Practical Data Science with R

@MatthewRenze

#KCDC

Motivation

The ability to take data—to be able to understand it, to process it, to extract value from it, to visualize it, to communicate it—that's going to be a hugely important skill in the next decades, … because now we really do have essentially free and ubiquitous data. So the complimentary scarce factor is the ability to understand that data and extract value from it.

Hal Varian, Google's Chief Economist
The McKinsey Quarterly, Jan 2009

The New York Times

For Today's Graduate, Just One Word: Statistics

By STEVE LOHR
Published: August 5, 2009

MOUNTAIN VIEW, Calif. — At Harvard, Carrie Grimes majored in anthropology and archaeology and ventured to places like Honduras, where she studied Mayan settlement patterns by mapping where artifacts were found. But she was drawn to what she calls "all the computer and math stuff" that was part of the job.

TWITTER
LINKEDIN
COMMENTS (58)
SIGN IN TO E-MAIL

AVERAGE SALARY FOR High Paying Skills and Experience

SKILL	2013	YR/YR CHANGE
R	$ 115,531	n/a
NoSQL	$ 114,796	1.6%
MapReduce	$ 114,396	n/a
PMBok	$ 112,382	1.3%
Cassandra	$ 112,382	n/a
Omnigraffle	$ 111,039	0.3%
Pig	$ 109,561	n/a
SOA (Service Oriented Architecture)	$ 108,997	-0.5%
Hadoop	$ 108,669	-5.6%
Mongo DB	$ 107,825	-0.4%

Source: Dice 2014 Tech Salary Survey Results

A Flood of Data is Coming...

Source: http://www.dot.gov.nt.ca/

Source: Wikipedia

Sink or Swim

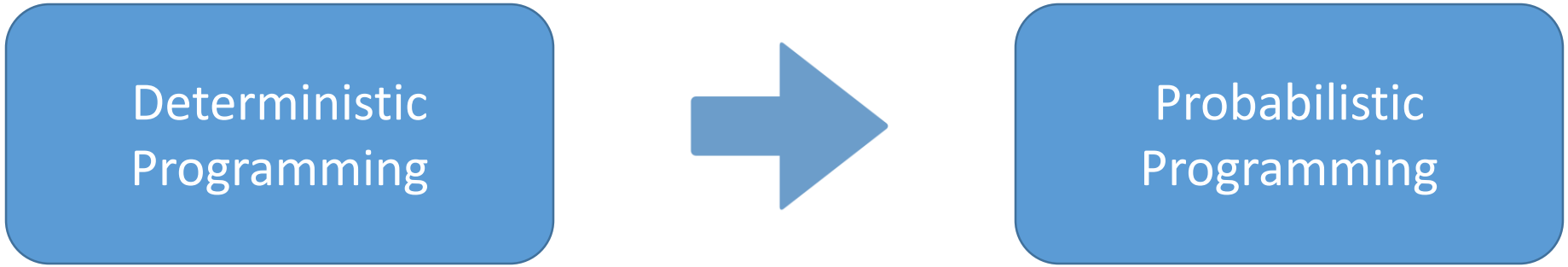
Overview

1. Introduction
2. Transforming Data
3. Descriptive Statistics
4. Data Visualization
5. Statistical Modeling
6. Handling Big Data
7. Machine Learning
8. R in Practice

How Does This Apply to Me?

- As a software developer, I often:
  - ☑ Perform log file analysis
  - ☑ Analyze software performance
  - ☑ Analyze code metrics for code quality
  - ☑ Detect anomalies in source data
  - ☑ Transform or clean data files to make them usable
  - ☑ Help decision makers make decisions based on data

How Does This Apply to Me?



If x and y then z

If P(x) > y then z

About Me

Independent software consultant

Education

- B.S. in Computer Science
- B.A. in Philosophy

Community

- Pluralsight Author
- ASPInsider
- Public Speaker
- Open-Source Software

IOWA STATE UNIVERSITY

About You

What's your name?

What do you do?

Why did you attend?

Favorite super power?

Source: www.thatsmyface.com

Logistics

Time table

- 8 Lectures (10 min)
- 8 Demos (5 min)
- 8 Labs (15 min)
- Break in the middle

Pairing for labs is optional

Ask questions if needed

Come and go as needed

Feedback forms at the end

Lab Options

Type all code

Copy and paste

Run demo scripts

Workshop URL

http://www.matthewrenze.com/workshops/practical-data-science-with-r/

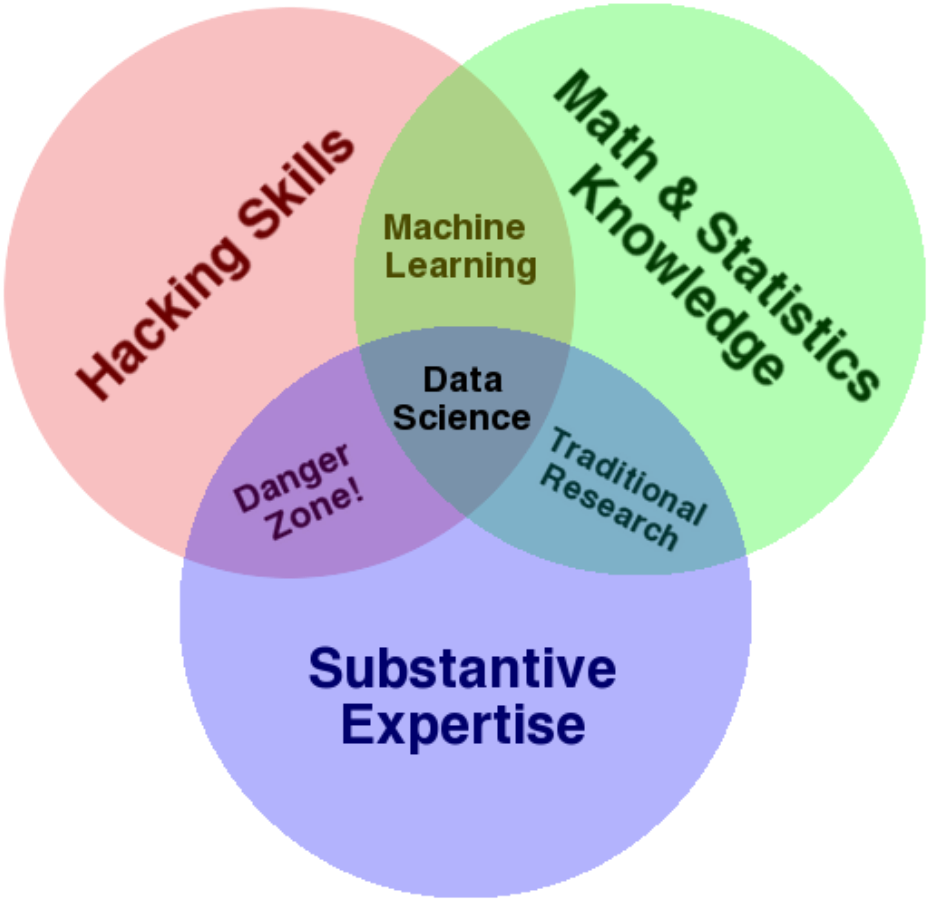
Introduction to Data Science

What is Data Science

Interdisciplinary field

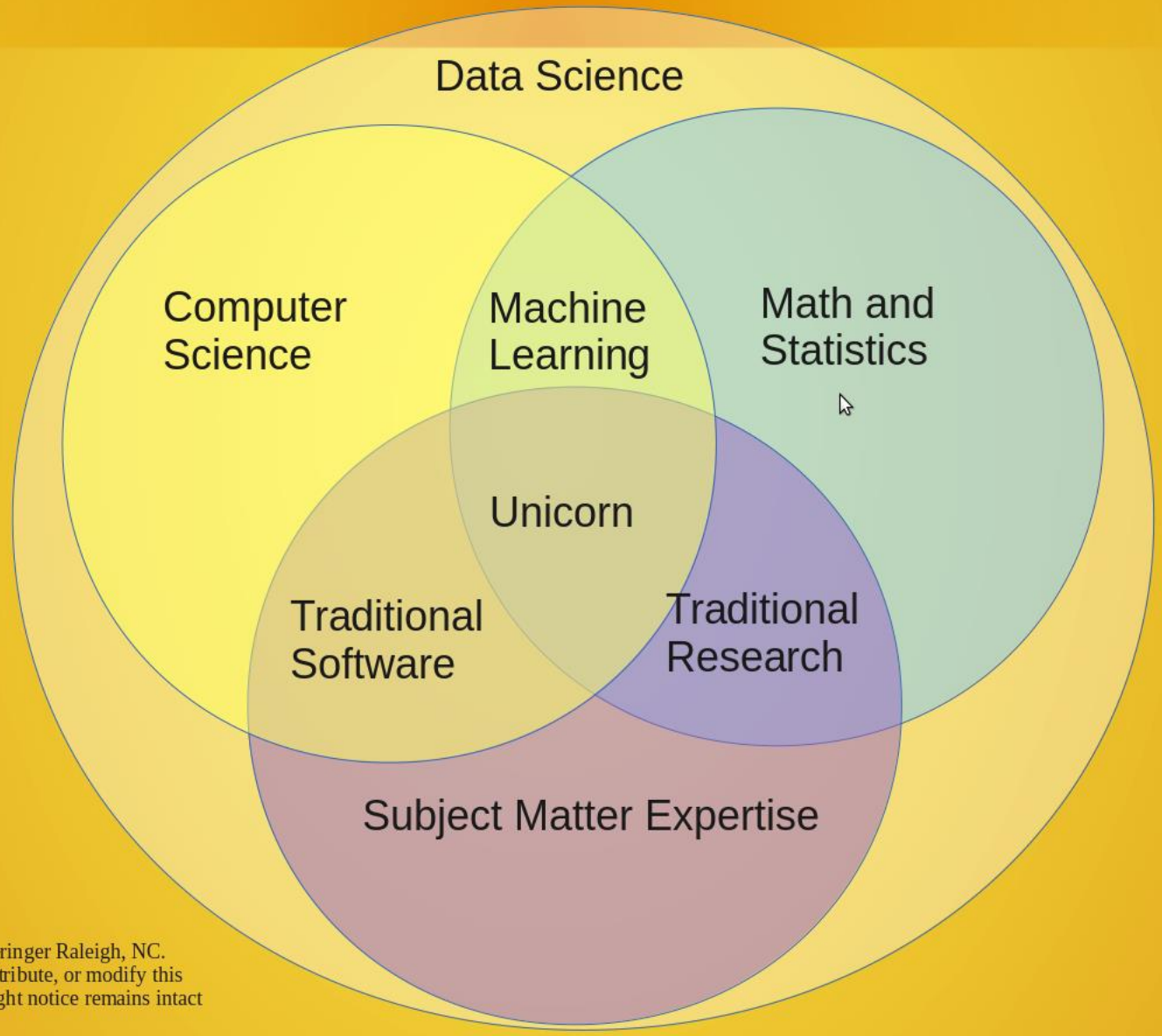
Derive insight from data

Transform data into knowledge



Source:www.drewconway.com

Data Science Venn Diagram v2.0



What is a Data Scientist?

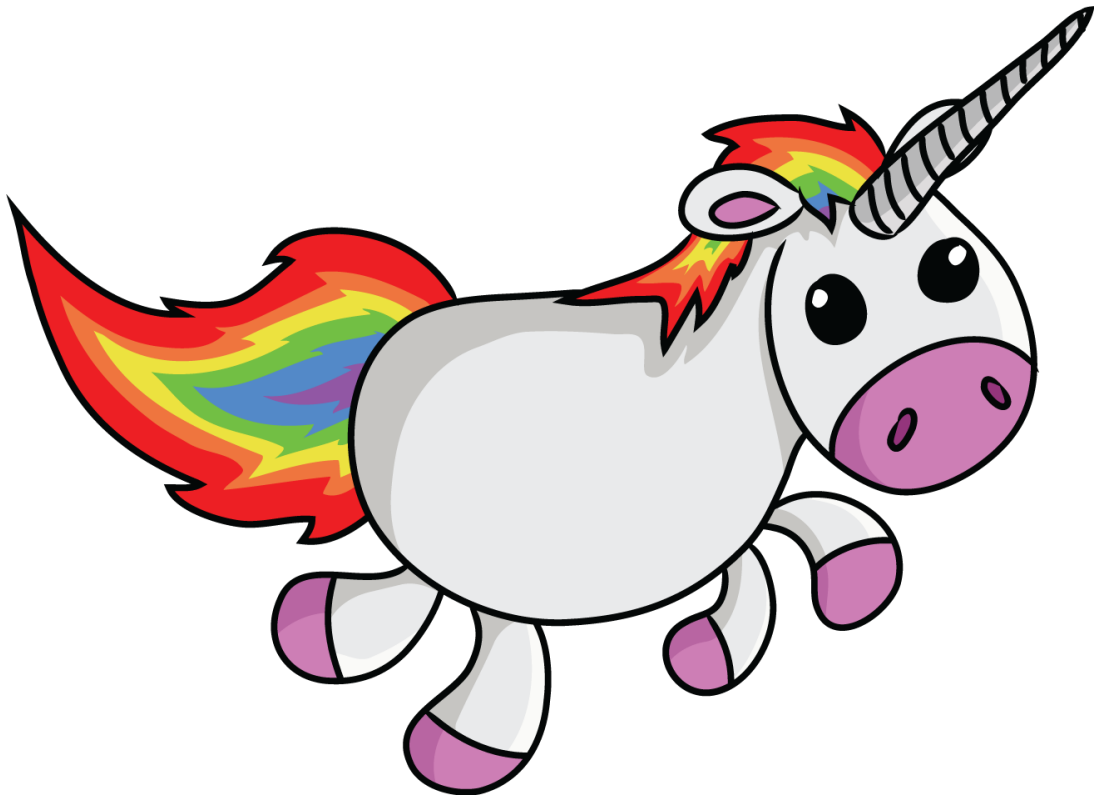
Performs data science

Proper accreditations

More than a scientist

More than an analyst

More than a developer



The Sexiest Job of the 21st Century

Source: http://www.clipartpanda.com


Job Trends from Indeed.com
"Data Scientist"
Percentage of Matching Job Postings
0.04
0.02
0
Jan '06
Jan '07
Jan '08
Jan '09
Jan '10
Jan '11
Jan '12
Jan '13
Jan '14
Jan '15
indeed
one search. all jobs.

The Data Science Toolkit

Programming

Data transformation

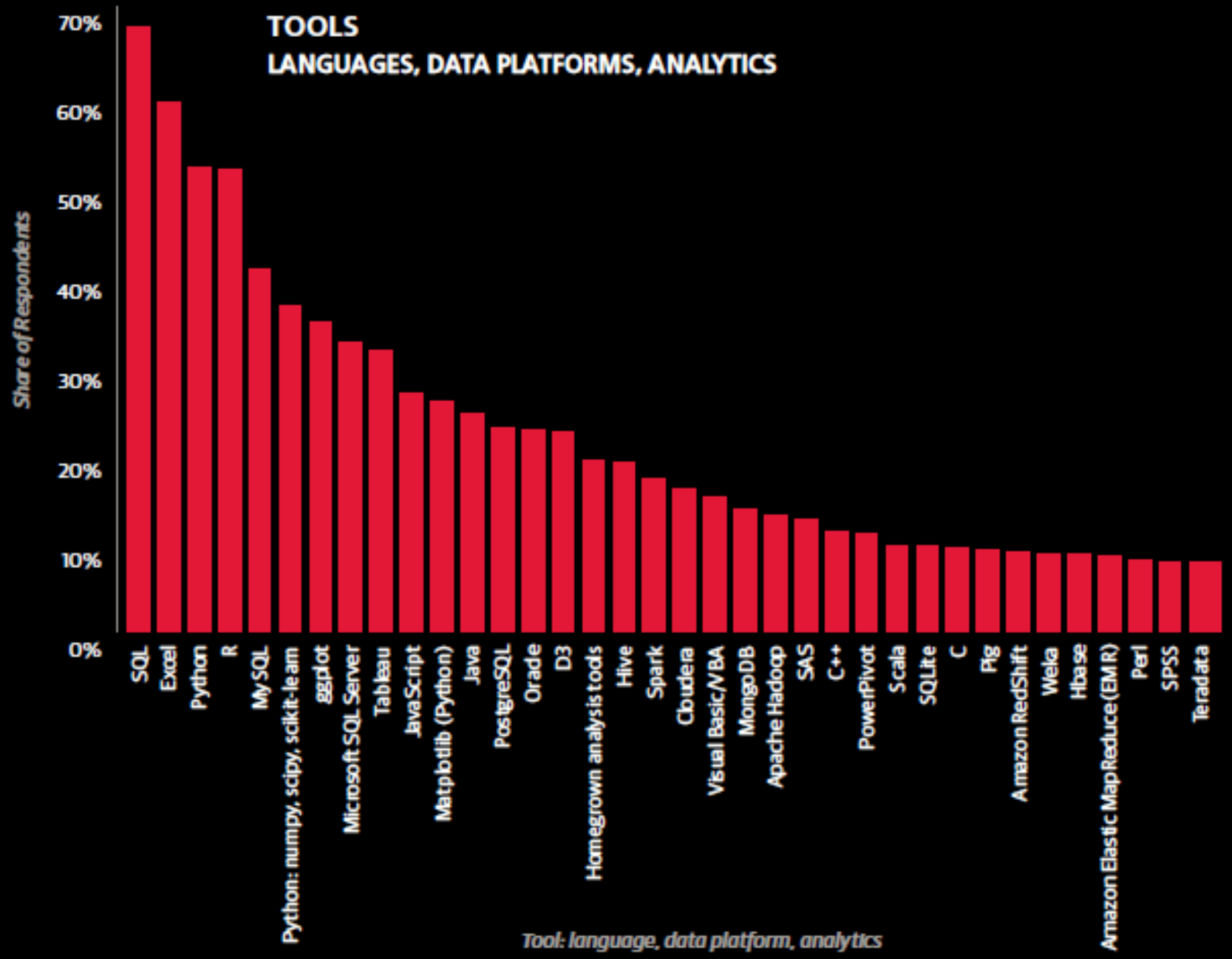
Descriptive statistics

Data visualization

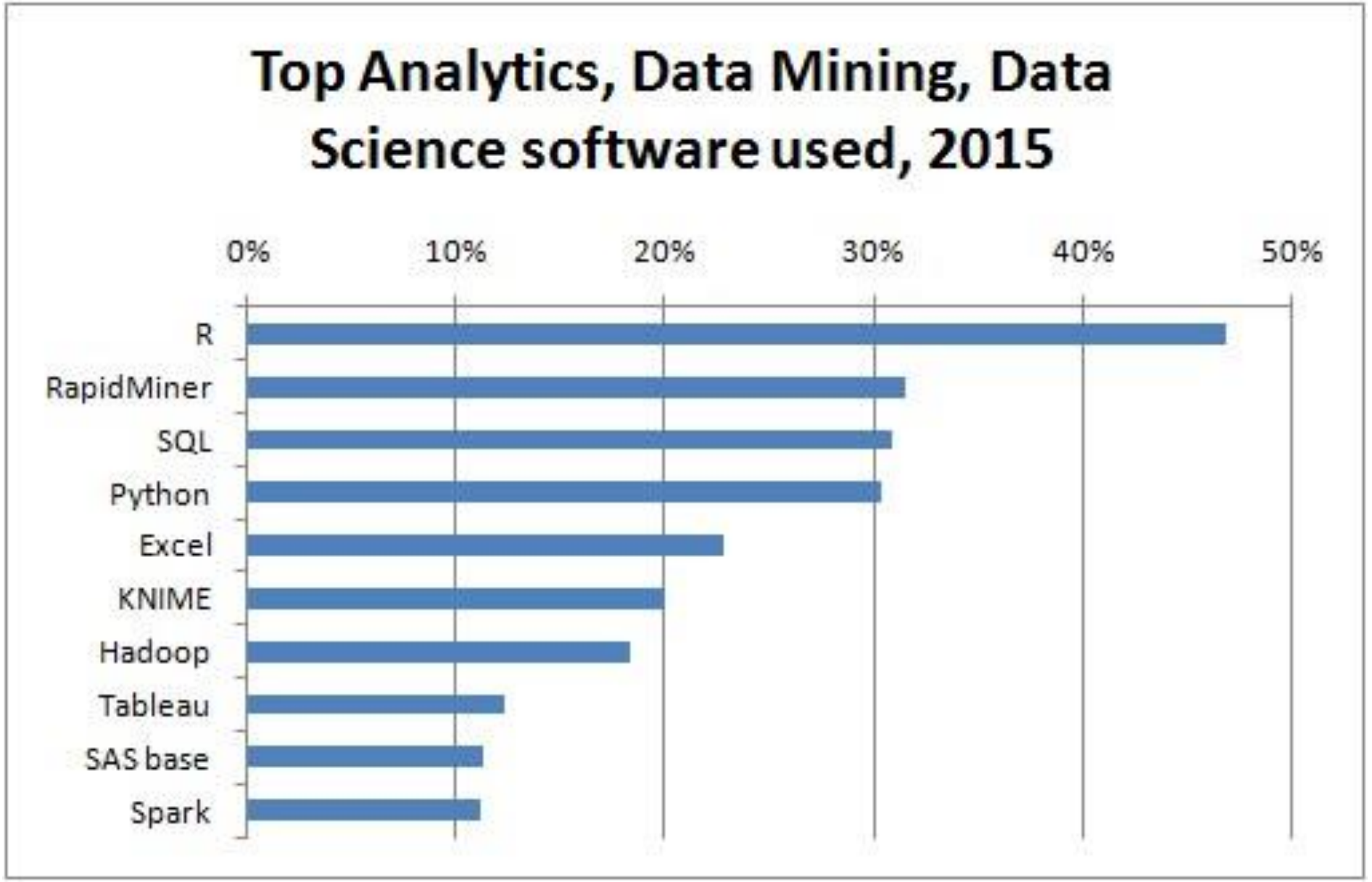
Statistical modeling

Big Data

Machine learning

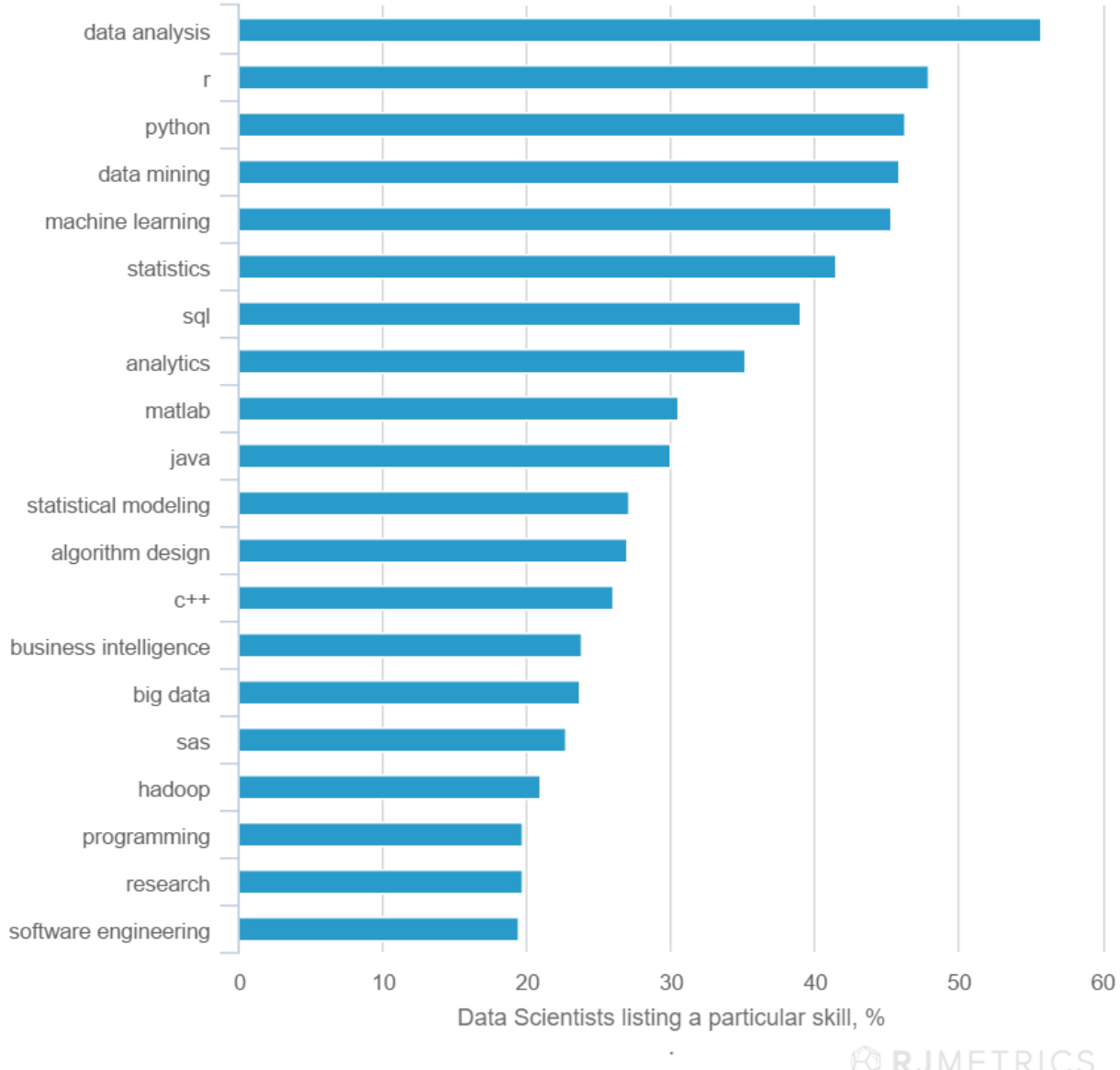


Source: O'Reilly 2015 Data Science Salary Survey



http://www.kdnuggets.com/polls/2015/analytics-data-mining-data-science-software-used.html

TOP 20 SKILLS OF A DATA SCIENTIST



Why is Data Science Important?

