Table of Contents

Pref	Preface		
Par	I. The Data Science Lifecycle		
1.	The Data Science Lifecycle	3	
	The Stages of the Lifecycle	3	
	Examples of the Lifecycle	6	
	Summary	7	
2.	Questions and Data Scope	9	
	Big Data and New Opportunities	10	
	Example: Google Flu Trends	10	
	Target Population, Access Frame, and Sample	12	
	Example: What Makes Members of an Online Community Active?	14	
	Example: Who Will Win the Election?	14	
	Example: How Do Environmental Hazards Relate		
	to an Individual's Health?	15	
	Instruments and Protocols	16	
	Measuring Natural Phenomena	17	
	Example: What Is the Level of CO_2 in the Air?	18	
	Accuracy	19	
	Types of Bias	20	
	Types of Variation	22	
	Summary	24	

3.	Simulation and Data Design	27
	The Urn Model	28
	Sampling Designs	30
	Sampling Distribution of a Statistic	32
	Simulating the Sampling Distribution	33
	Simulation with the Hypergeometric Distribution	35
	Example: Simulating Election Poll Bias and Variance	36
	The Pennsylvania Urn Model	38
	An Urn Model with Bias	40
	Conducting Larger Polls	41
	Example: Simulating a Randomized Trial for a Vaccine	43
	Scope	43
	The Urn Model for Random Assignment	44
	Example: Measuring Air Quality	46
	Summary	49
4	Modeling with Summary Statistics	51
-10	The Constant Model	52
	Minimizing Loss	54
	Mean Absolute Error	55
	Mean Squared Error	57
	Choosing Loss Functions	59
	Summary	60
F	Case Study, Why Is My Dus Always Late?	62
э.		03
	Question and Scope	64
	Data Wrangling	64
	Exploring Bus Times	67
	Modeling Wait Times	70
	Summary	74
Par	t II. Rectangular Data	

Subsetting Data Scope and Question Dataframes and Indices Slicing **Filtering Rows** Example: How Recently Has Luna Become a Popular Name?

80

80

81

83

86

89

Aggregating	91
Basic Group-Aggregate	92
Grouping on Multiple Columns	95
Custom Aggregation Functions	96
Pivoting	98
Joining	100
Inner Joins	101
Left, Right, and Outer Joins	103
Example: Popularity of NYT Name Categories	105
Transforming	107
Apply	107
Example: Popularity of "L" Names	109
The Price of Apply	110
How Are Dataframes Different from Other Data Representations?	111
Dataframes and Spreadsheets	111
Dataframes and Matrices	112
Dataframes and Relations	113
Summary	113
7. Working with Relations Using SOL	115
Subsetting	115
SQL Basics: SELECT and FROM	116
What's a Relation?	117
Slicing	118
Filtering Rows	119
Example: How Recently Has Luna Become a Popular Name?	121
Aggregating	122
Basic Group-Aggregate Using GROUP BY	123
Grouping on Multiple Columns	124
Other Aggregation Functions	125
Joining	126
Inner Joins	127
Left and Right Joins	129
Example: Popularity of NYT Name Categories	130
Transforming and Common Table Expressions	131
SQL Functions	131
Multistep Queries Using a WITH Clause	134
Example: Popularity of "L" Names	134
Summary	135

Part III. Understanding The Data

8.	Wrangling Files	139
	Data Source Examples	140
	Drug Abuse Warning Network (DAWN) Survey	140
	San Francisco Restaurant Food Safety	140
	File Formats	142
	Delimited Format	142
	Fixed-Width Format	144
	Hierarchical Formats	145
	Loosely Formatted Text	145
	File Encoding	146
	File Size	148
	The Shell and Command-Line Tools	151
	Table Shape and Granularity	155
	Granularity of Restaurant Inspections and Violations	156
	DAWN Survey Shape and Granularity	158
	Summary	161
9.	Wrangling Dataframes	163
	Example: Wrangling CO ₂ Measurements from the Mauna Loa Observatory	164
	Ouality Checks	167
	Addressing Missing Data	170
	Reshaping the Data Table	171
	Quality Checks	172
	Quality Based on Scope	172
	Quality of Measurements and Recorded Values	173
	Quality Across Related Features	174
	Quality for Analysis	174
	Fixing the Data or Not	175
	Missing Values and Records	176
	Transformations and Timestamps	178
	Transforming Timestamps	179
	Piping for Transformations	182
	Modifying Structure	183
	Example: Wrangling Restaurant Safety Violations	186
	Narrowing the Focus	187
	Aggregating Violations	188
	Extracting Information from Violation Descriptions	190
	Summary	193

