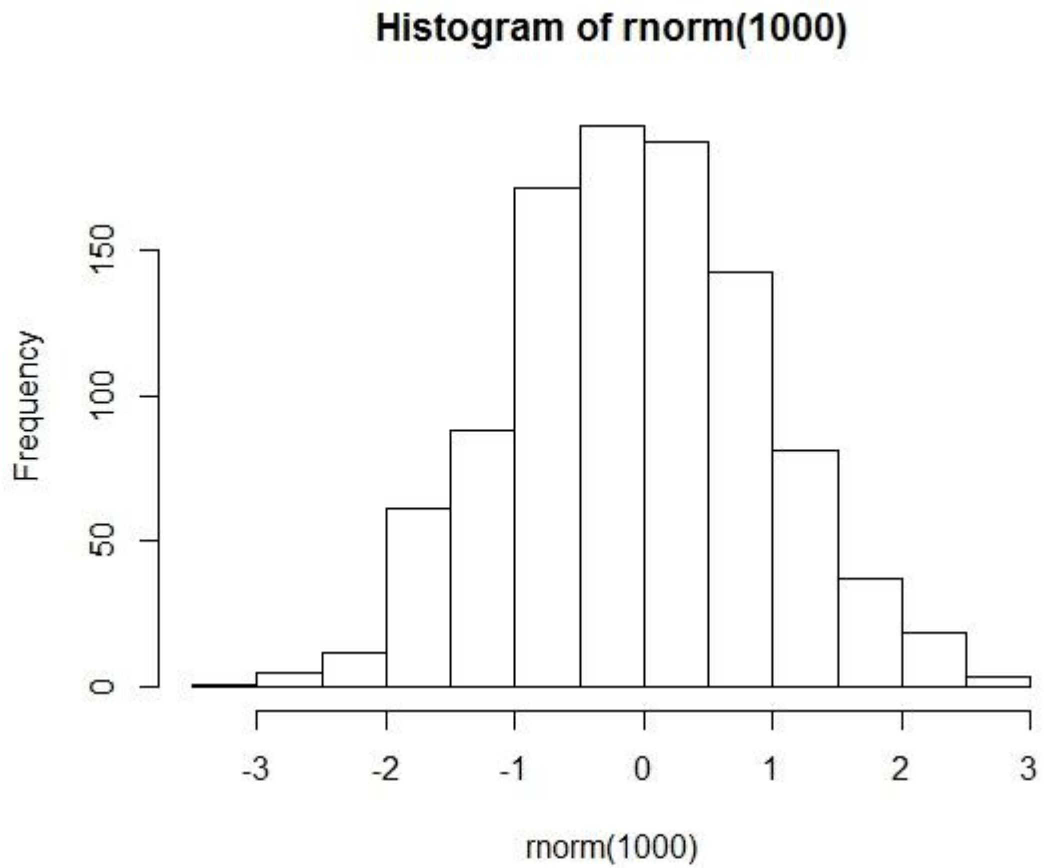
$$cor(x,y) = \frac{E\left((x-\mu_x)(y-\mu_y)\right)}{\sigma_x \sigma_y}$$

  - Bounded between 0 and 1.
  - Not as interpretable.



Visual Exploration

> Histograms:

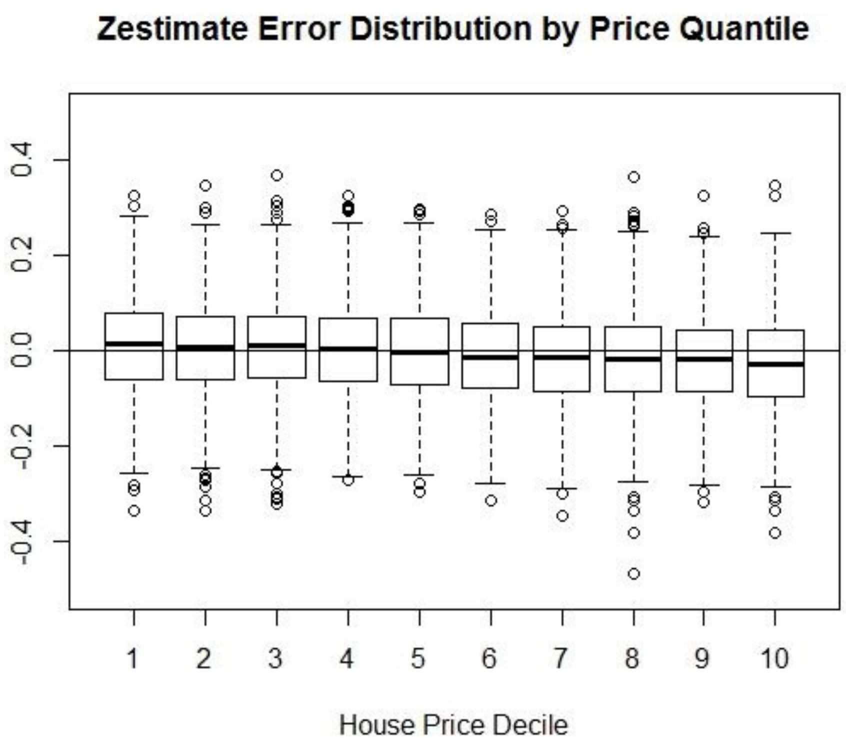


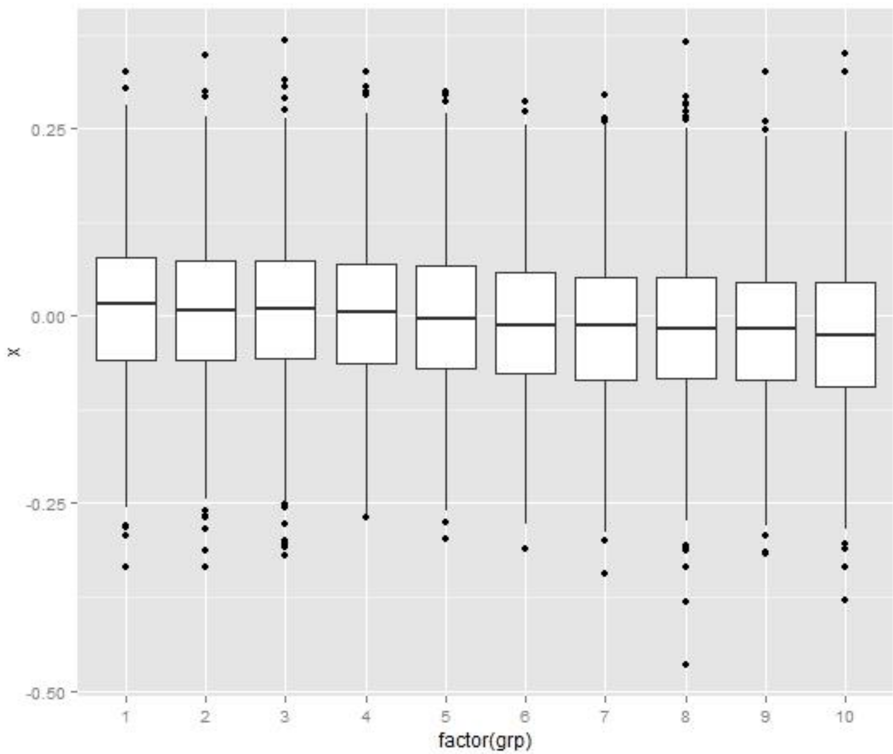
Base:
hist()

ggplot2:
+ geom_histogram()

Visual Exploration

> Boxplots:



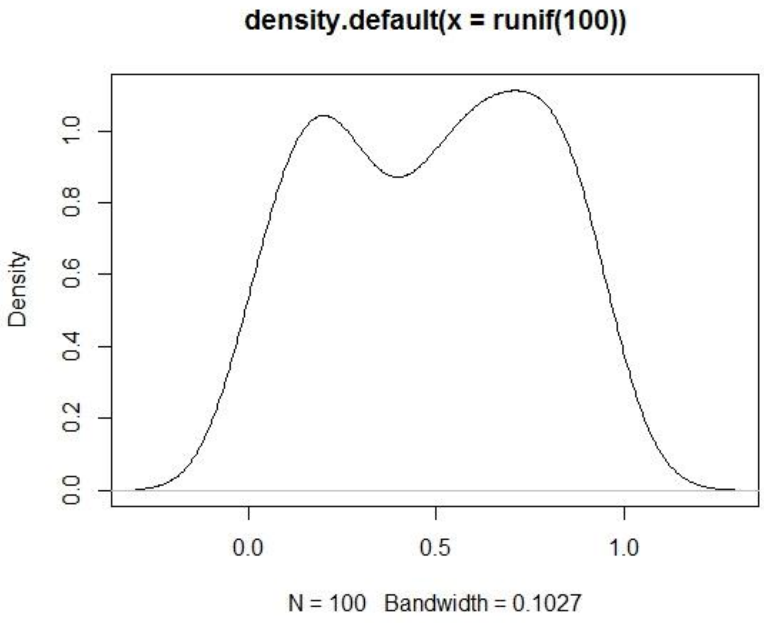


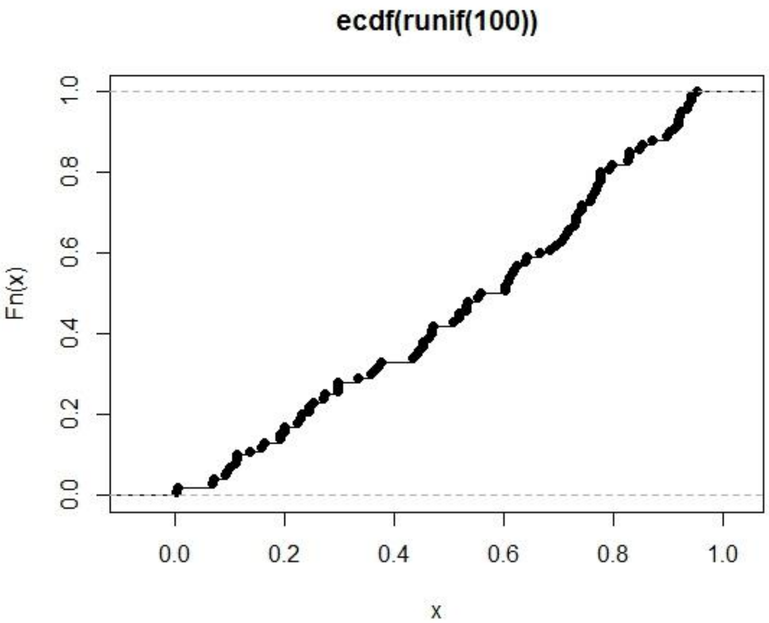
Base:
boxplot()

ggplot2:
+ geom_boxplot()

Visual Exploration

> Densities/CDFs:



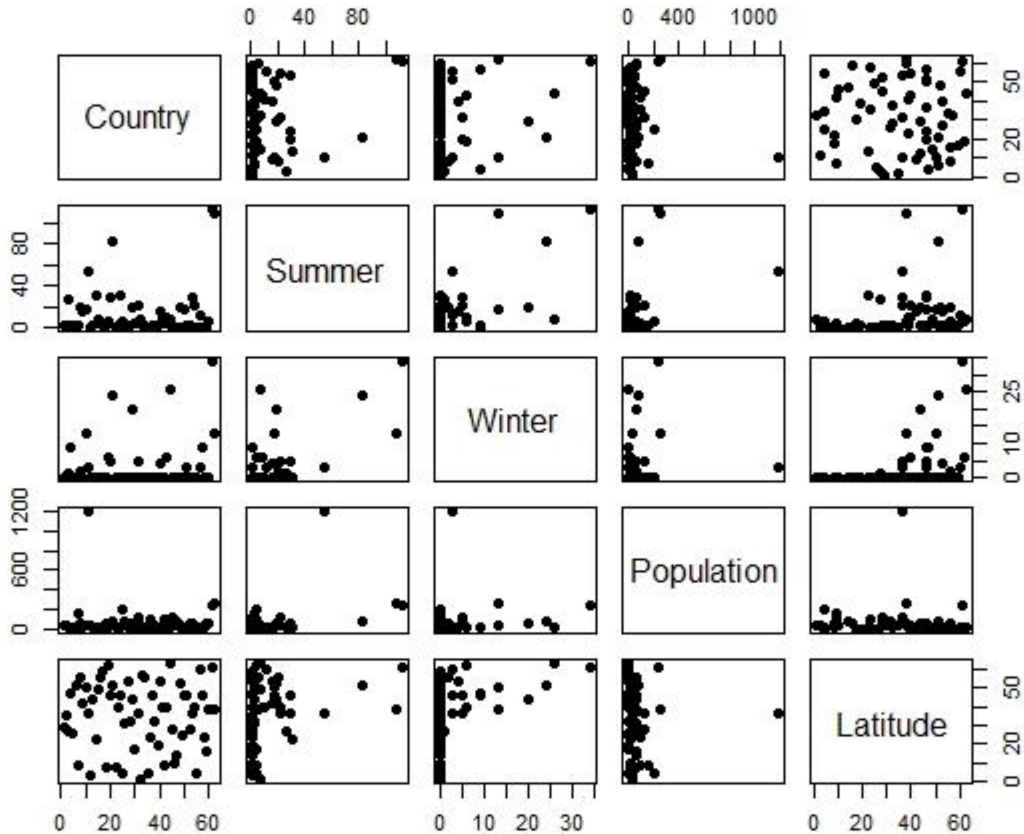


Base:
plot(density())
plot(ecdf())

ggplot2:
+ geom_density()
+ stat_ecdf()

Visual Exploration

> Scatterplots



Base:
pairs()

ggplot2:
ggpairs()

Distribution Transformations

- The purpose of transforming a variable is to make it easier to distinguish between values.
  - Most commonly we are looking to transform a distribution to be normal.
- Common Transformations
  - Log-based:
    - Log(x), log(x+1), log(x-min(x) + 1)
  - N-th Root based:
    - X^(1/n)
  - Any combination you can think of (remembering math rules).
- We will cover normality tests in a later class.

Simpsons Paradox

> Slicing up data in different ways can create different results.

> http://vudlab.com/simpsons/

Department	#male applicants	#female applicants	%male admit	%female admit
A	825	108	62	82
B	560	25	63	68
C	325	593	37	34
D	417	375	33	54

The explanation is that women applied in larger numbers to departments that had lower admission rates.

Production Level Scripts

- Logging
- Functionalize everything possible
- interactive()
- One Unit Test
- R-example: Weather Scraping R script

Assignment

- Go to:
  - Vote for extra topics (time permitting)
  - https://www.surveymonkey.com/r/SK6VX5T
- Complete Homework 1:
  - Explore ‘JitteredHeadCount.csv’, a data set from Caesar’s Entertainment that has falsified/jittered table headcounts.
  - Write ***script level*** R program that shows/illustrates 3 key takeaways of your choosing from exploring the data.
  - You should submit:
    - **ONE R-script.**
    - **One word document with 3 key points.** (example next page).

Example Takeaway

> The aggregate table headcounts on the weekends are X% higher than non-weekends (figure 1). In fact, the game that has the highest difference between average highs and average low days is Gamecode AA with a difference of x.xx heads/table.