Lots of data

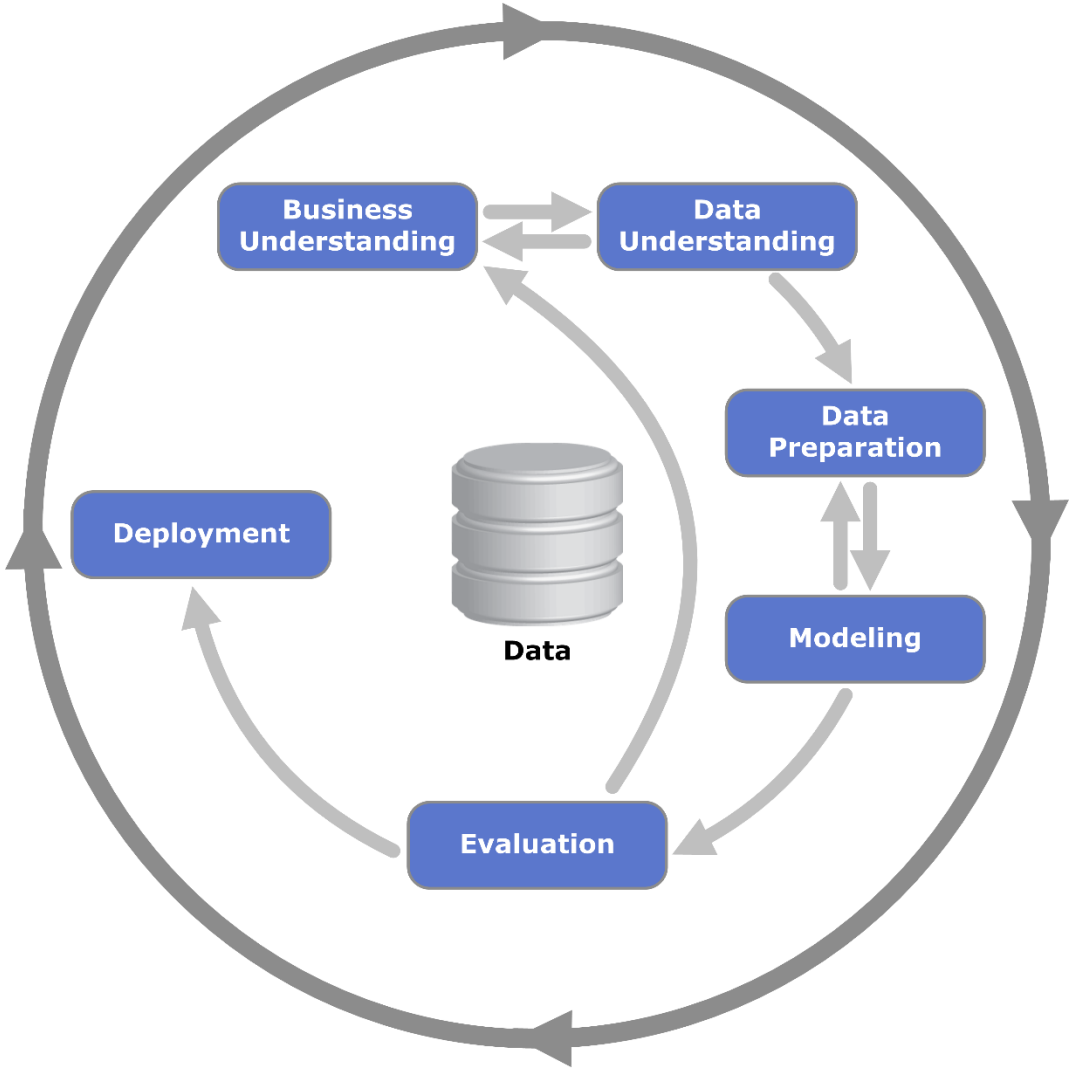
Fast computers

Powerful analysis tools

Prediction vs. explanation

The Data Science Process

1. Ask a question
2. Explore the data
3. Prepare the data
4. Create a model
5. Evaluate the model
6. Deploy the model / results



https://en.wikipedia.org/wiki/Cross_Industry_Standard_Process_for_Data_Mining

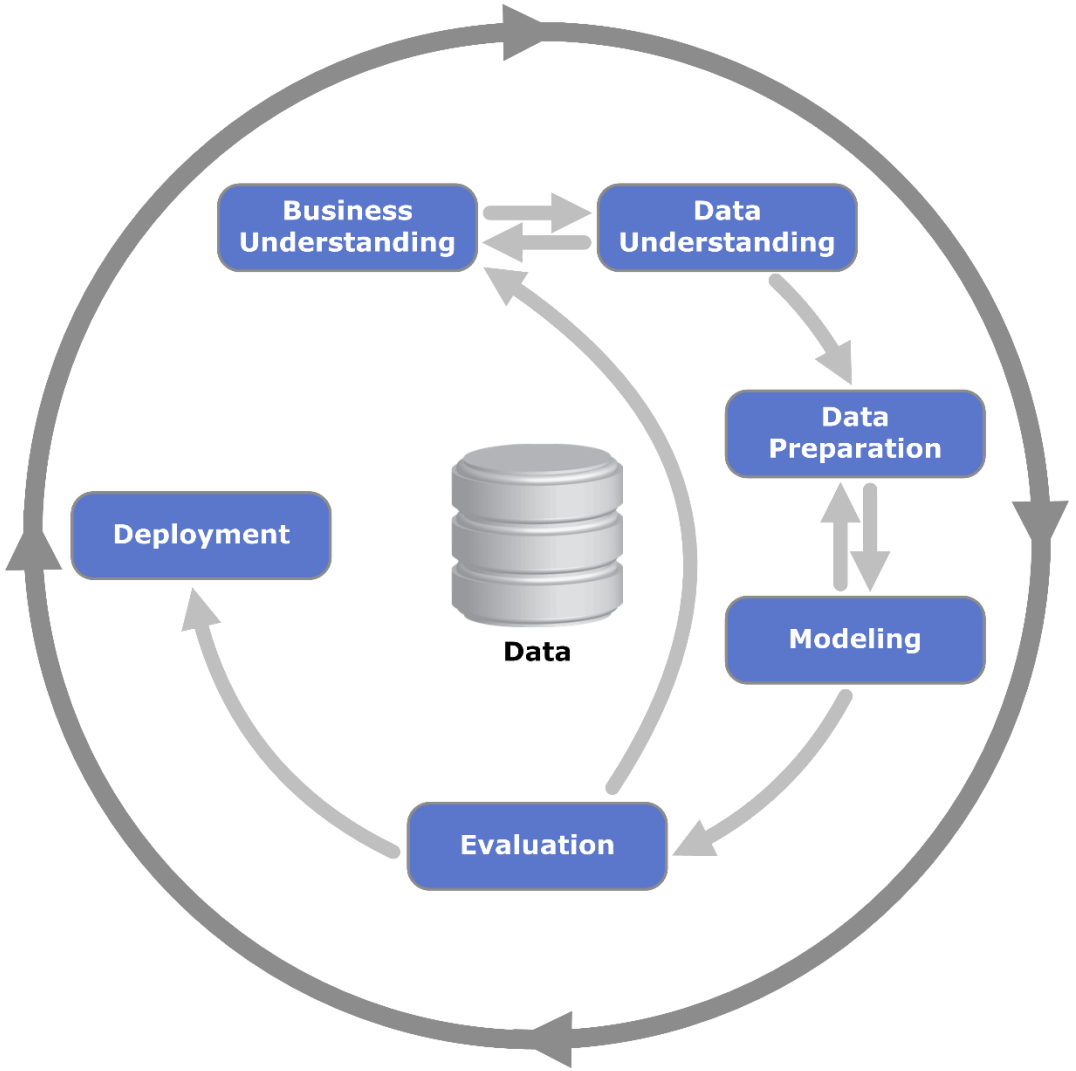
The Data Science Process

Iterative process

Non-sequential

Early termination

Established process (CRISP-DM)



https://en.wikipedia.org/wiki/Cross_Industry_Standard_Process_for_Data_Mining

Introduction to R

What is R?

Open source

Language and environment

Numerical and graphical analysis

Cross platform

What is R?

Active development

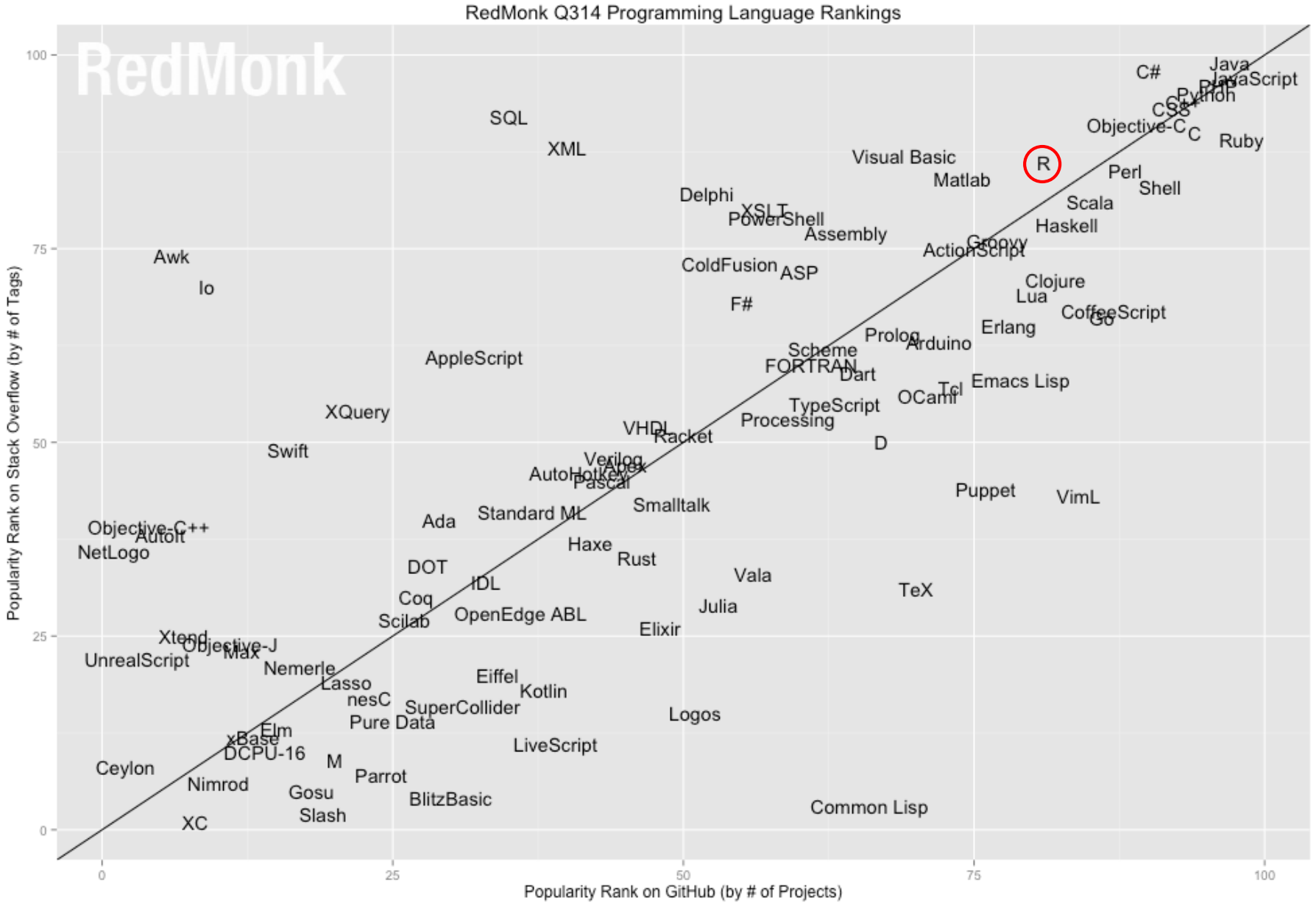
Large user community

Modular and extensible

6700+ extensions


FREE


FREE



Source: http://redmonk.com/sogrady/2014/06/13/language-rankings-6-14/

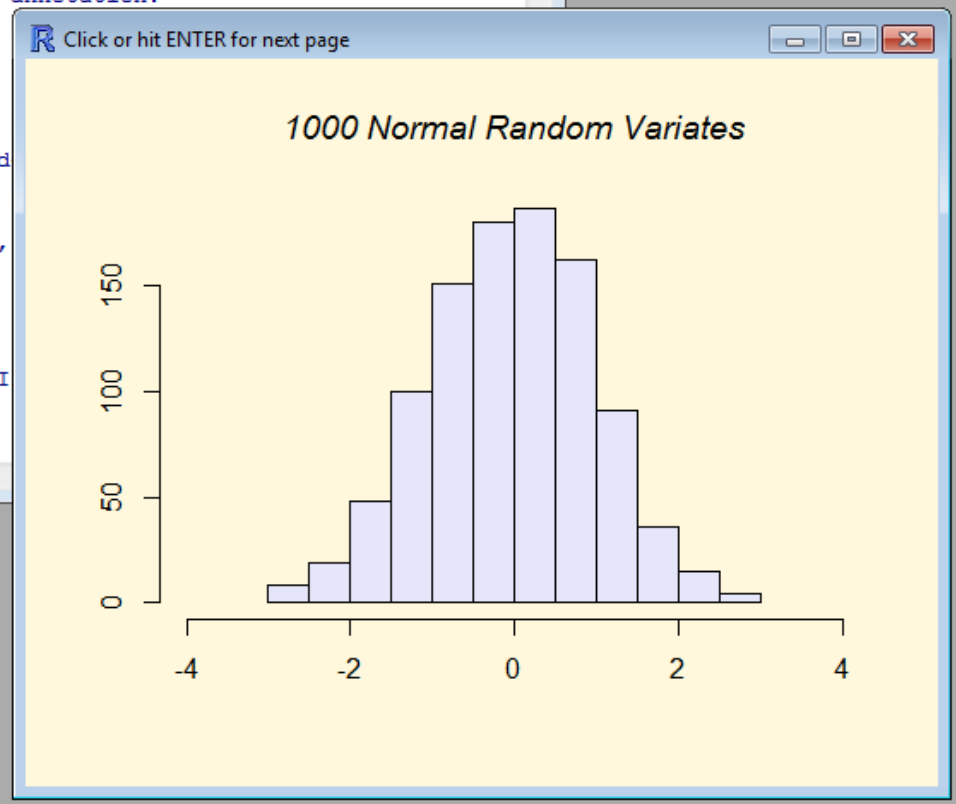
RGui (64-bit)

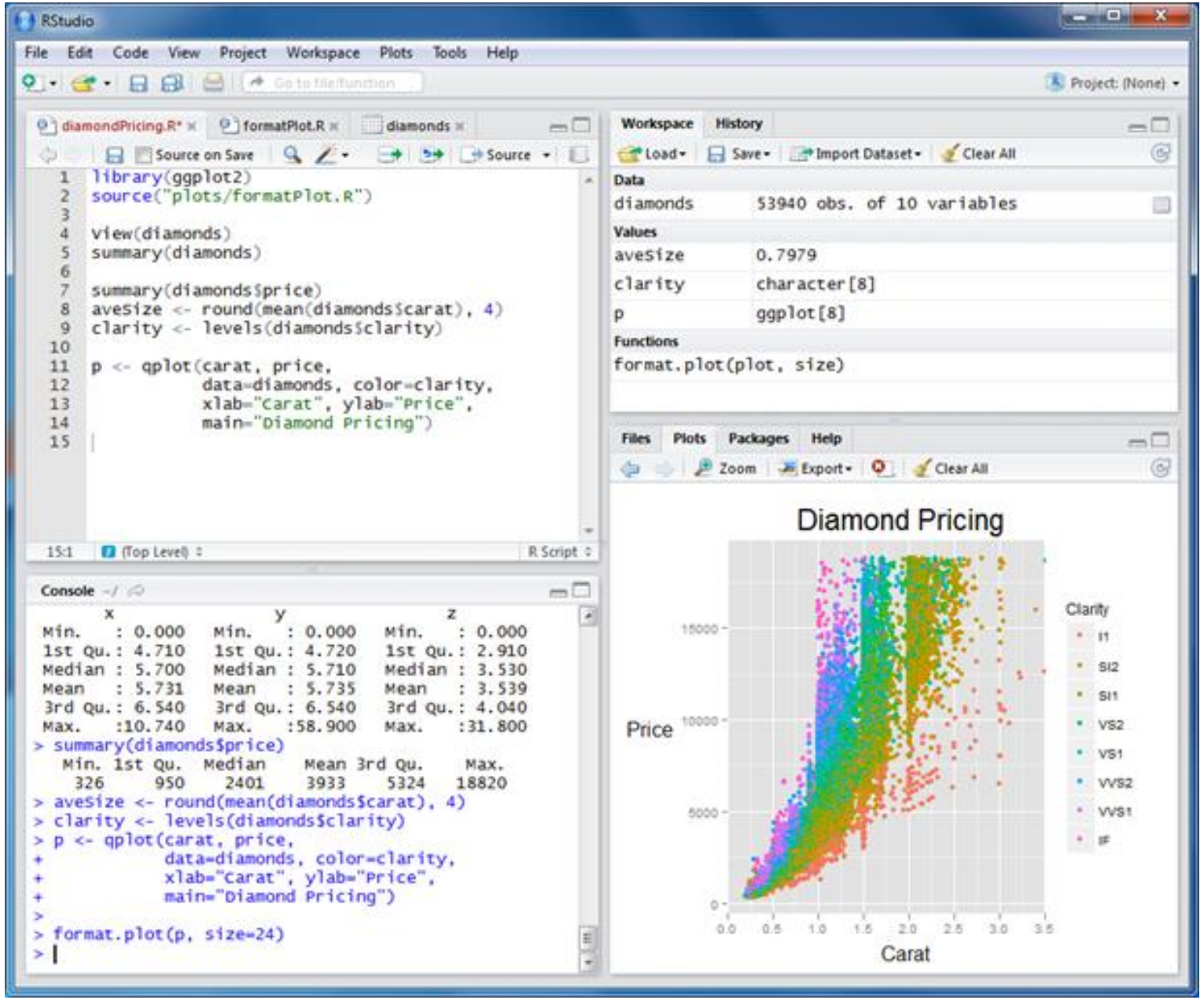
Next

R Console

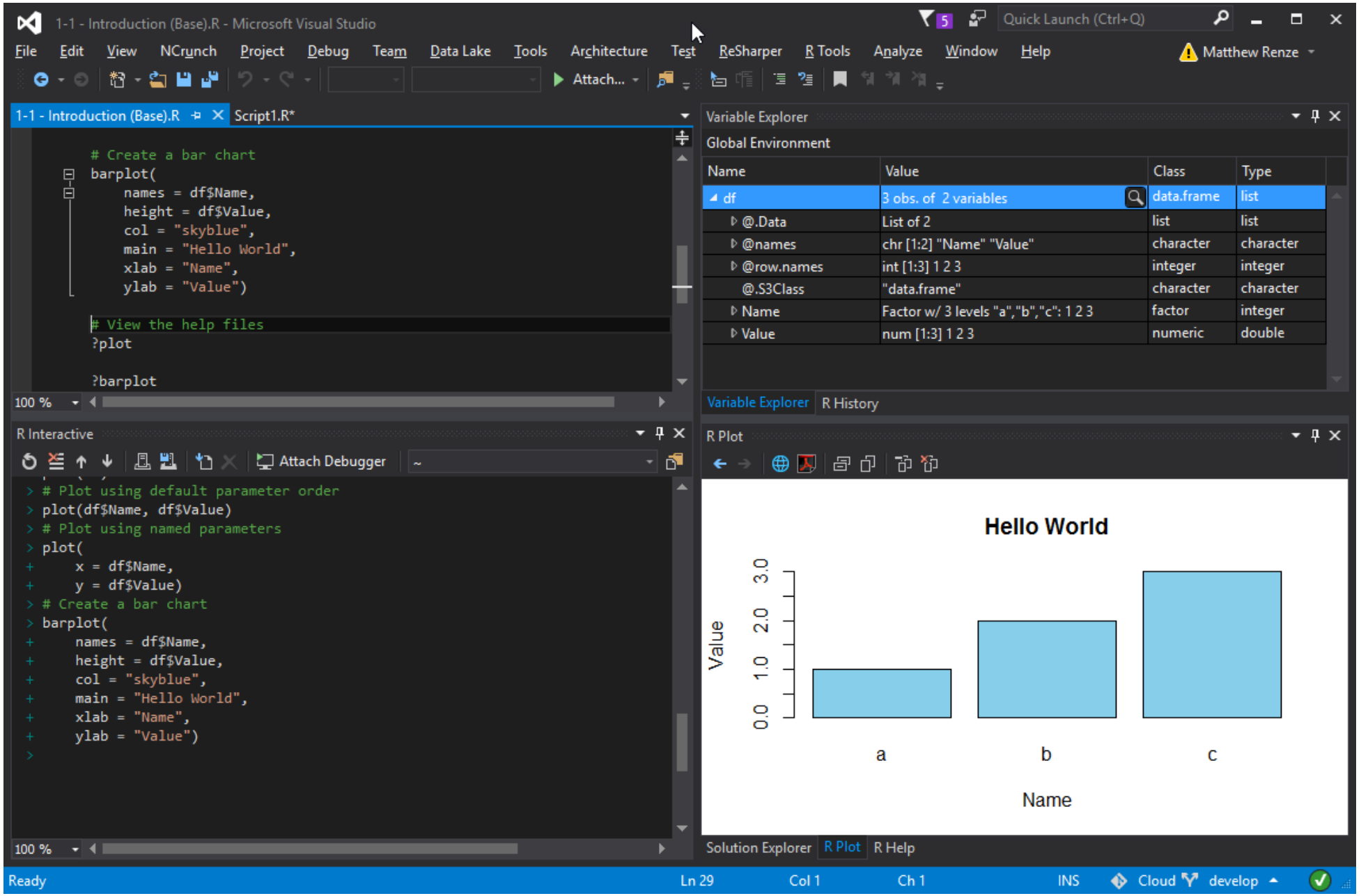
```
> box()

> title(main= "The Level of Interest in R", font.main=4, col.main="red")

> title(xlab= "1996", col.lab="red")

> ## A filled histogram, showing how to change the font used for the
> ## main title without changing the other annotation.
>
> par(bg="cornsilk")

> x <- rnorm(1000)

> hist(x, xlim=range(-4, 4, x), col="lavend
Waiting to confirm page change...

> title(main="1000 Normal Random Variates",

> ## A scatterplot matrix
> ## The good old Iris data (yet again)
>
> pairs(iris[1:4], main="Edgar Anderson's I
Waiting to confirm page change...
```

Click or hit ENTER for next page





Source: www.rstudio.com/ide/


1-1 - Introduction (Base).R - Microsoft Visual Studio
Quick Launch (Ctrl+Q)
File Edit View NCrunch Project Debug Team Data Lake Tools Architecture Test ReSharper R Tools Analyze Window Help
Matthew Renze
Attach...
1-1 - Introduction (Base).R
Script1.R*
Create a bar chart
barplot(
names = df$Name,
height = df$Value,
col = "skyblue",
main = "Hello World",
xlab = "Name",
ylab = "Value")
# View the help files
?plot
?barplot
100 %
Variable Explorer
Global Environment
Name
Value
Class
Type
df
3 obs. of 2 variables
data.frame
list
@.Data
List of 2
list
list
@names
chr [1:2] "Name" "Value"
character
character
@row.names
int [1:3] 1 2 3
integer
integer
@.S3Class
"data.frame"
character
character
Name
Factor w/ 3 levels "a","b","c": 1 2 3
factor
integer
Value
num [1:3] 1 2 3
numeric
double
Variable Explorer
R History
R Interactive
Attach Debugger
> # Plot using default parameter order
> plot(df$Name, df$Value)
> # Plot using named parameters
> plot(
+ x = df$Name,
+ y = df$Value)
> # Create a bar chart
> barplot(
+ names = df$Name,
+ height = df$Value,
+ col = "skyblue",
+ main = "Hello World",
+ xlab = "Name",
+ ylab = "Value")
>
100 %
R Plot
Hello World
Value
0.0
1.0
2.0
3.0
a
b
c
Name
Solution Explorer
R Plot
R Help
Ready
Ln 29
Col 1
Ch 1
INS
Cloud
develop

Code Demo

Lab 1
R Programming Basics

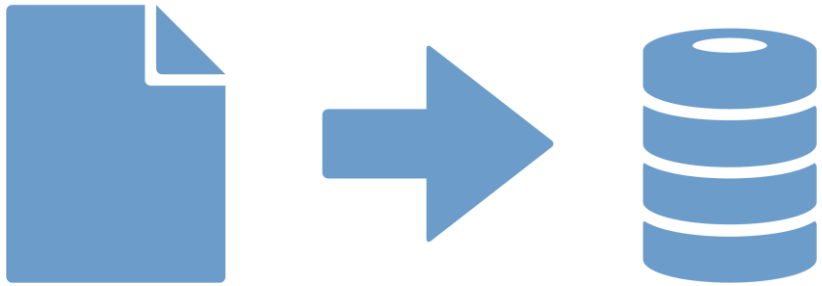
Transforming Data

Data Munging

Transforming data

Raw data to usable data

Data must be cleaned first



Data Munging Tasks

Renaming variables

Data type conversion

Encoding, decoding or recoding data

Merging data sets

Transforming data

Handling missing data (imputing)

Handling anomalous values

Loading Data in R

File-based data

Web-based data

Databases

Statistical data

And many more…

Cleaning Data

This step is often the

- Most difficult
- Most time consuming

TIP: Record all steps

Data Munging Tools in R

plyr

dplyr

reshape2

tidyr

stringr

lubridate

dplyr

Single Data Frame Verbs

- Select
- Filter
- Mutate
- Summarize
- Arrange

Multiple Data Frame Verbs

- Inner join
- Left join
- Semi join
- Anti join
- Union
- Intersect
- Set difference

Open Movies Database

Movies								
Title	Year	Rating	Runtime (minutes)	Genre	Critic Score	Box Office	Awards	Inter-national
The Whole Nine Yards	2000	R	98	Comedy	45%	$57.3M	No	No
Cirque du Soleil	2000	G	39	Family	45%	$13.4M	Yes	No
Gladiator	2000	R	155	Action	76%	$187.3M	Yes	Yes
Dinosaur	2000	PG	82	Family	65%	$135.6M	Yes	No
Big Momma's House	2000	PG-13	99	Comedy	30%	$0.5M	Yes	Yes


PROD. NO.
SCENE
TAKE
ROLL

1. Column with wrong name
2. Rows with missing values
3. Runtime column has units
4. Revenue in multiple scales
5. Wrong file format

Code Demo

Lab 2
Transforming Data

Descriptive Statistics

Descriptive Statistics

Describe data

Provides a summary

aka: Summary statistics

Movie Runtime	
Statistic	**Value (minutes)**
Minimum	38
1st Quartile	93
Median	101
Mean	104
3rd Quartile	113
Maximum	219

Statistical Terms

Observations

Variables

Qualitative variable

Quantitative variable

ID	Date	Customer	Product	Quantity
1	2015-08-27	John	Pizza	2
2	2015-08-27	John	Soda	2
3	2015-08-27	Jill	Salad	1
4	2015-08-27	Jill	Milk	1
5	2015-08-28	Miko	Pizza	3
6	2015-08-28	Miko	Soda	2
7	2015-08-28	Sam	Pizza	1
8	2015-08-28	Sam	Milk	1

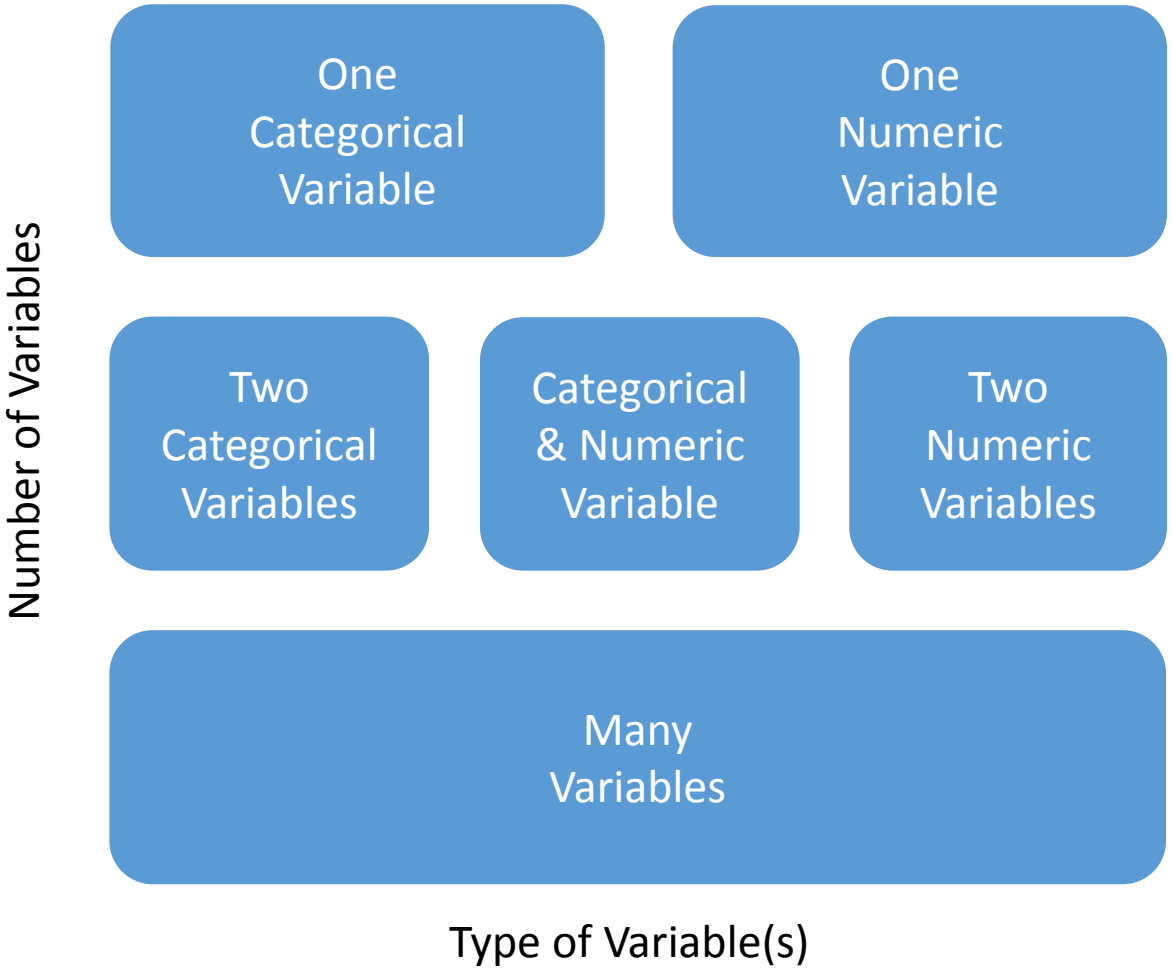
Types of Analysis

Number of variables

- 1 - Univariate
- 2 - Bivariate
- n - Multivariate

Type of variables

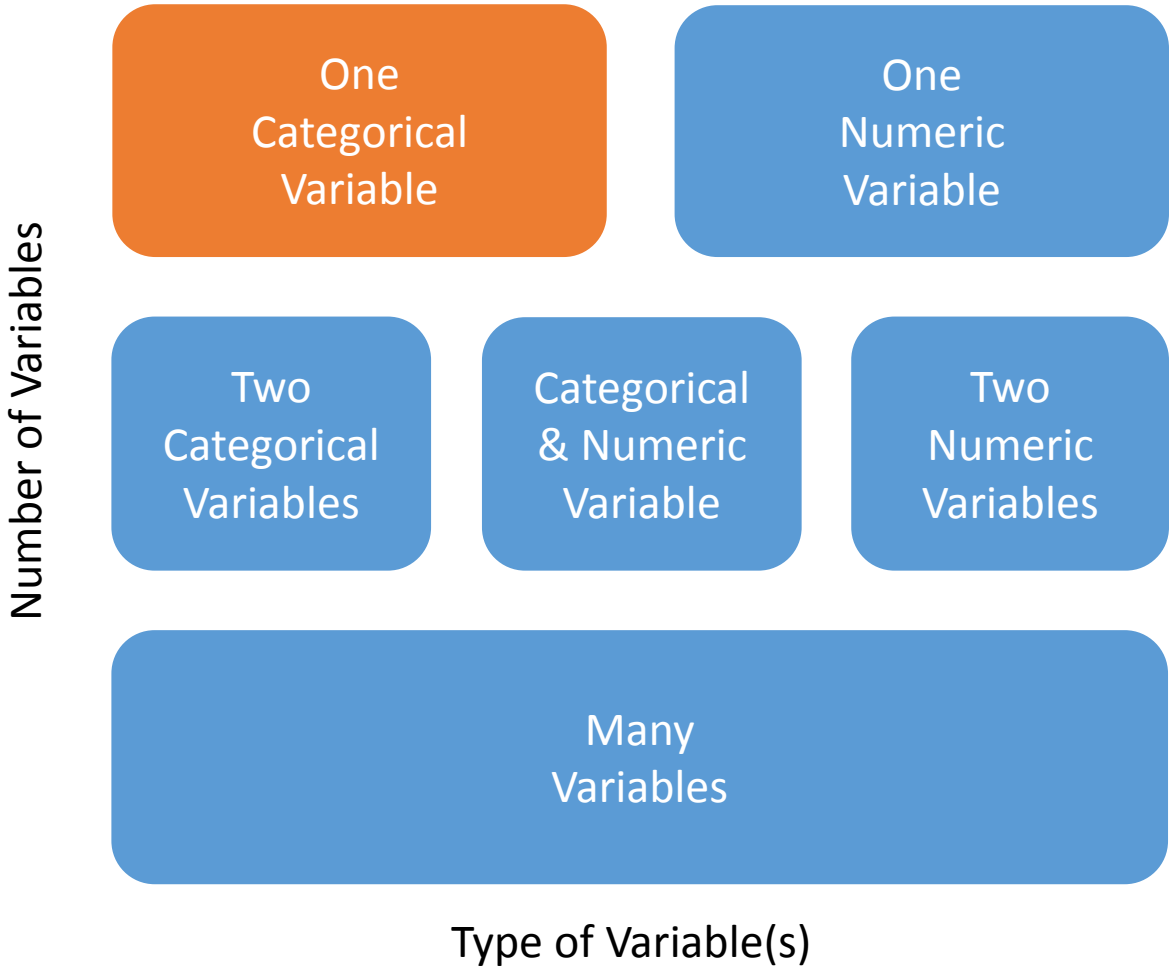
- Categorical - Qualitative
- Numeric - Quantitative



Analyzing One Categorical Variable

Qualitative univariate analysis

Frequency of observations

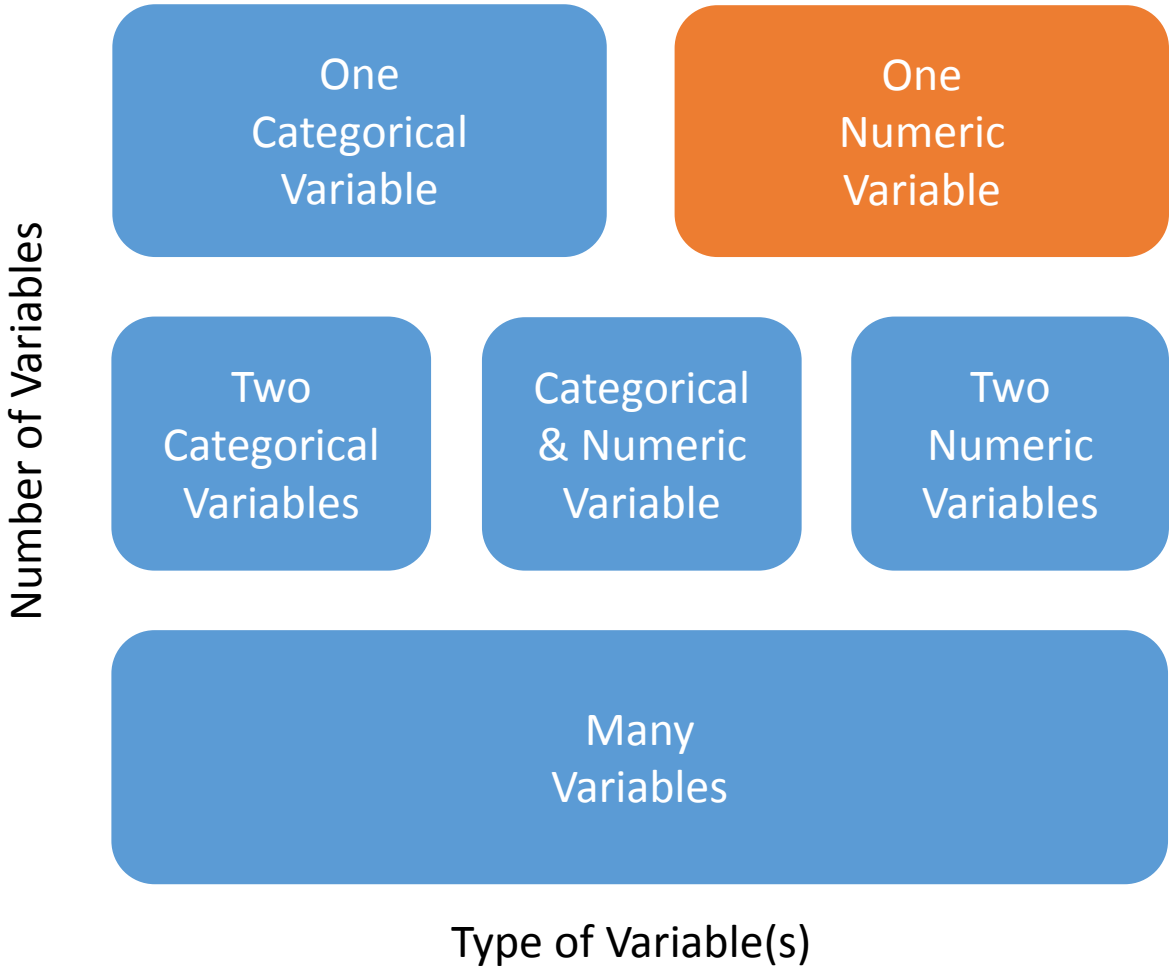


Analyzing One Numeric Variable

Quantitative univariate analysis

Measures

- Central tendency
- Dispersion
- Shape

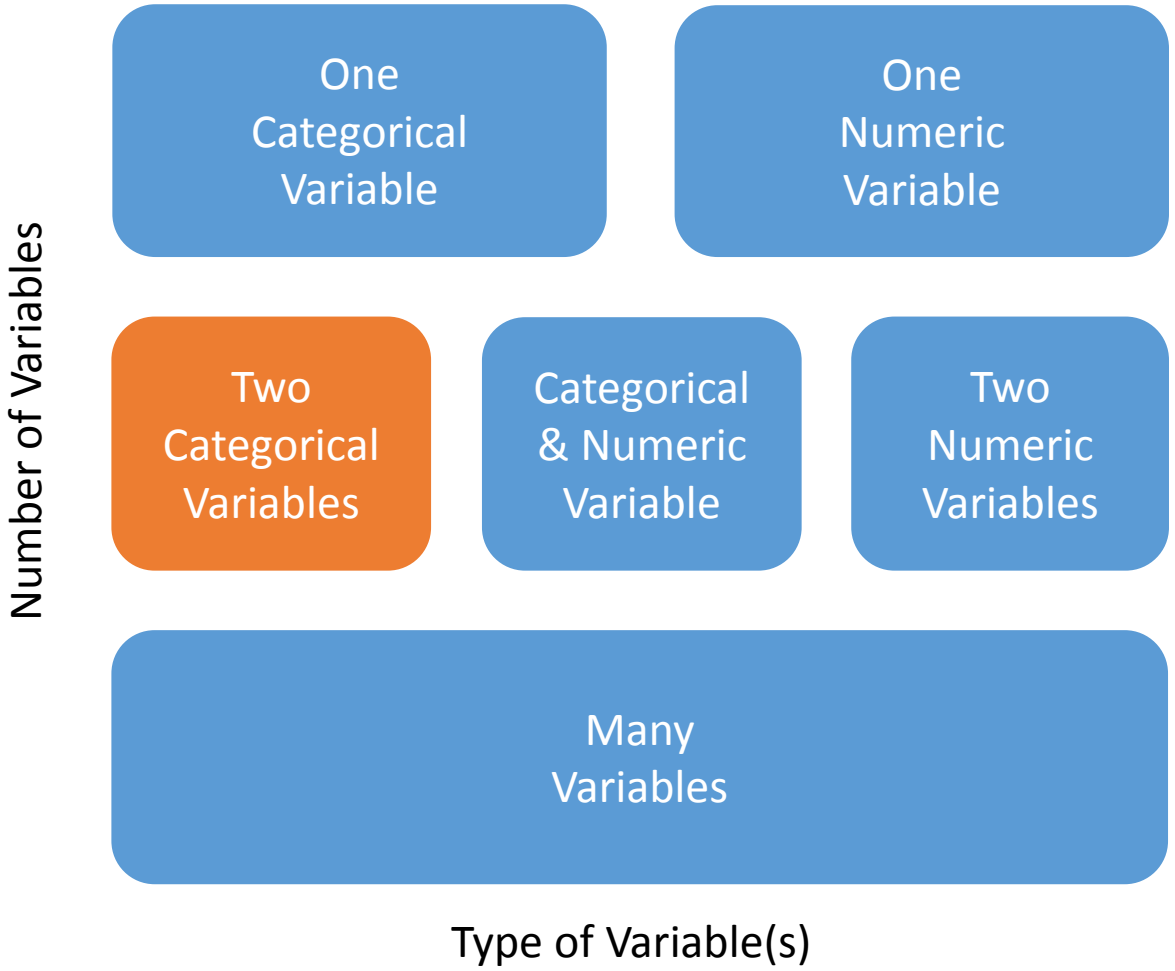


Analyzing Two Categorical Variables

Qualitative bivariate analysis

Joint frequency

Contingency tables



Analyzing Two Numeric Variables

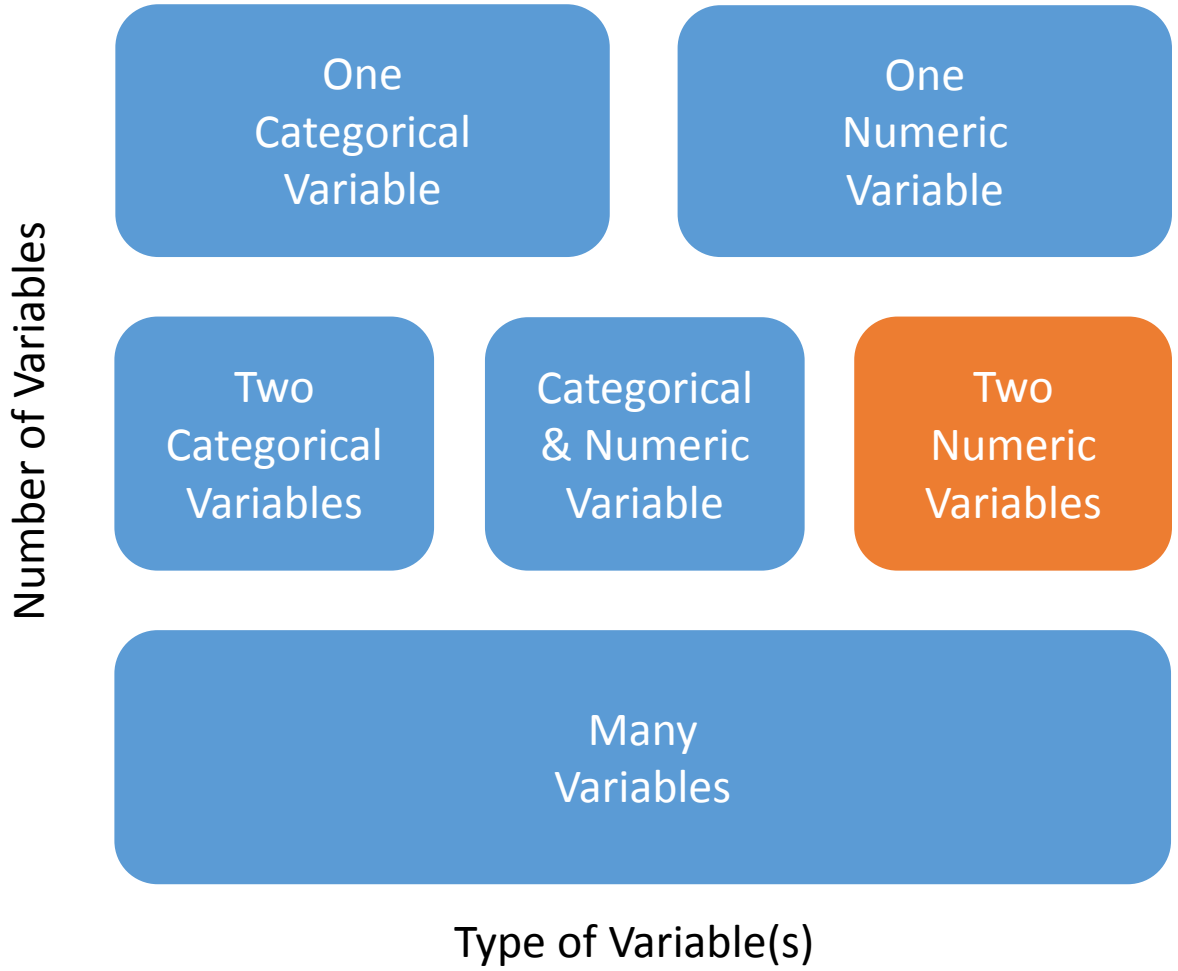
Quantitative bivariate analysis

Two variables

- Predictor
- Outcome

Measures

- Covariance
- Correlation

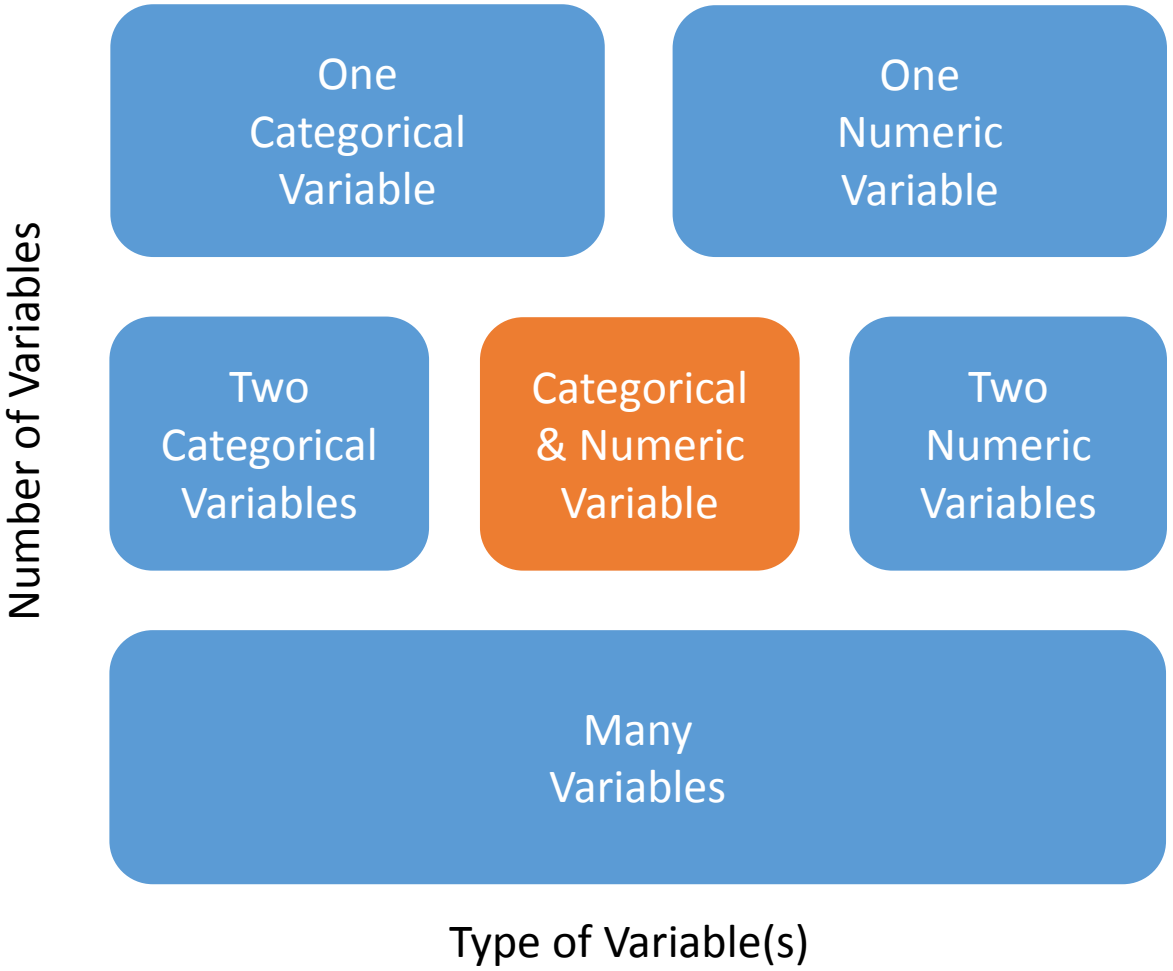


Analyzing a Numeric Variable Grouped By a Categorical Variable

One categorical variable

One numeric variable

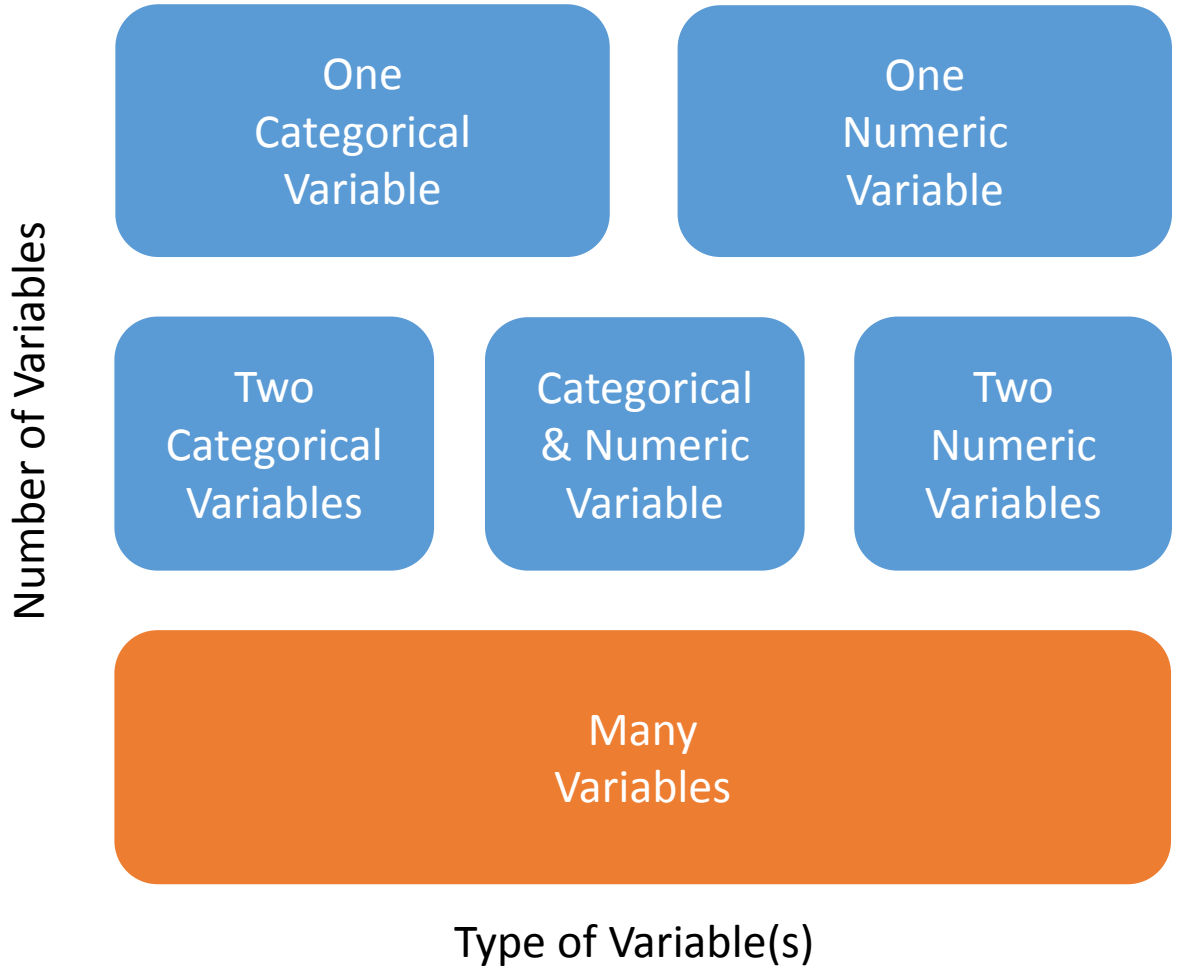
Aggregate measures



Analyzing Many Variables

Multivariate analysis

Specific meaning in statistics




COWBOYS &
Space Invaders:
The Musical
Extended Edition
R

Code Demo

Lab 3
Descriptive Statistics


COWBOYS &
Space Invaders:
The Musical
Extended Edition
R


COWBOYS &
Extended Edition
R

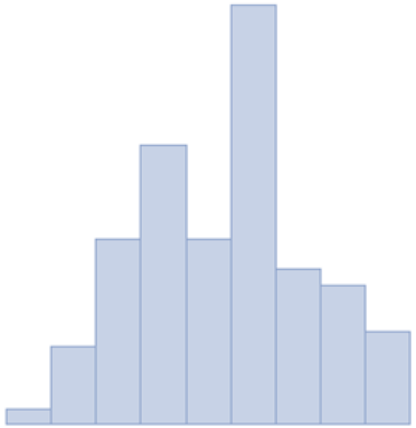
Data Visualization

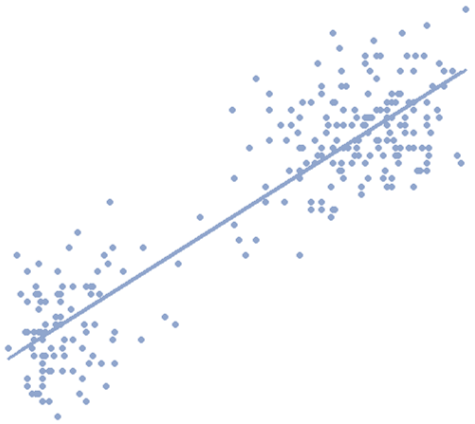
Data Visualization

Visual data representation

For human pattern recognition

Map dimensions to visual





Data Visualization

ID	Date	Customer	Product	Quantity
1	2015-08-27	John	Pizza	2
2	2015-08-27	John	Soda	2
3	2015-08-27	Jill	Salad	1
4	2015-08-27	Jill	Milk	1
5	2015-08-28	Miko	Pizza	3
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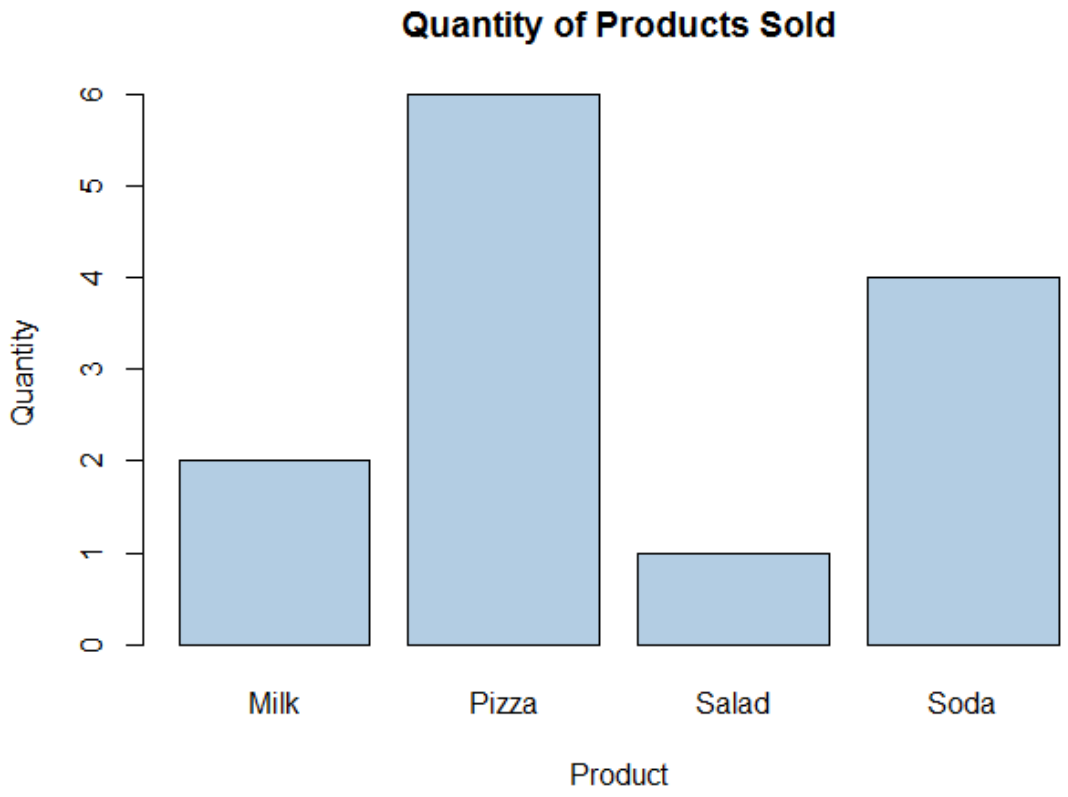
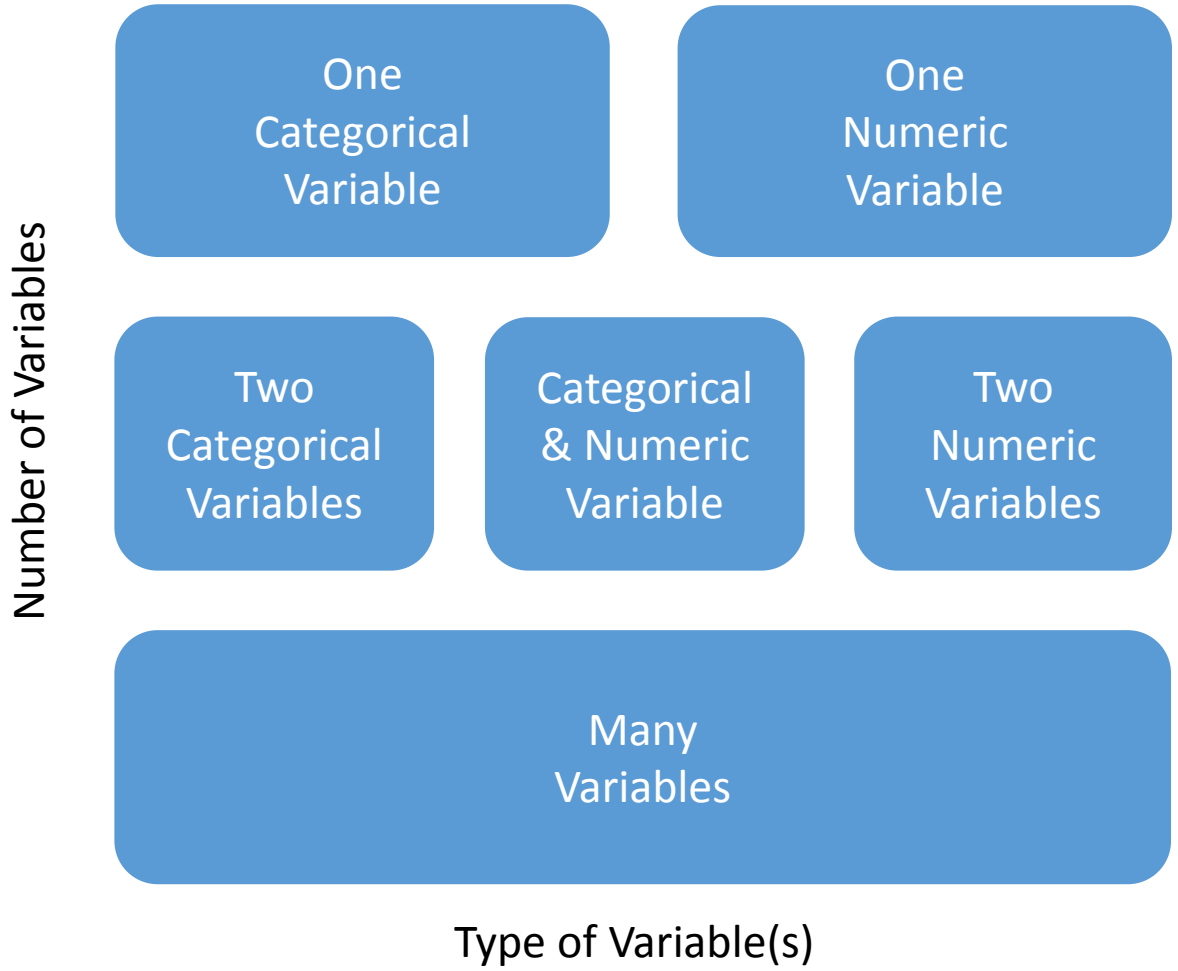


Types of Data Visualizations

Number of variables

Type of variable(s)



Visualizing One Categorical Variable

Frequency

Proportion

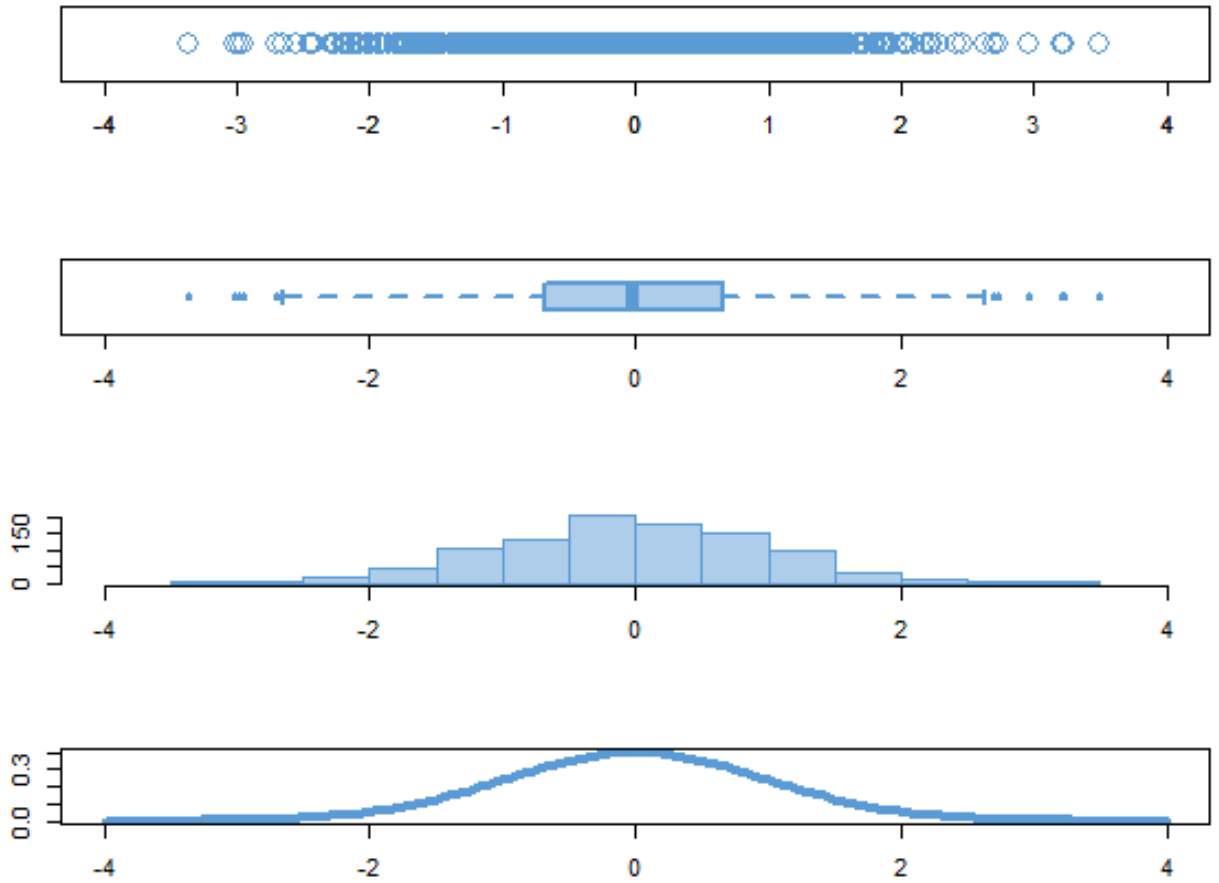
Movies by Genre		
Genre	Frequency	Percentage
Action	612	9%
Adventure	496	7%
Animation	168	2%
Comedy	1281	18%
Drama	1570	22%
Horror	269	4%
…	…	…

Visualizing One Numeric Variable

Location

Spread

Shape



Visualizing Two Categorical Variables

Joint frequency

Marginal frequency

Relative frequency

Movies by Genre and Rating					
Genre	G	PG	PG-13	R	Total
Action	2	70	311	229	612
Adventure	44	179	209	64	496
Animation	43	111	8	6	168
Comedy	45	258	472	506	1218
Drama	12	136	586	836	1570
Family	38	181	10	1	230
…	…	…	…	…	…
Total	230	1207	2686	3058	7181

Visualizing Two Categorical Variables

Joint frequency

Marginal frequency

Relative frequency

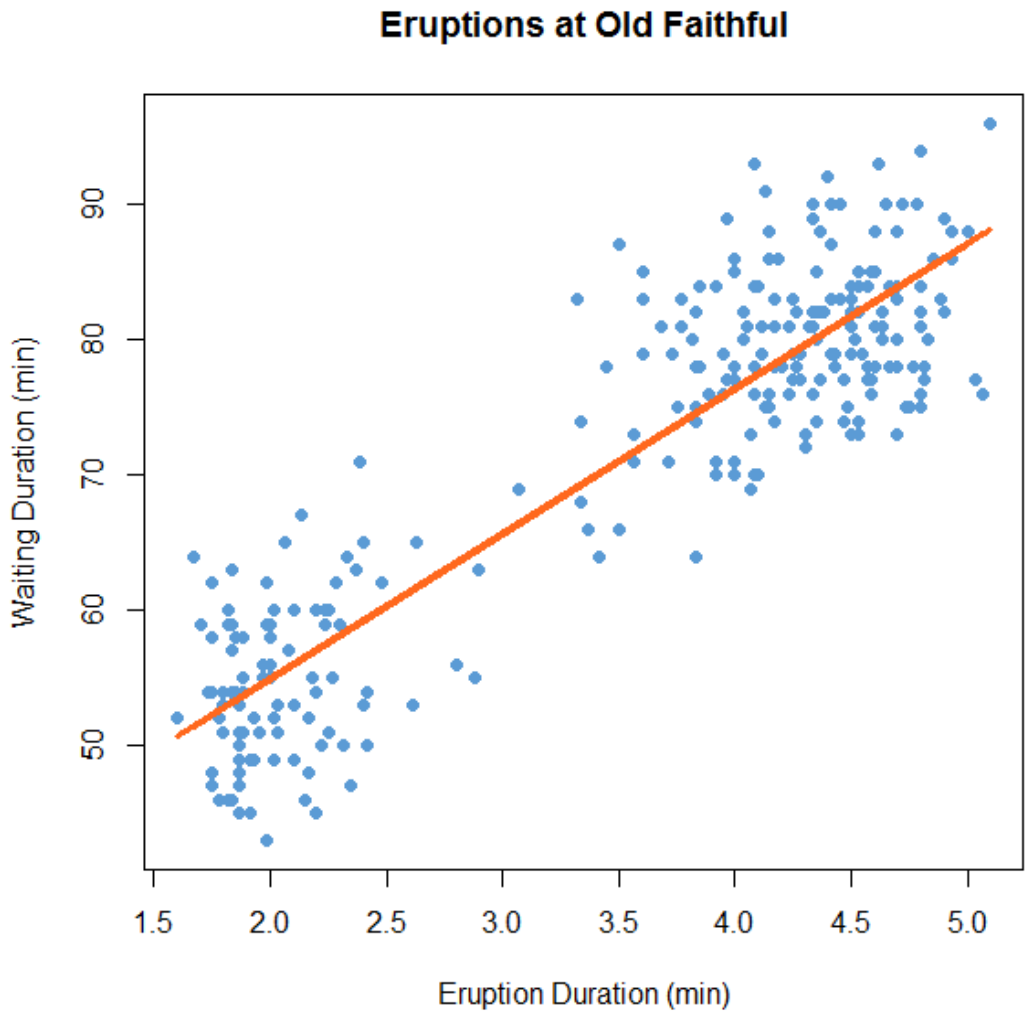
Movies by Genre and Rating					
Genre	G	PG	PG-13	R	Total
Action	0.001	0.010	0.043	0.032	0.086
Adventure	0.006	0.025	0.029	0.009	0.069
Animation	0.006	0.015	0.001	0.001	0.023
Comedy	0.006	0.036	0.066	0.070	0.170
Drama	0.002	0.019	0.082	0.116	0.219
Family	0.005	0.025	0.001	0.001	0.033
…	…	…	…	…	…
Total	0.032	0.168	0.374	0.426	1.000

Visualizing Two Numeric Variables

Relationship

Correlation

Distribution

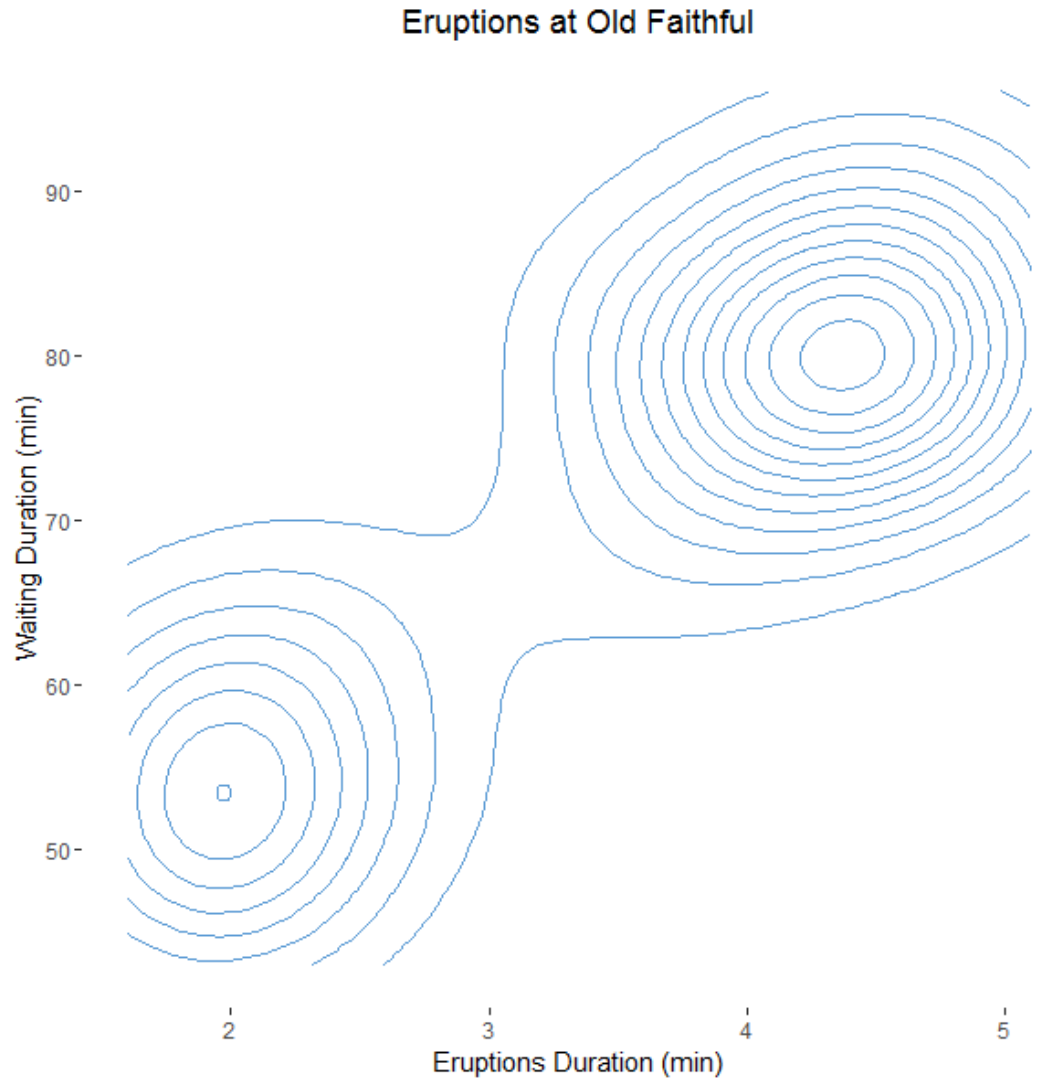


Visualizing Two Numeric Variables

Relationship

Correlation

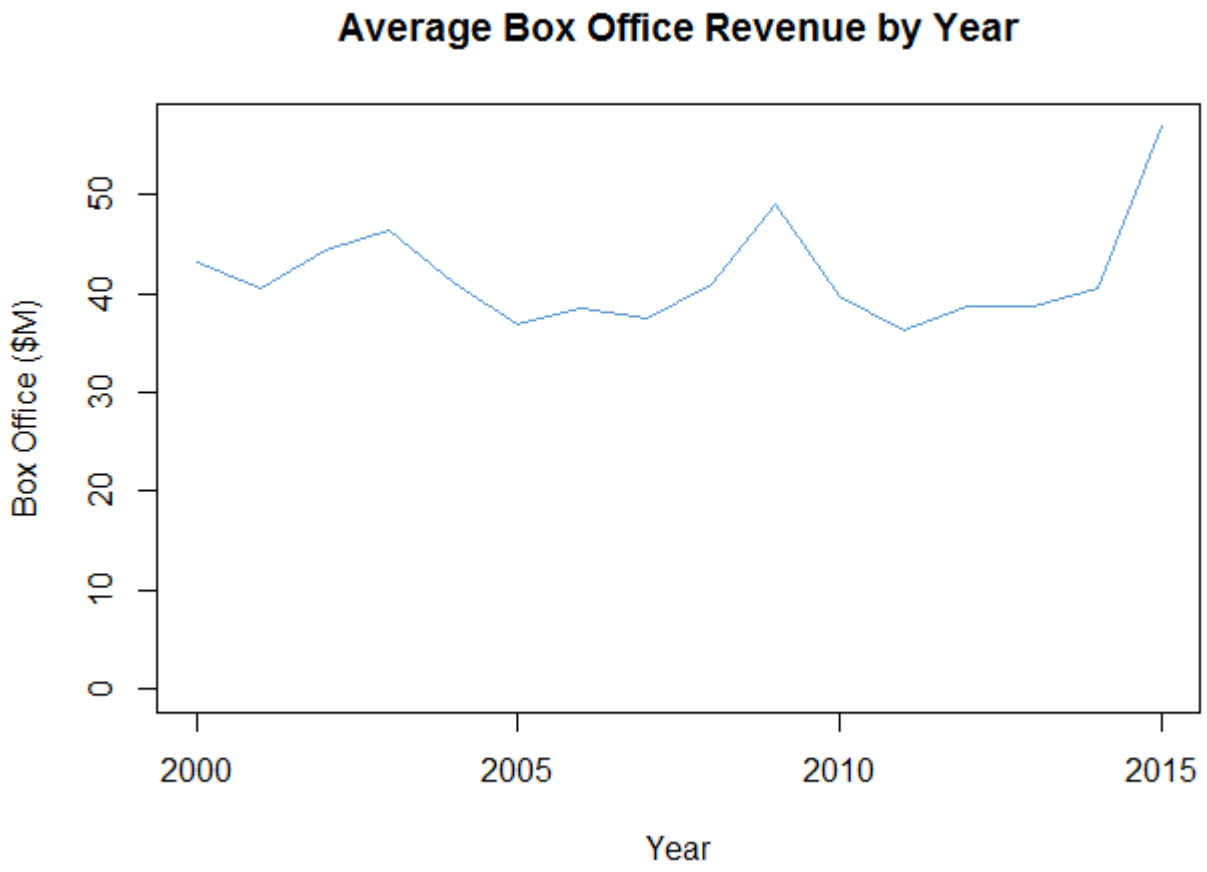
Distribution



Visualizing Time Series Data

Values over time

Rate of change

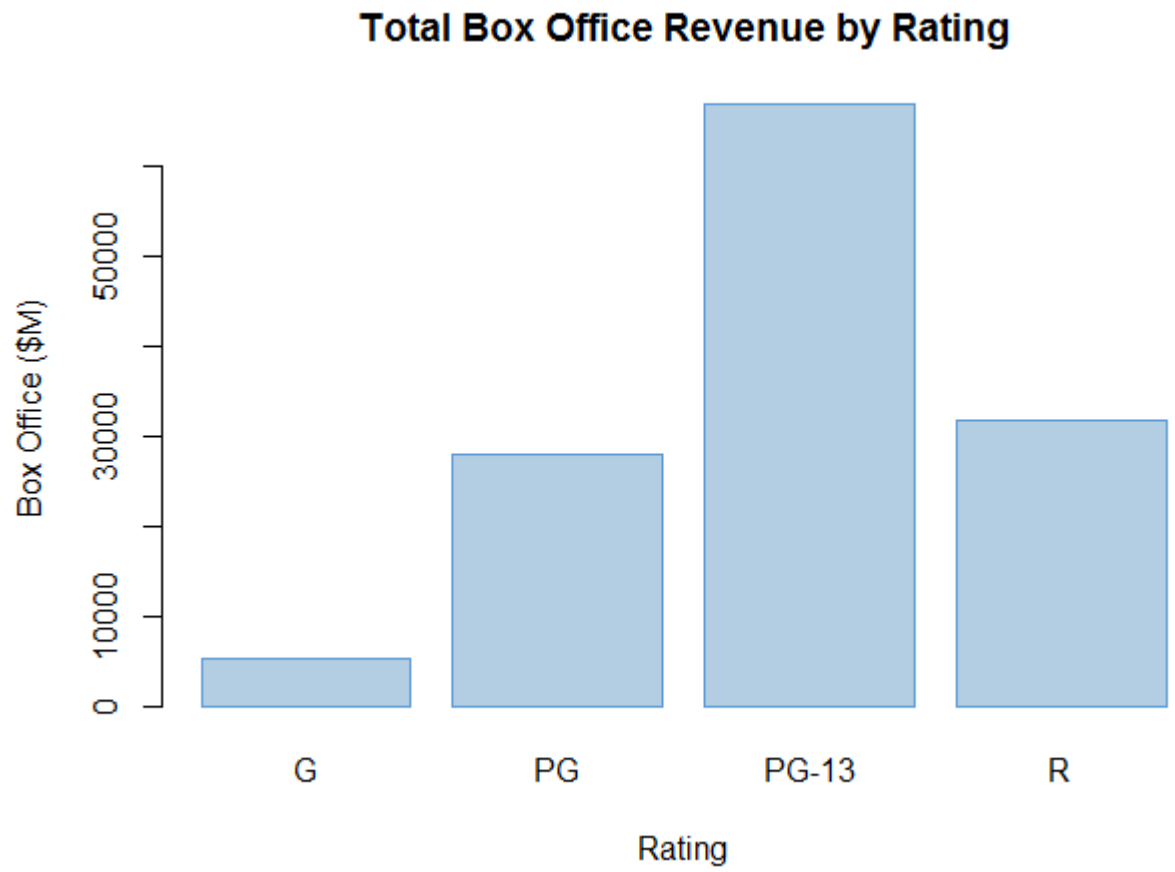


Visualizing a Numeric Variable Grouped by a Categorical Variable

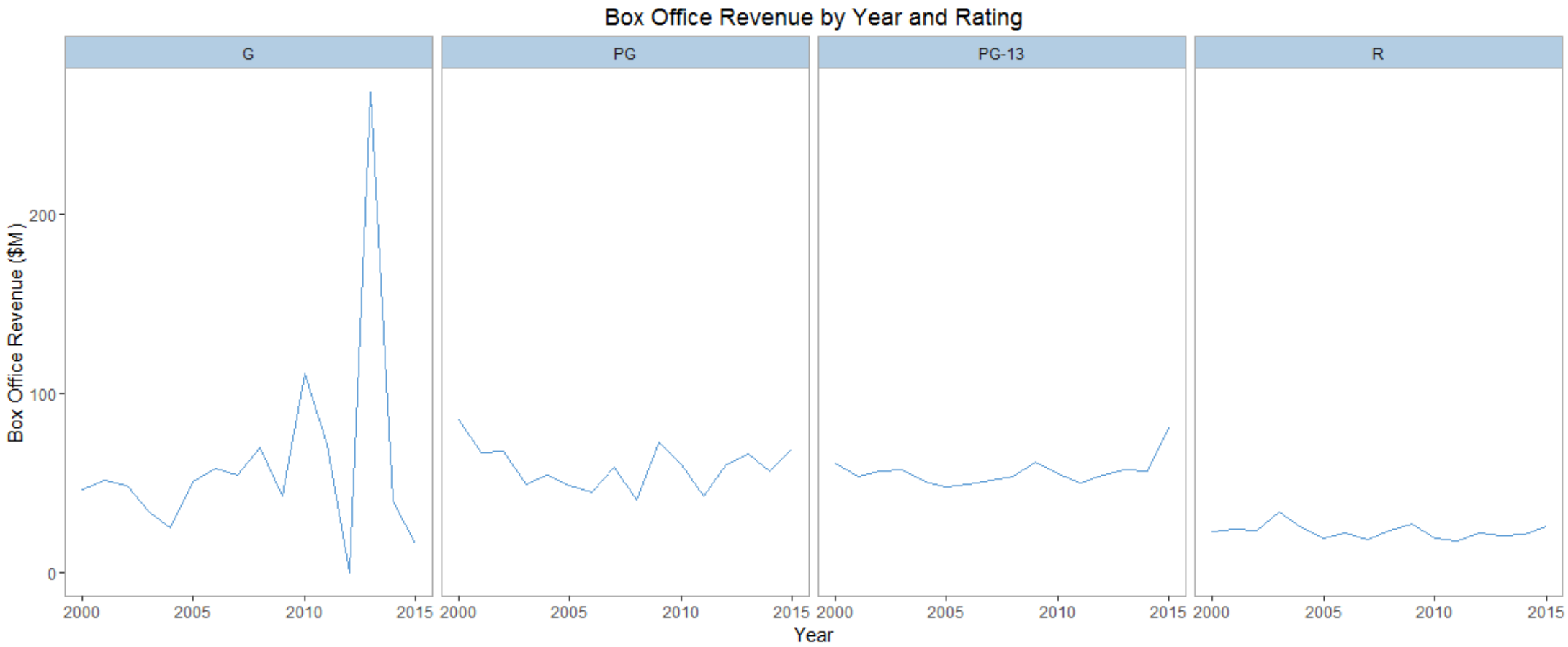
Aggregate

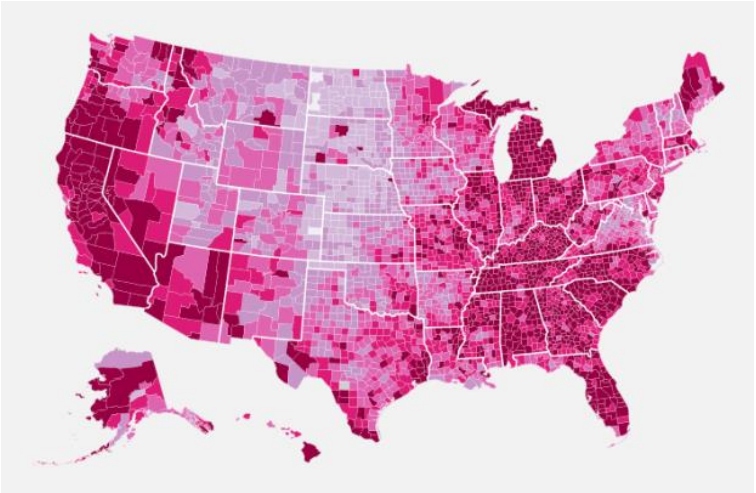
Grouped

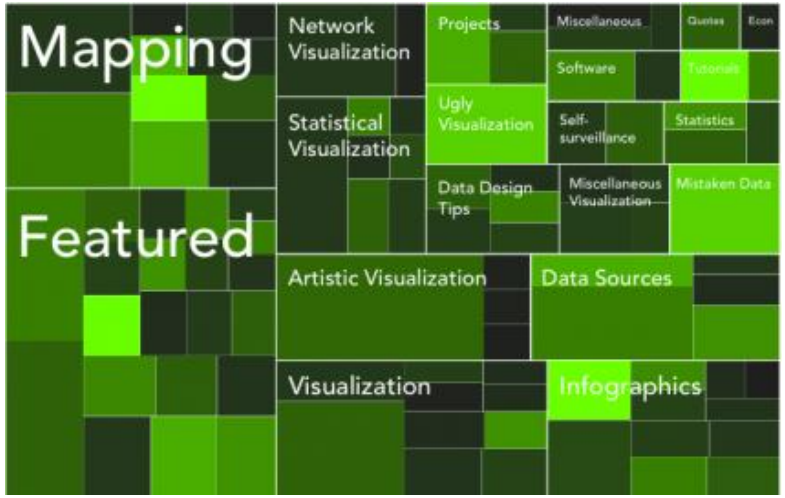
Comparison

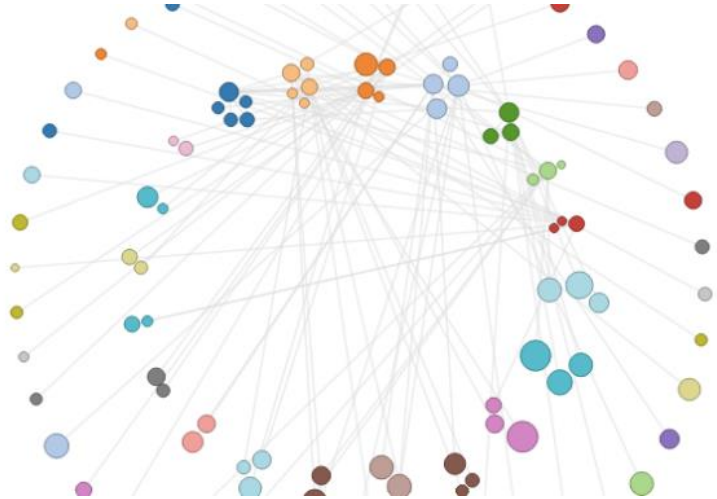


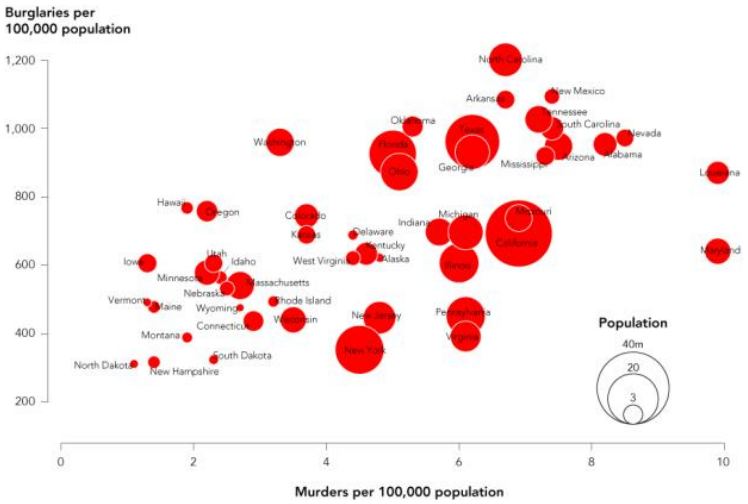
Visualizing Many Variables

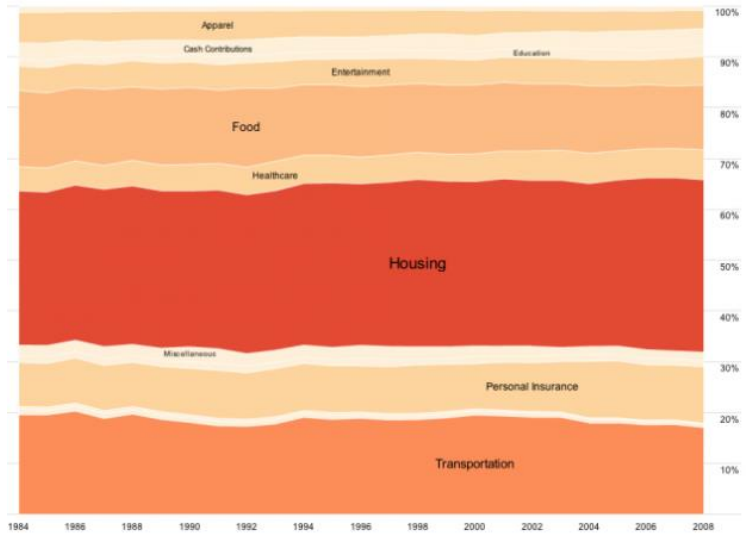


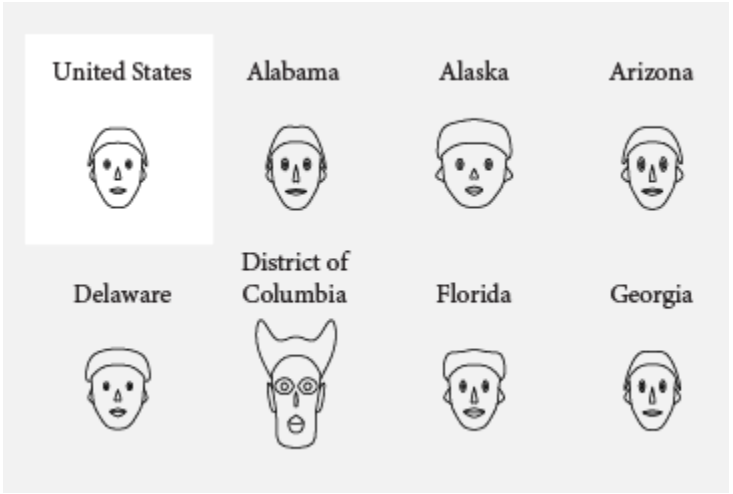






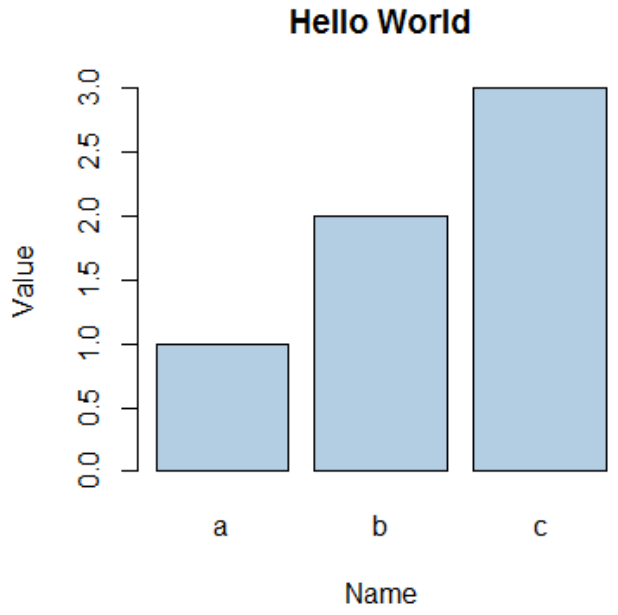




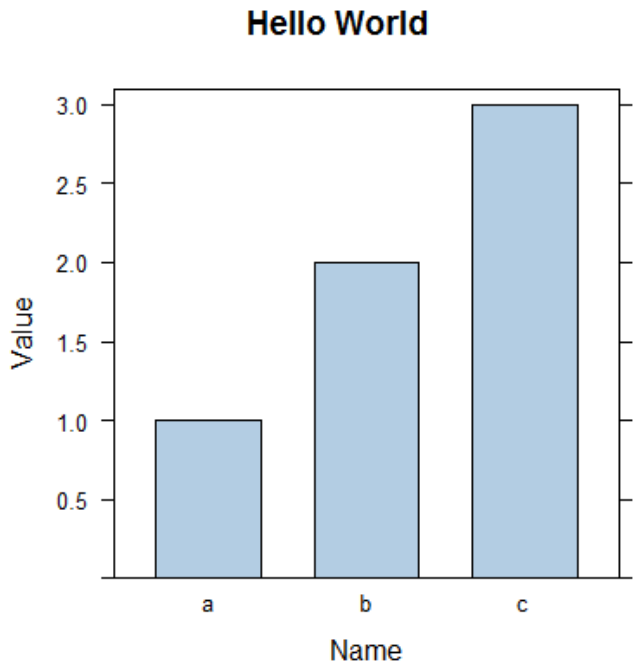


Source: Nathan Yau (www.flowingdata.com)

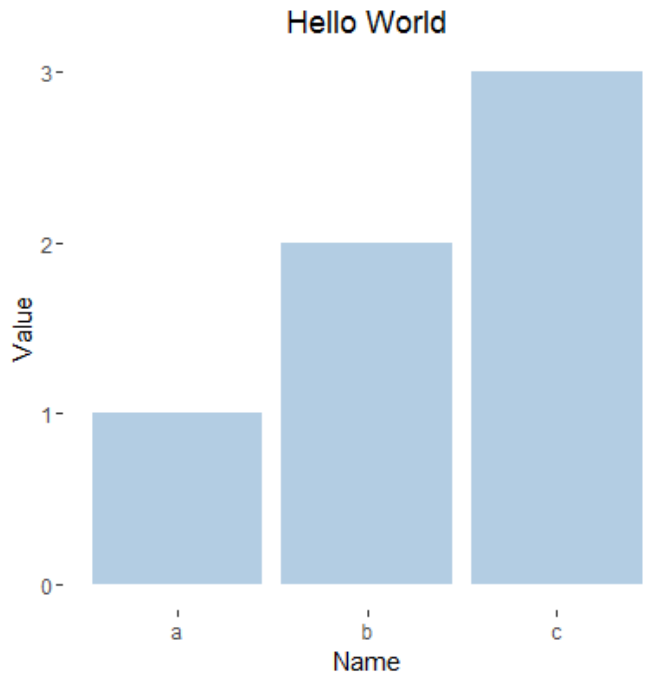
Plotting Systems in R



Base



Lattice



ggplot2


COWBOYS &
Space Invaders:
The Musical
Extended Edition
R

Code Demo

Lab 4
Data Visualization

The

Warlord

of the

Rings :

An Unexpected Adventure

Feature Length

PG

Statistical Modeling

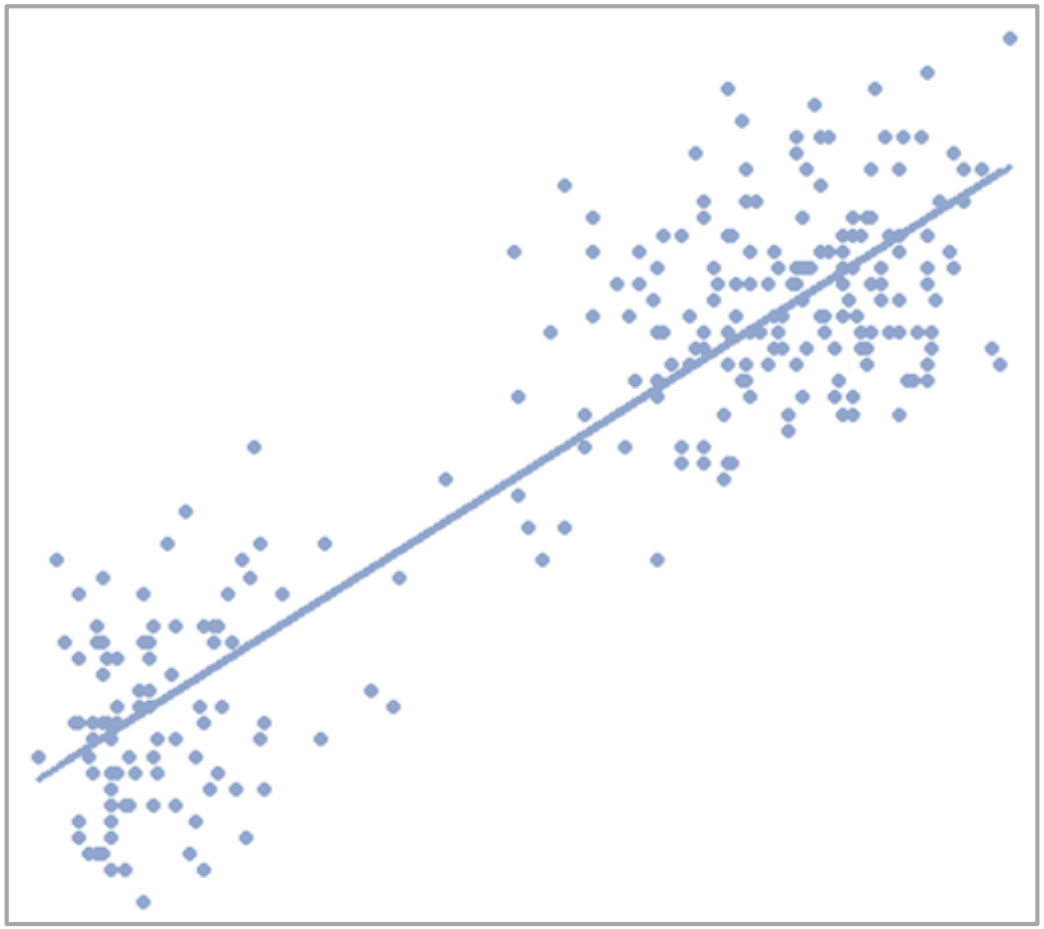
Statistical Models

Representation of reality

Mathematical function

Parametric models

Non-parametric models



Types of Statistical Models

Probability distribution

ANOVA

Linear regression

Non-linear regression

Bayesian network

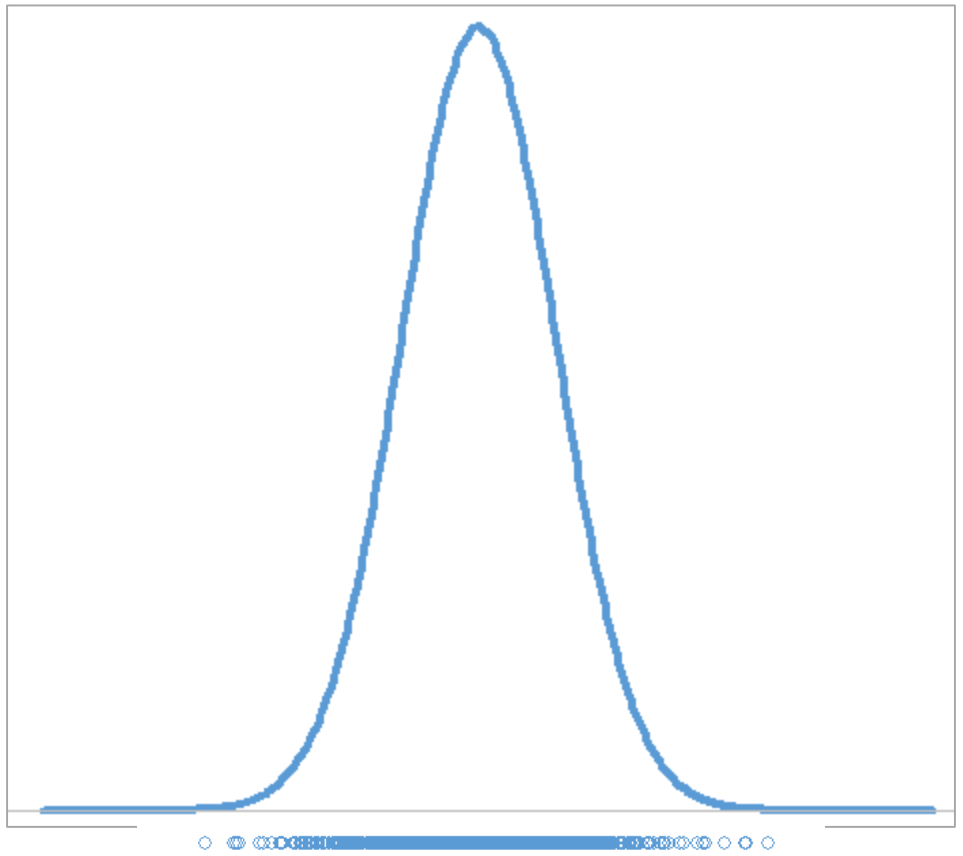
Gaussian Distribution

Probability distribution

Parametric model

- Mean
- Standard deviation

Generative model



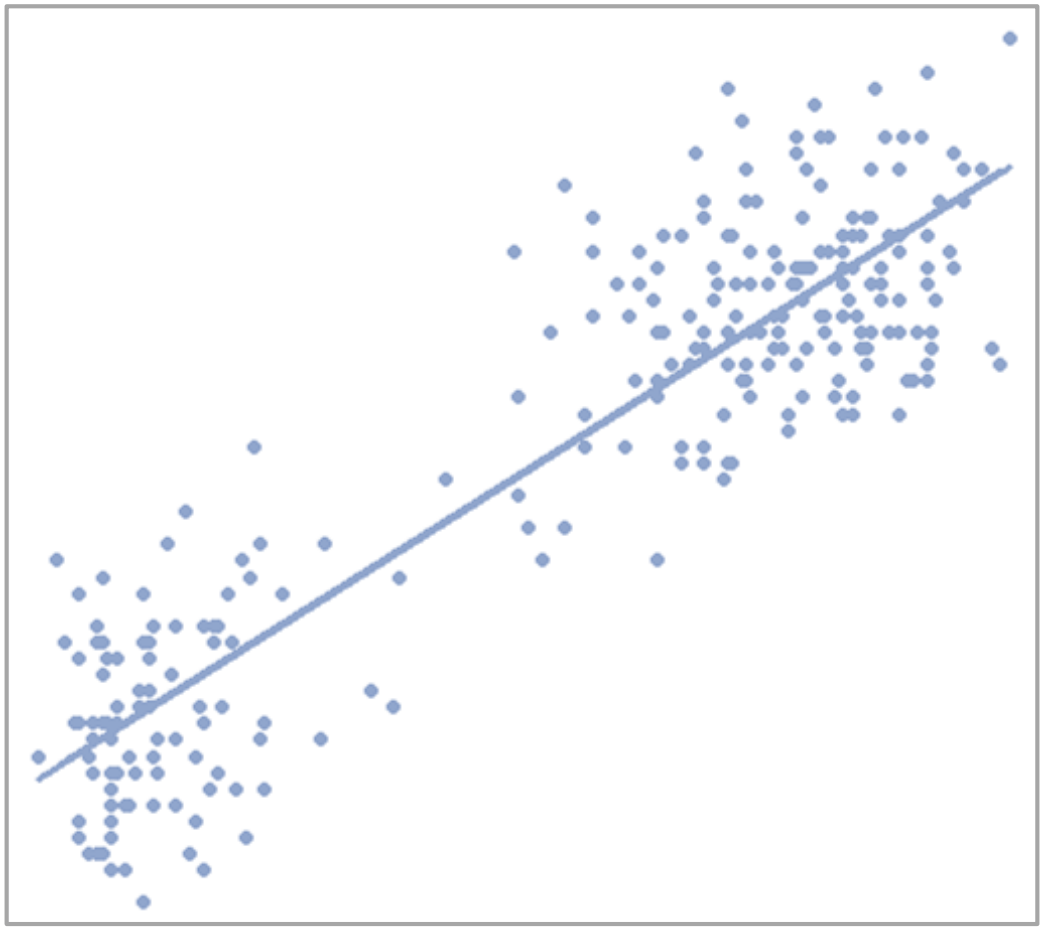
Simple Linear Regression

Linear model

Relationship between variables

Continuous explanatory variable

Single scalar dependent variable



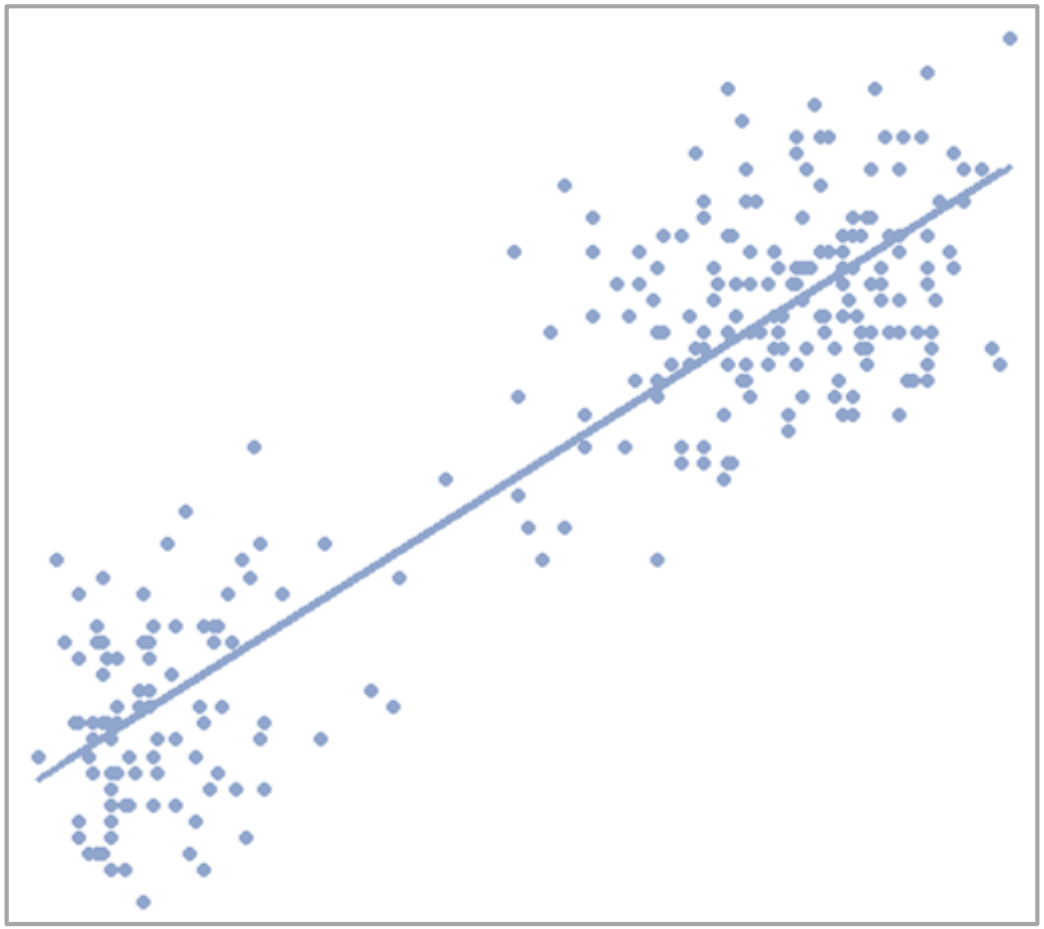
Simple Linear Regression

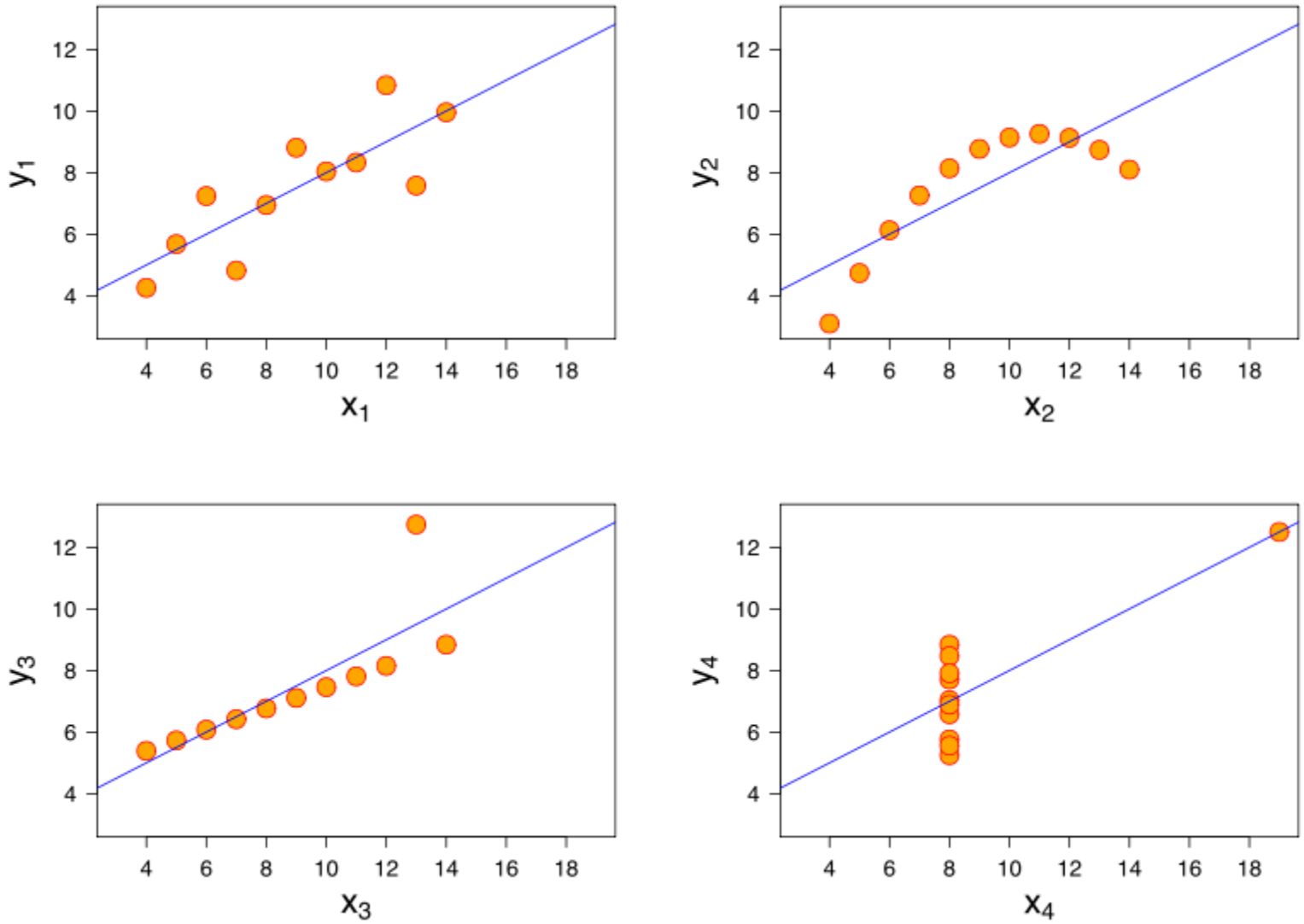
Linear predictor function

$y = m \cdot x + b$

Parameters estimated from data

Makes certain assumptions





Source: https://en.wikipedia.org/wiki/Anscombe%27s_quartet

Photo by Danielle Langlois

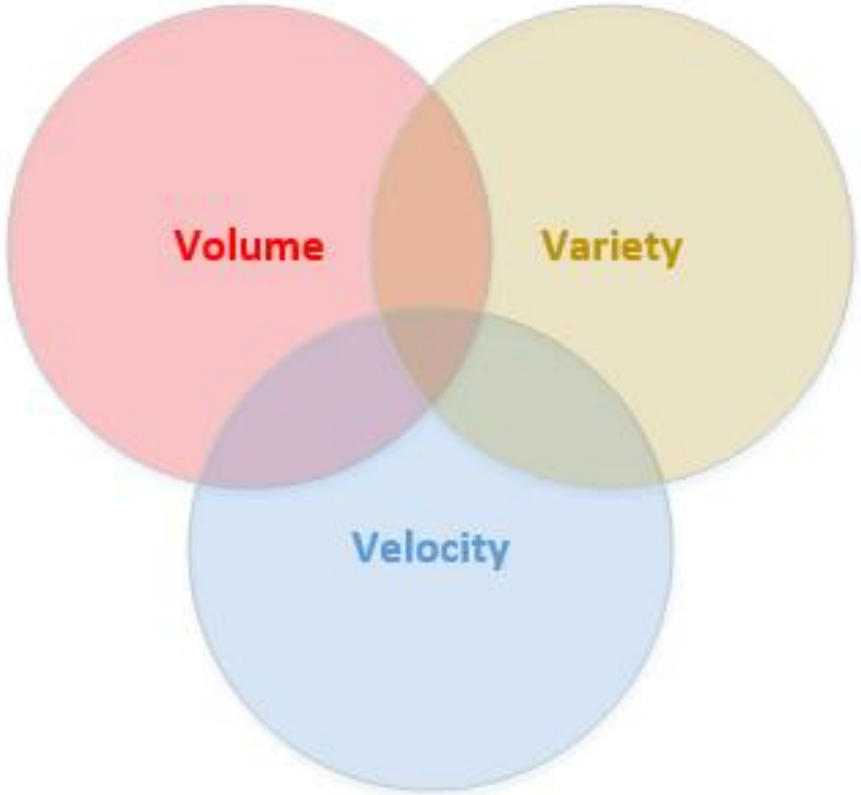
Code Demo

Lab 5
Statistical Models

Photos by Radomił Binek,
Danielle Langlois, and Frank Mayfield

Handling Big Data

What is Big Data?



Big Data is a Moving Target

What is Big Data today

Will not be Big Data tomorrow

Do I Have Big Data?

Can it fit in memory?

Can it fit on your hard drive?

Can you process it in a day?

Does it fit into tables?

Big Data Decision Table

class	size	manage with	how it fits	examples
small	< 10 GB	Excel, R	fits in one machine's memory	thousands of sales figures
medium	10GB-1TB	indexed files, monolothic DB	fits on one machine's disk	millions of web pages
Big	> 1TB	Hadoop, distributed DBs	stored across many machines	billions of web clicks

Note: Last updated in 2010

Source: Michael E Driscoll

Decision Table for Big Data in R

Class	Rows	Manage with
Small	Less than 1 million	R on desktop computer
Medium	1 million to 1 billion	R with 3rd party support
Big	More than 1 billion	R with big data support

Source: Jan Wijffels at useR!-Conference (2013)

If you don’t have a big data problem,
but you think you got a big data problem,
then you’ve just created a big data problem!

How to Handle Big Data in R

Sampling

Microsoft R Open

3rd-party medium data packages

3rd-party big data packages

Microsoft R Server

Sampling

Randomly selected

Subset of original data

Low-cost solution

Microsoft R Open

Enhance 64-bit R distribution

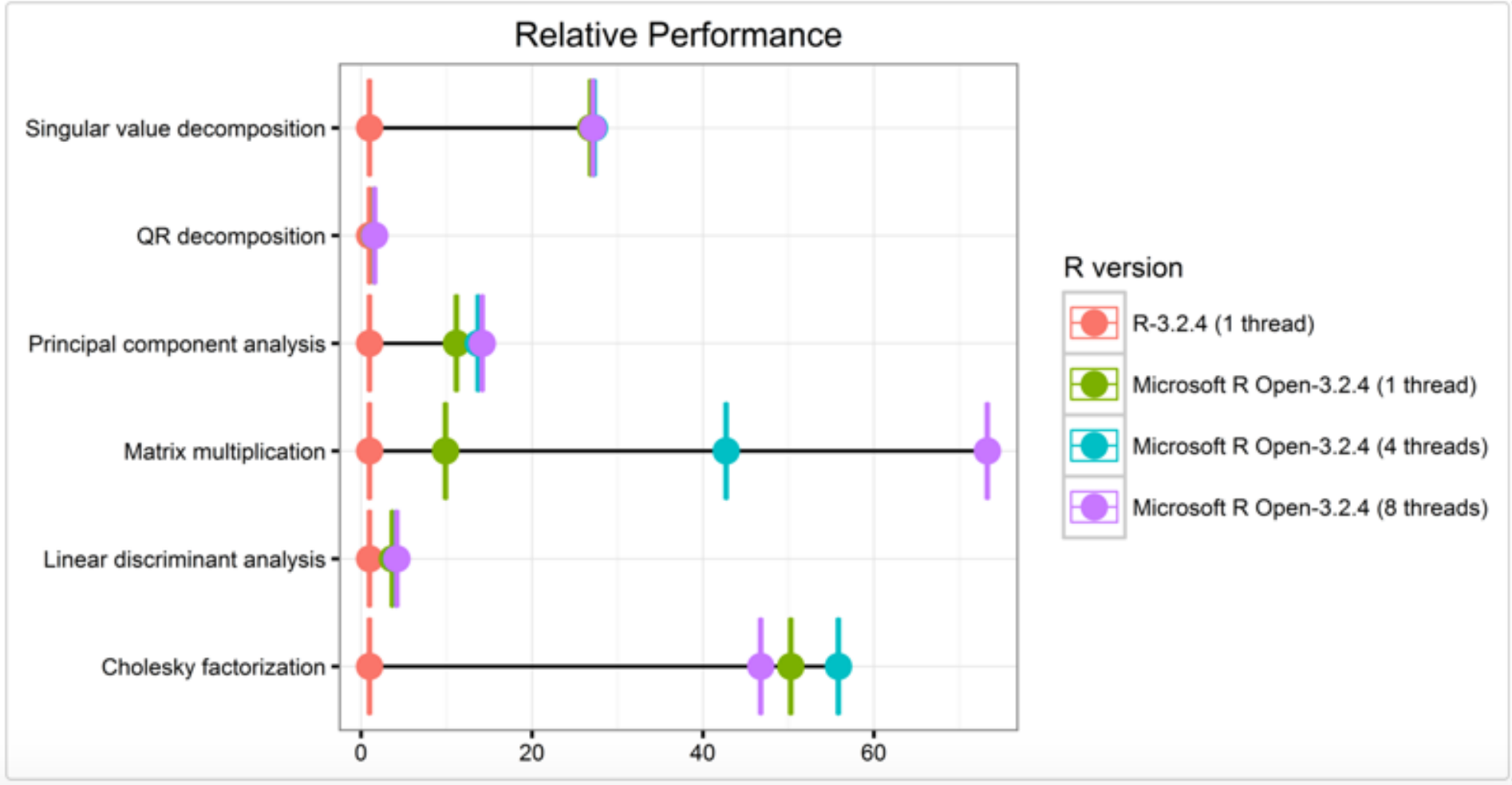
Multithreaded performance

Only helps with CPU constraint

Package repository snapshots

Source: Microsoft R Open

Microsoft R Open Performance



Source: https://mran.microsoft.com/documents/rro/multithread/#mt-bench

3rd-Party Extension Packages

Big Memory

ff

3rd-Party Extension Packages

pbdR

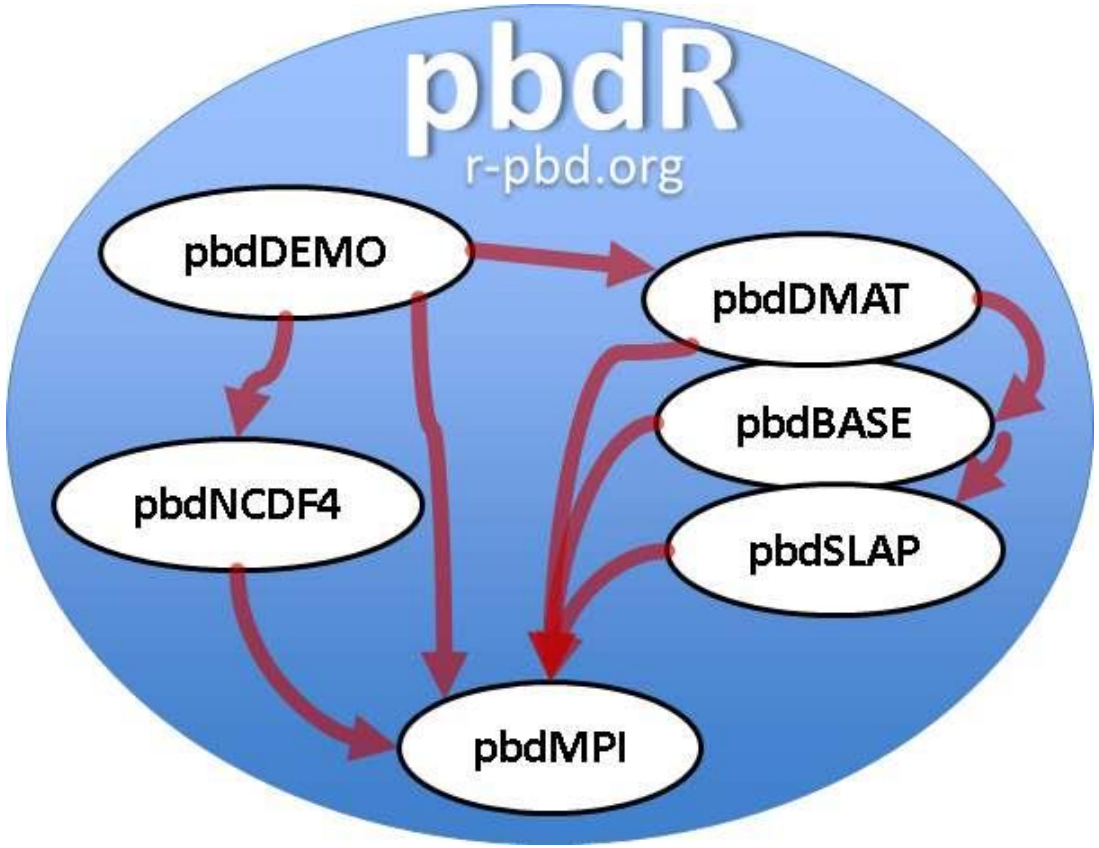
Rhipe

Rhive

Rhbase

Rhdfs,

Rmr



Source: Wikipedia

Microsoft R Server

Windows

SQL Server 2016

SUSE Linux

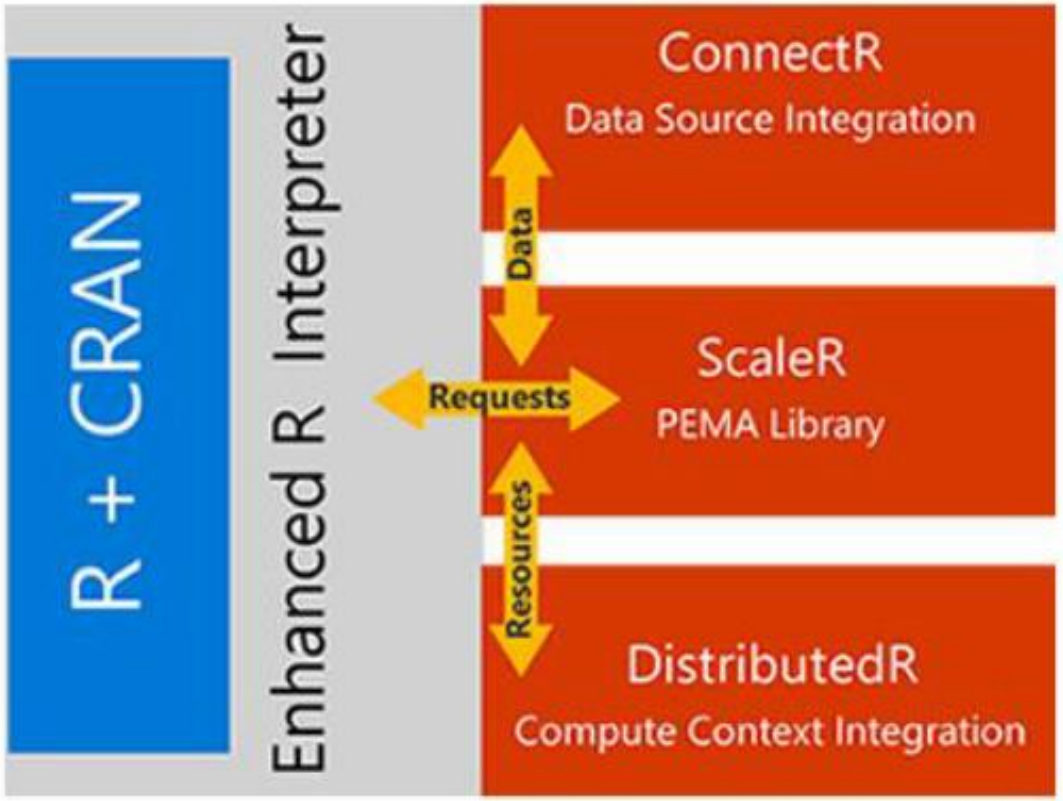
Redhat Linux

Teradata

Hadoop

HD Insight

Microsoft R Server



Source: Microsoft R Server

No Demo
or Lab 6

Machine Learning

What is Machine Learning?

Subtype of artificial intelligence

Learning without being programmed

Similar to statistical modeling

Similar to data mining

Source: Futurama

How does Machine Learning Work?

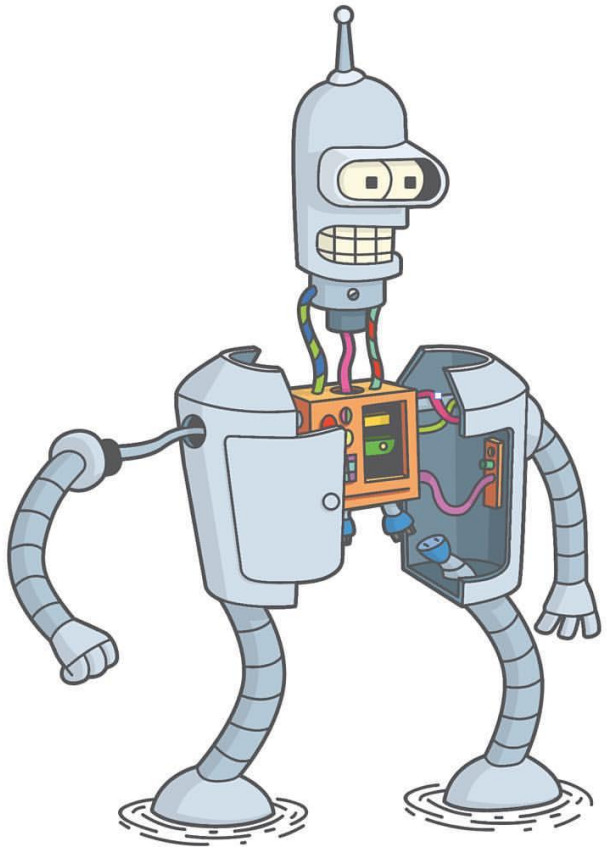
Uses statistical models

Model's parameters are trained

Trained with algorithm and data

Model is used to predict output

Prediction vs. explanation



Source: Futurama

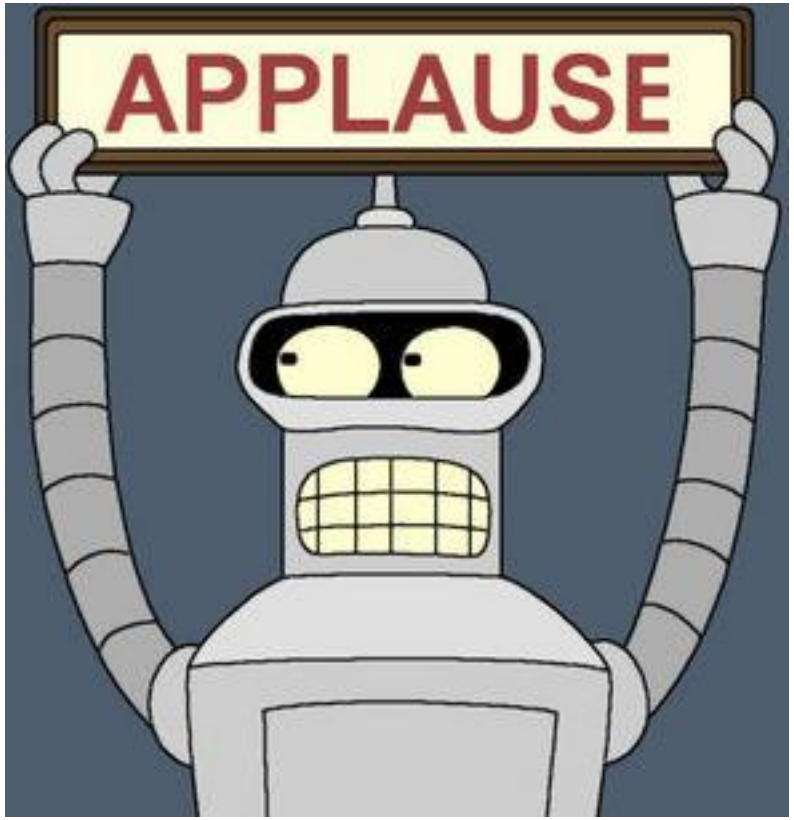
What Can Machine Learning Do?

Classification

Regression

Clustering

Anomaly detection



Source: Futurama

Types of Machine Learning

Supervised

Unsupervised

Reinforcement

Source: Futurama

Types of ML Algorithms

Decision Trees

Naïve Bayes Classifier

Linear Regression

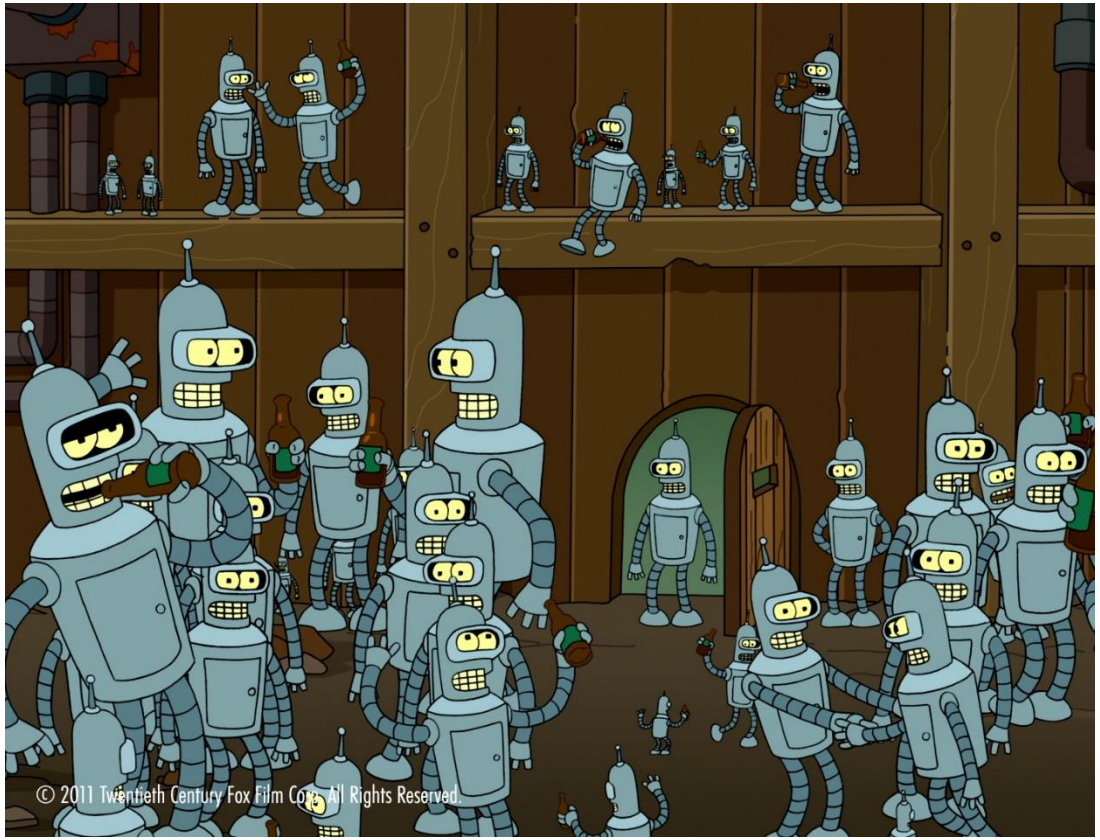
Logistic Regression

Support Vector Machines

Neural Networks

K-Means Clustering

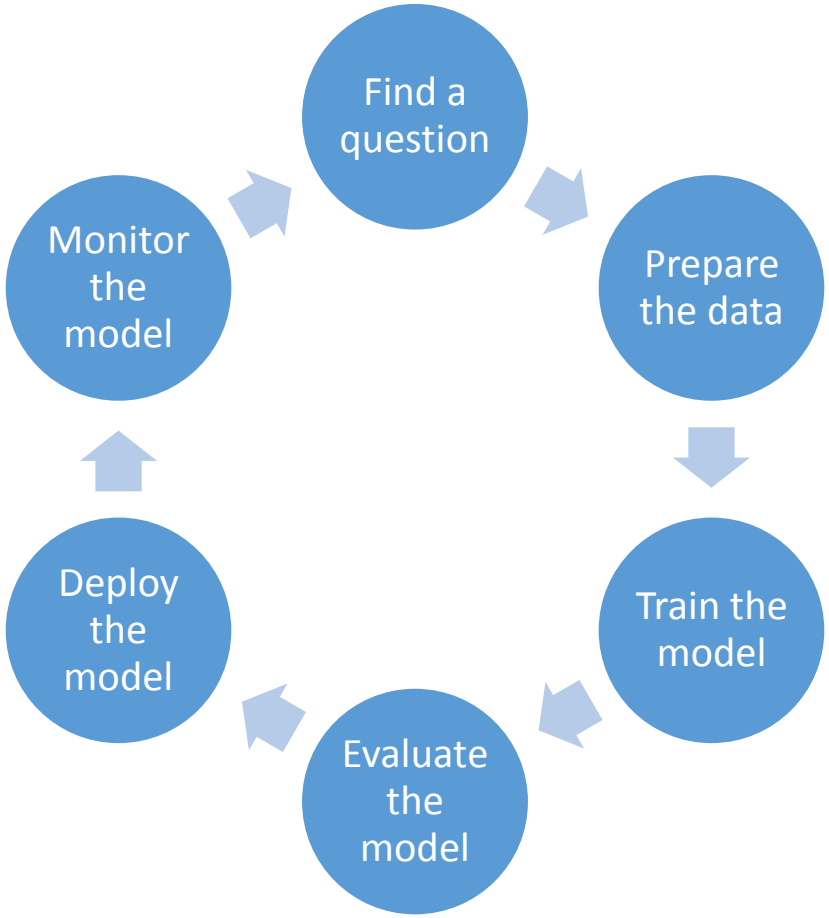
Ensemble Learning



Source: Futurama

The Machine Learning Process

1. Find a question
2. Prepare the data
3. Train the model
4. Evaluate the model
5. Deploy the model
6. Monitor the model



Photos by Radomił Binek,
Danielle Langlois, and Frank Mayfield

Code Demo

Lab 7
Machine Learning

R in Practice

How to Use R in Practice?

1. Deploying R to production
2. Best Practices
3. Creating reproducible research

How to Deploy to Production

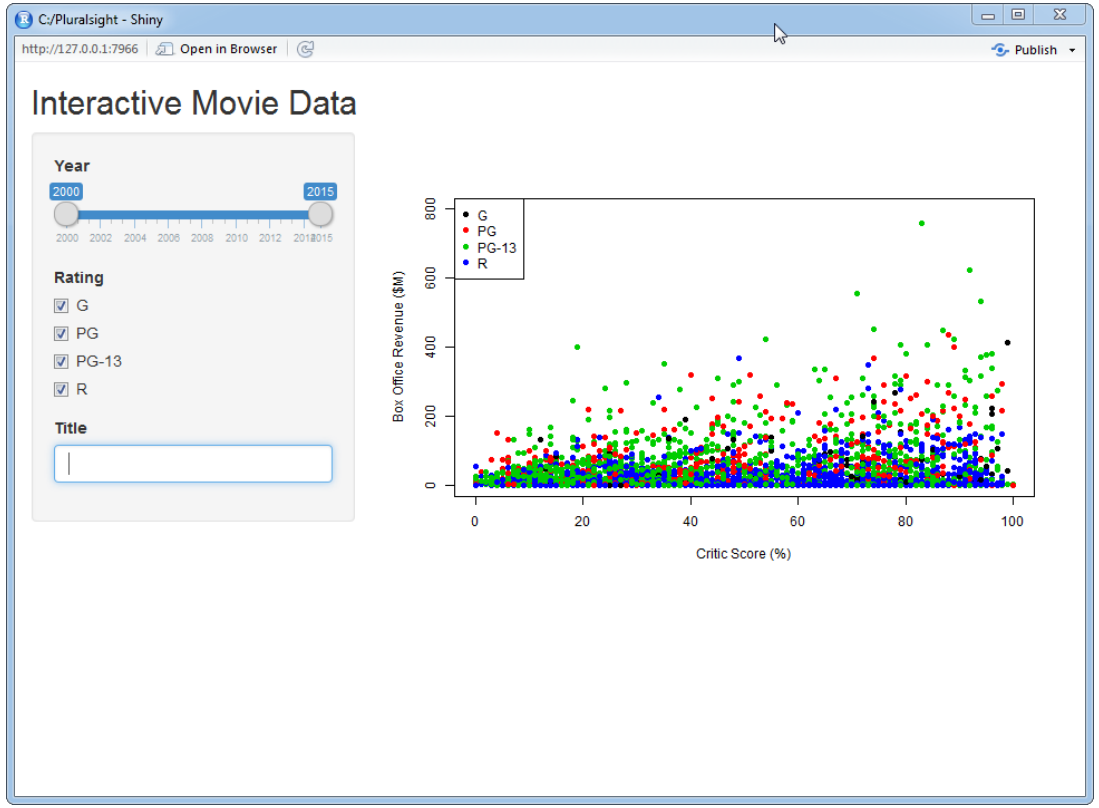
Export charts (Rstudio)

Create documents (Markdown)

Create interactive reports (Shiny)

Deploy to Server (R Server)

Deploy to Cloud (Azure ML)

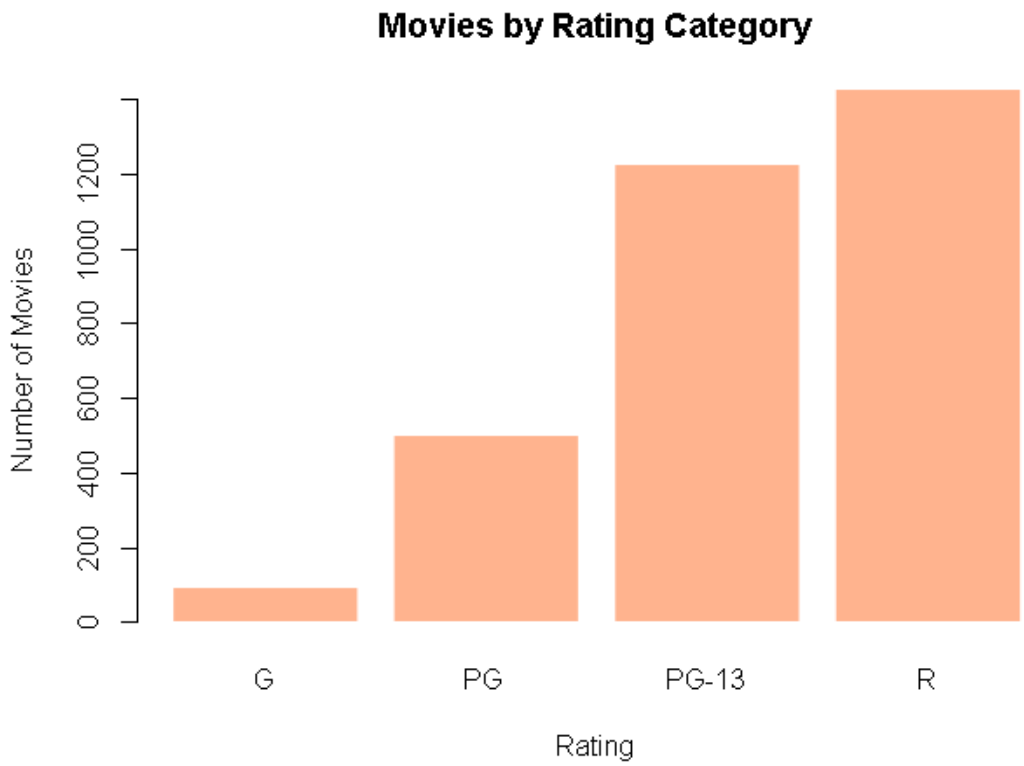


Code Demo

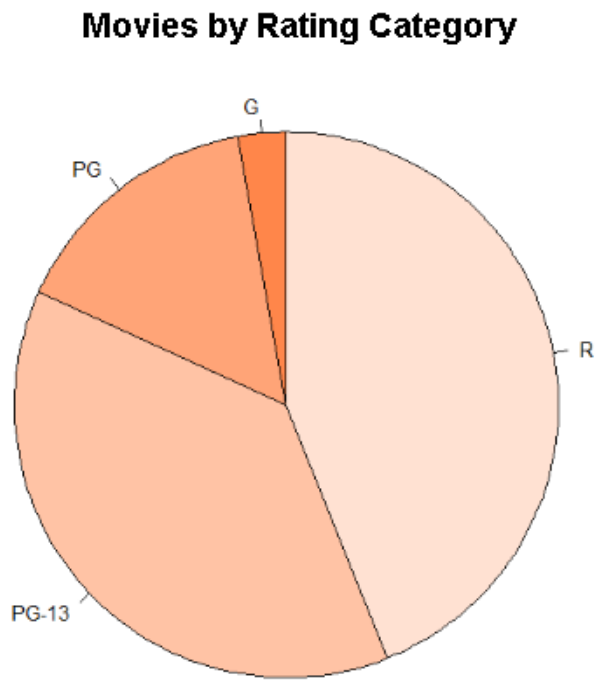

ADVICE
HELP
TIPS
SUPPORT
GUIDAN

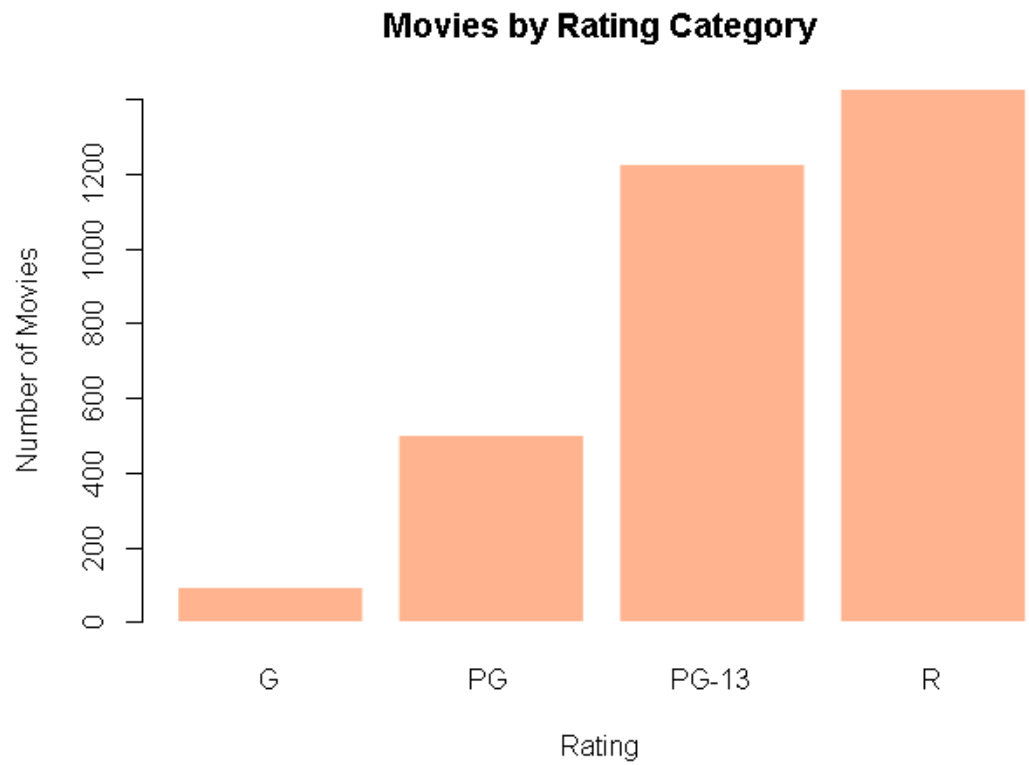
Start with a Question

How many movies were released in each rating category from 2000 to 2015?

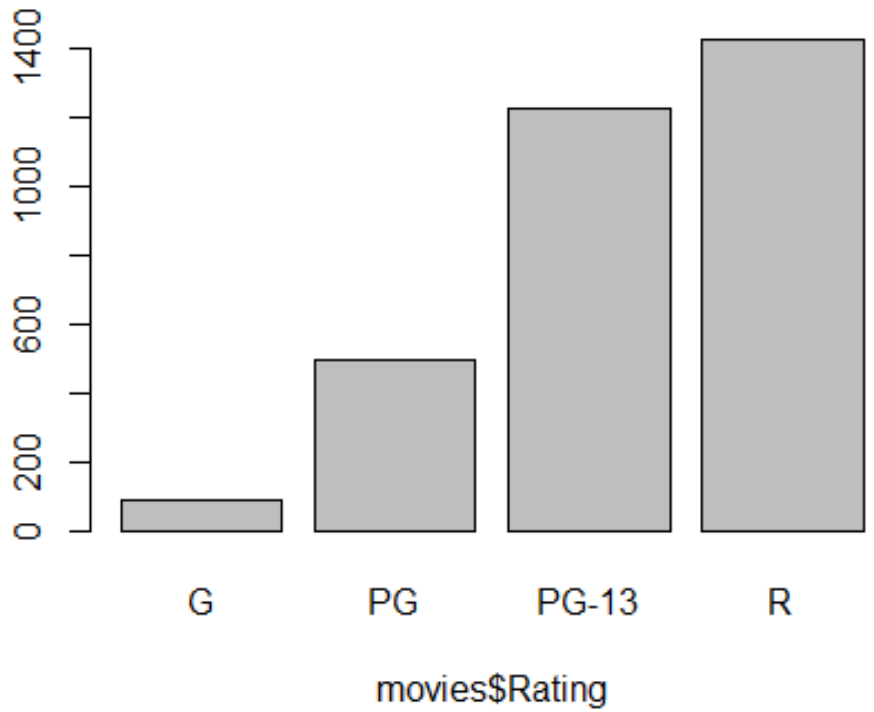


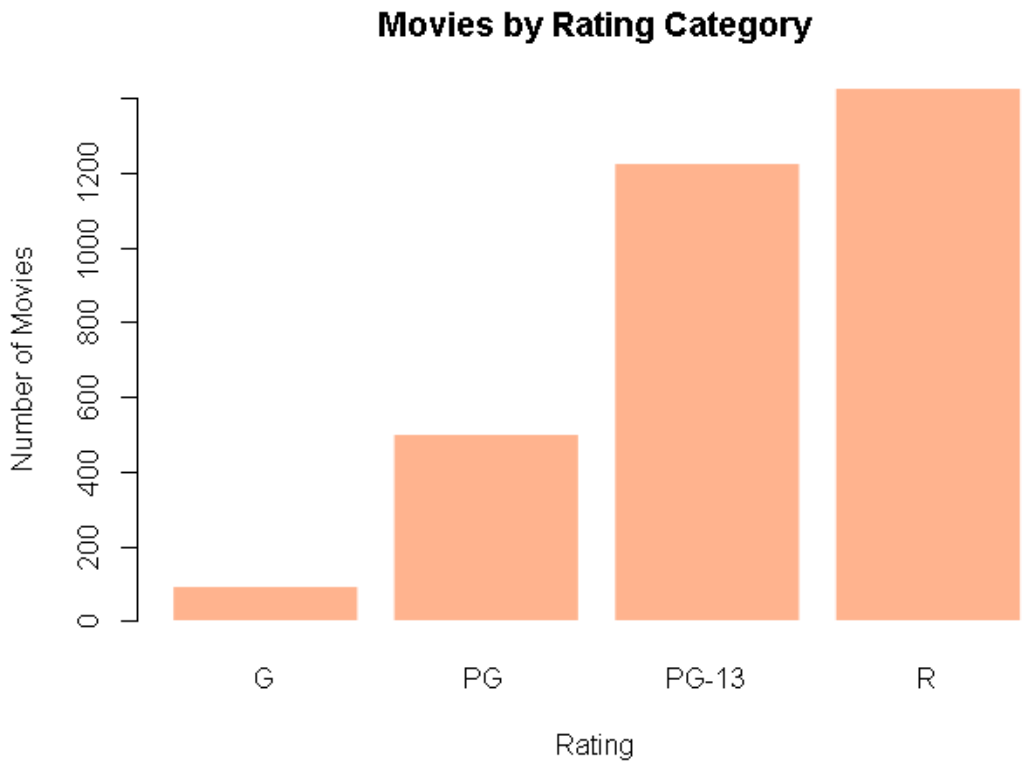
Use the Right Tool for the Job



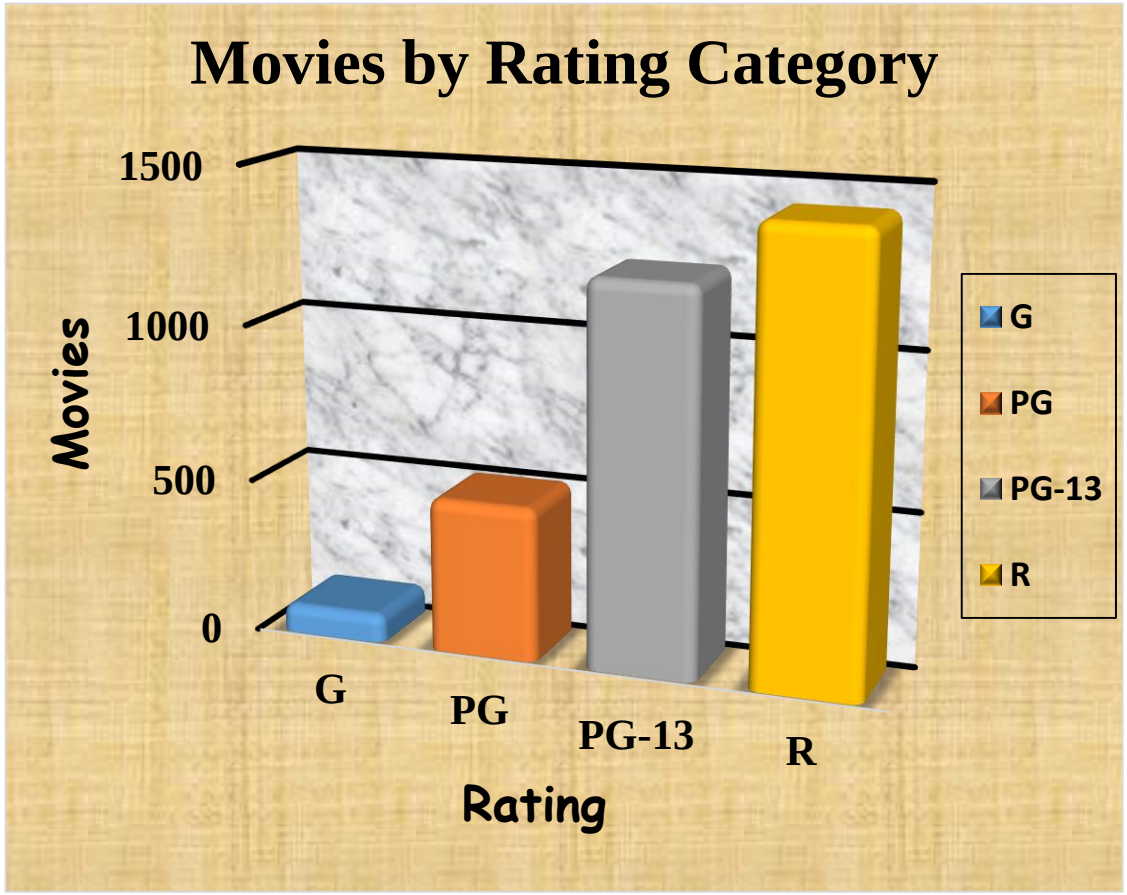


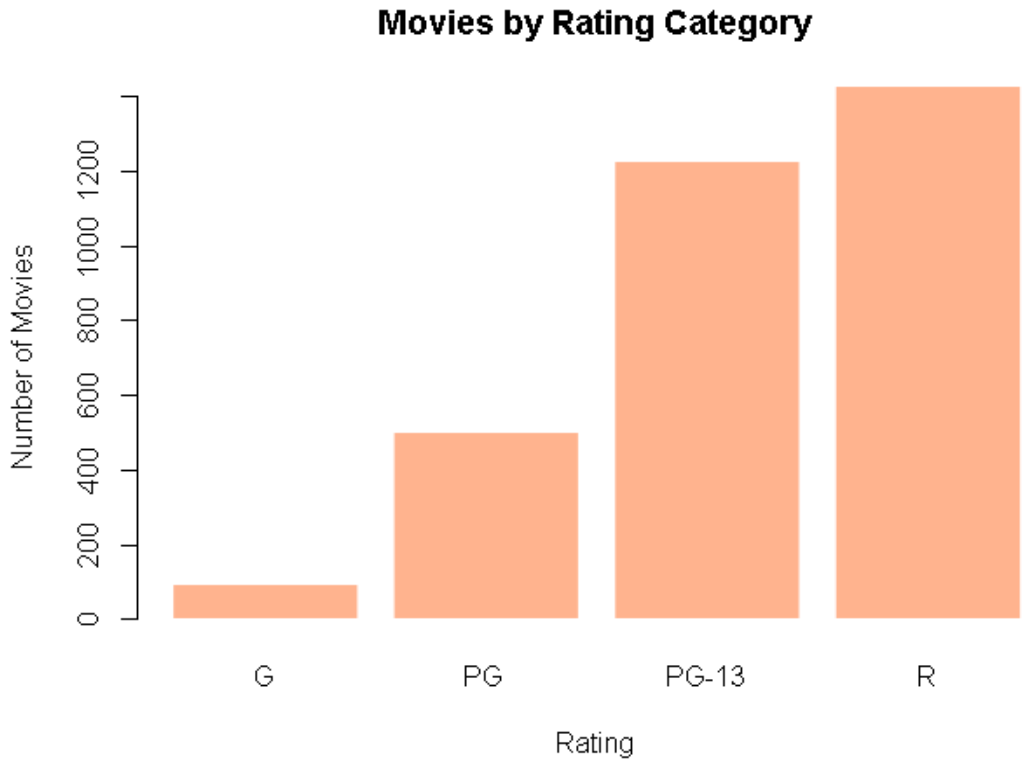
Know Your Audience



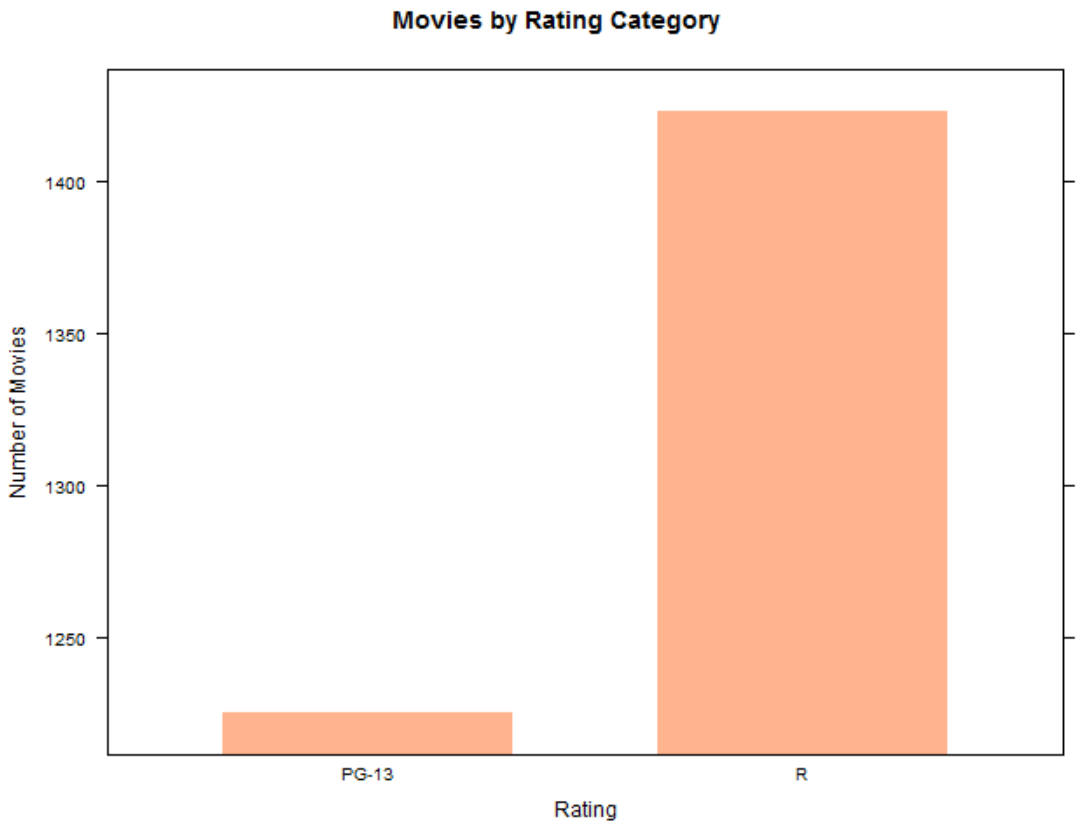


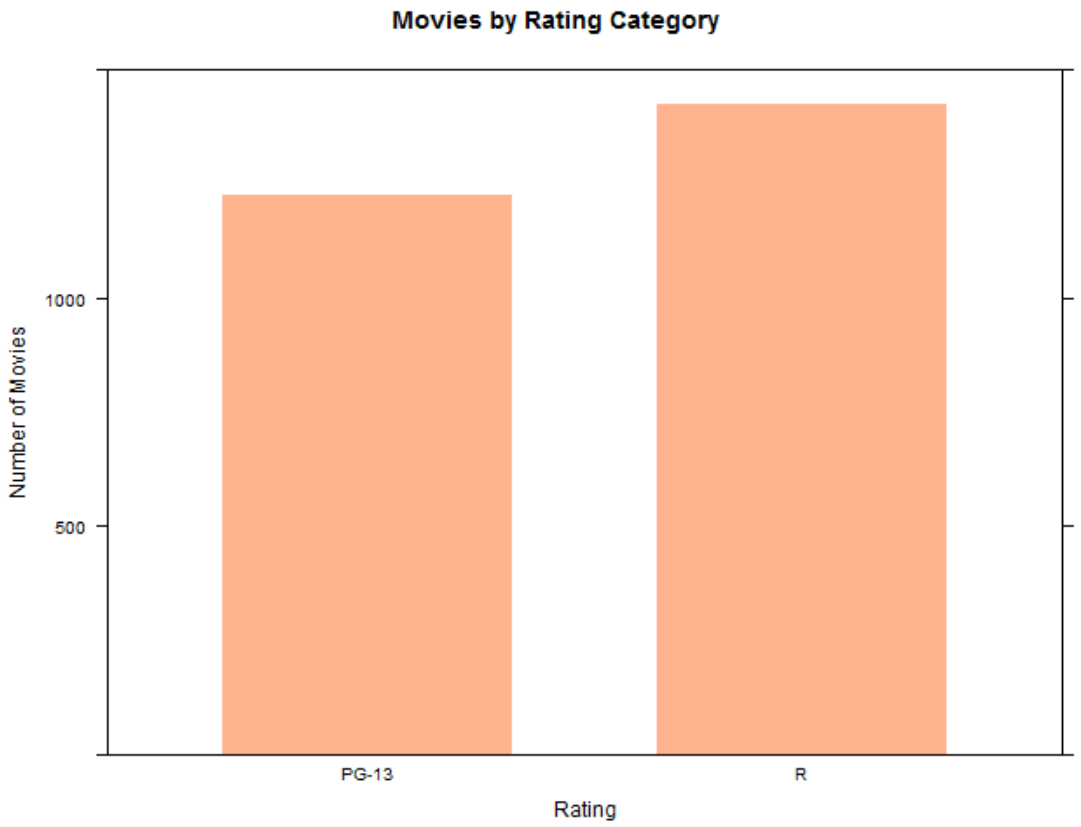
Create Clean Data Analyses





Avoid Biases and Information Distortions





Create Reproducible Research

Replication is hallmark of science

Big issue in science right now

Allows other to verify findings

Creates transparency

Allows other to build upon work

Source: https://blog.mendeley.com

How Do We Create Reproducible Research?

Provide raw data and code

Script all analysis steps

Use source control

State all assumptions

Use markdown

Source: https://blog.mendeley.com

Where to Go Next…

Coursera: https://www.coursera.org/specializations/jhu-data-science

Revolutions: http://blog.revolutionanalytics.com

Flowing Data: http://flowingdata.com

R-Blogger: http://www.r-bloggers.com

My Website

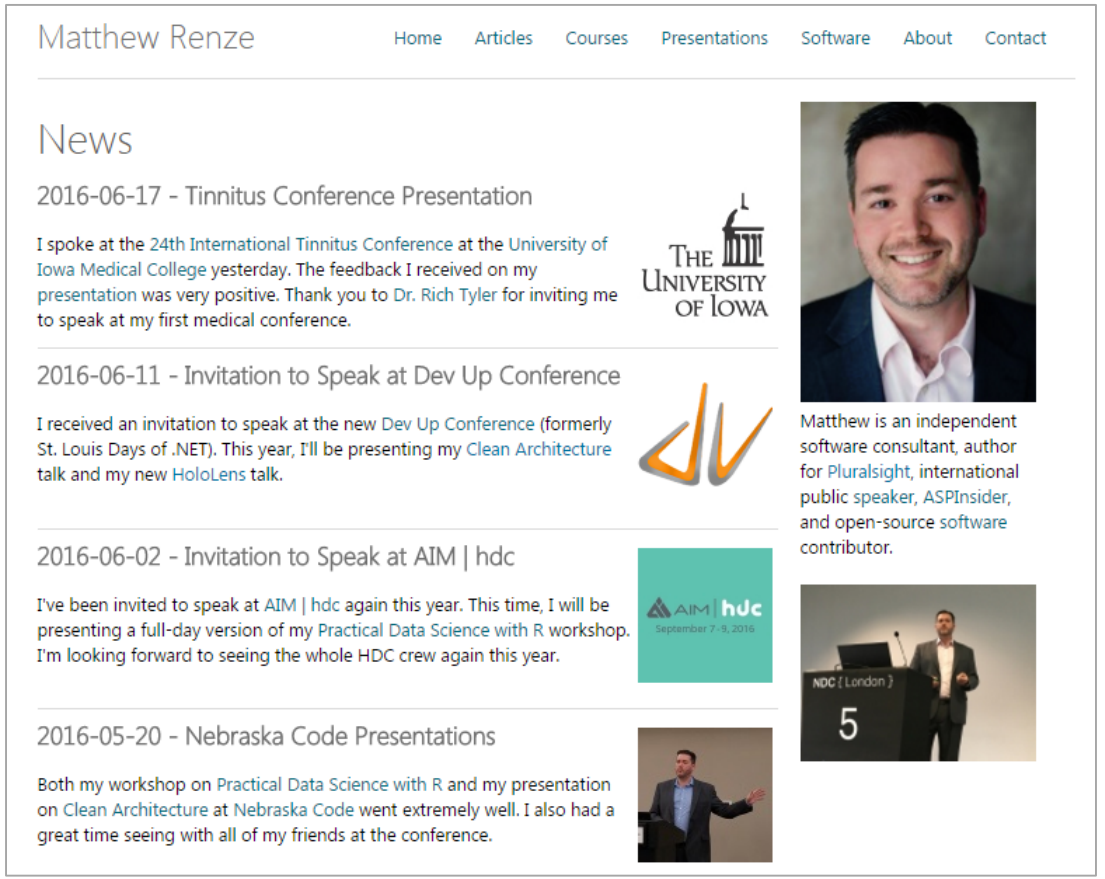
Articles

Presentations

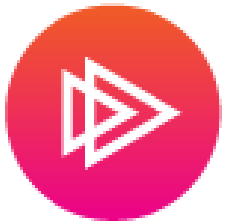
Source Code

Videos

Workshops



www.matthewrenze.com



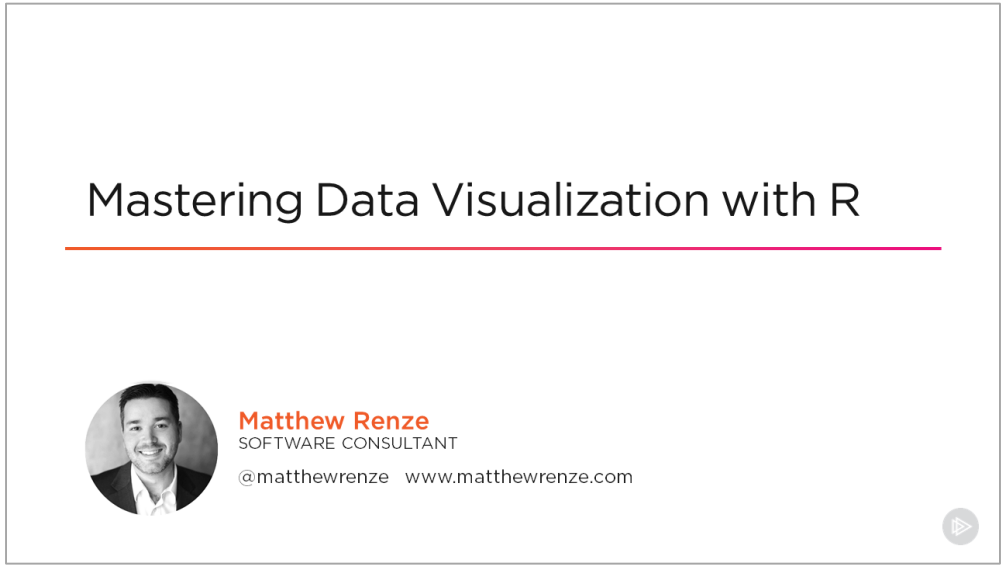
PLURALSIGHT

Exploratory Data Analysis with R

Beginning Data Visualization with R

Multivariate Data Visualization with R

Mastering Data Visualization with R



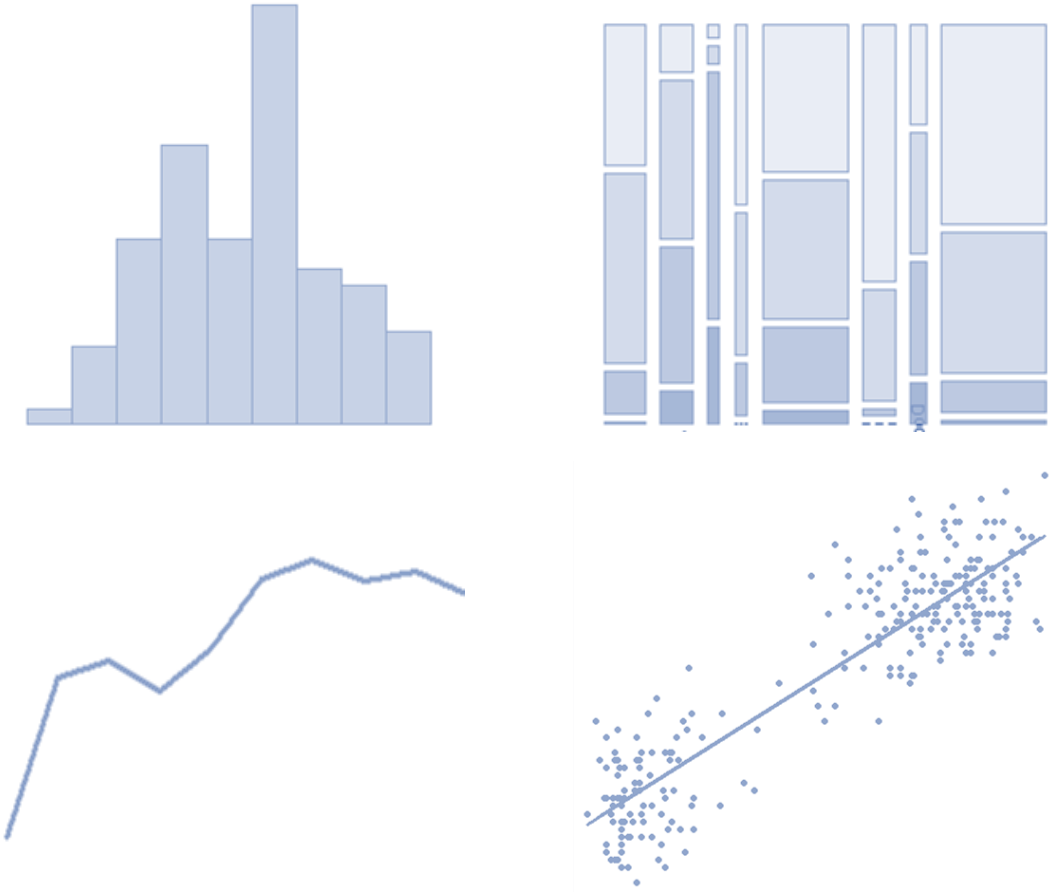
www.pluralsight.com/authors/matthew-renze

Data Visualization with R

Thursday

2:00pm

Room 2207



Conclusion

Conclusion

1. Introduction
2. Transforming Data
3. Descriptive Statistics
4. Data Visualization
5. Statistical Modeling
6. Handling Big Data
7. Machine Learning
8. R in Practice

Feedback

Feedback is very important to me!

One thing you liked?

One thing I could improve?

Contact Info

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Data Science Consultant

Renze Consulting

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Email: matthew@matthewrenze.com

Website: www.matthewrenze.com

Thank You! :)