10.	Exploratory Data Analysis	195
	Feature Types	196
	Example: Dog Breeds	198
	Transforming Qualitative Features	203
	The Importance of Feature Types	206
	What to Look For in a Distribution	207
	What to Look For in a Relationship	211
	Two Quantitative Features	211
	One Qualitative and One Quantitative Variable	212
	Two Qualitative Features	214
	Comparisons in Multivariate Settings	216
	Guidelines for Exploration	220
	Example: Sale Prices for Houses	221
	Understanding Price	222
	What Next?	224
	Examining Other Features	225
	Delving Deeper into Relationships	229
	Fixing Location	230
	EDA Discoveries	232
	Summary	233
11.	Data Visualization	235
11.	Data Visualization Choosing Scale to Reveal Structure	235 235
11.	Data Visualization. Choosing Scale to Reveal Structure Filling the Data Region	235 235 236
11.	Data Visualization. Choosing Scale to Reveal Structure Filling the Data Region Including Zero	235 235 236 237
11.	Data Visualization. Choosing Scale to Reveal Structure Filling the Data Region Including Zero Revealing Shape Through Transformations	235 235 236 237 239
11.	Data Visualization. Choosing Scale to Reveal Structure Filling the Data Region Including Zero Revealing Shape Through Transformations Banking to Decipher Relationships	235 235 236 237 239 241
11.	Data Visualization. Choosing Scale to Reveal Structure Filling the Data Region Including Zero Revealing Shape Through Transformations Banking to Decipher Relationships Revealing Relationships Through Straightening	235 235 236 237 239 241 242
11.	Data Visualization. Choosing Scale to Reveal Structure Filling the Data Region Including Zero Revealing Shape Through Transformations Banking to Decipher Relationships Revealing Relationships Through Straightening Smoothing and Aggregating Data	 235 236 237 239 241 242 245
11.	Data Visualization. Choosing Scale to Reveal Structure Filling the Data Region Including Zero Revealing Shape Through Transformations Banking to Decipher Relationships Revealing Relationships Through Straightening Smoothing and Aggregating Data Smoothing Techniques to Uncover Shape	 235 236 237 239 241 242 245 245
11.	Data Visualization. Choosing Scale to Reveal Structure Filling the Data Region Including Zero Revealing Shape Through Transformations Banking to Decipher Relationships Revealing Relationships Through Straightening Smoothing and Aggregating Data Smoothing Techniques to Uncover Shape Smoothing Techniques to Uncover Relationships and Trends	235 236 237 239 241 242 245 245 245 247
11.	Data Visualization. Choosing Scale to Reveal Structure Filling the Data Region Including Zero Revealing Shape Through Transformations Banking to Decipher Relationships Revealing Relationships Through Straightening Smoothing and Aggregating Data Smoothing Techniques to Uncover Shape Smoothing Techniques to Uncover Relationships and Trends Smoothing Techniques Need Tuning	 235 235 236 237 239 241 242 245 245 247 249
11.	Data Visualization. Choosing Scale to Reveal Structure Filling the Data Region Including Zero Revealing Shape Through Transformations Banking to Decipher Relationships Revealing Relationships Through Straightening Smoothing and Aggregating Data Smoothing Techniques to Uncover Shape Smoothing Techniques to Uncover Relationships and Trends Smoothing Techniques Need Tuning Reducing Distributions to Quantiles	235 236 237 239 241 242 245 245 245 247 249 250
11.	Data Visualization. Choosing Scale to Reveal Structure Filling the Data Region Including Zero Revealing Shape Through Transformations Banking to Decipher Relationships Revealing Relationships Through Straightening Smoothing and Aggregating Data Smoothing Techniques to Uncover Shape Smoothing Techniques to Uncover Relationships and Trends Smoothing Techniques Need Tuning Reducing Distributions to Quantiles When Not to Smooth	235 236 237 239 241 242 245 245 245 247 249 250 252
11.	Data Visualization. Choosing Scale to Reveal Structure Filling the Data Region Including Zero Revealing Shape Through Transformations Banking to Decipher Relationships Revealing Relationships Through Straightening Smoothing and Aggregating Data Smoothing Techniques to Uncover Shape Smoothing Techniques to Uncover Relationships and Trends Smoothing Techniques Need Tuning Reducing Distributions to Quantiles When Not to Smooth Facilitating Meaningful Comparisons	235 236 237 239 241 242 245 245 245 247 249 250 252 254
11.	Data Visualization. Choosing Scale to Reveal Structure Filling the Data Region Including Zero Revealing Shape Through Transformations Banking to Decipher Relationships Revealing Relationships Through Straightening Smoothing and Aggregating Data Smoothing Techniques to Uncover Shape Smoothing Techniques to Uncover Relationships and Trends Smoothing Techniques Need Tuning Reducing Distributions to Quantiles When Not to Smooth Facilitating Meaningful Comparisons Emphasize the Important Difference	235 236 237 239 241 242 245 245 245 245 247 249 250 252 254 254
11.	Data Visualization. Choosing Scale to Reveal Structure Filling the Data Region Including Zero Revealing Shape Through Transformations Banking to Decipher Relationships Revealing Relationships Through Straightening Smoothing and Aggregating Data Smoothing Techniques to Uncover Shape Smoothing Techniques to Uncover Relationships and Trends Smoothing Techniques Need Tuning Reducing Distributions to Quantiles When Not to Smooth Facilitating Meaningful Comparisons Emphasize the Important Difference Ordering Groups	235 236 237 239 241 242 245 245 245 245 247 250 252 254 254 254 256
11.	Data Visualization. Choosing Scale to Reveal Structure Filling the Data Region Including Zero Revealing Shape Through Transformations Banking to Decipher Relationships Revealing Relationships Through Straightening Smoothing and Aggregating Data Smoothing Techniques to Uncover Shape Smoothing Techniques to Uncover Relationships and Trends Smoothing Techniques Need Tuning Reducing Distributions to Quantiles When Not to Smooth Facilitating Meaningful Comparisons Emphasize the Important Difference Ordering Groups Avoid Stacking	235 236 237 239 241 242 245 245 245 245 247 250 252 254 254 254 256 258
11.	Data Visualization. Choosing Scale to Reveal Structure Filling the Data Region Including Zero Revealing Shape Through Transformations Banking to Decipher Relationships Revealing Relationships Through Straightening Smoothing and Aggregating Data Smoothing Techniques to Uncover Shape Smoothing Techniques to Uncover Relationships and Trends Smoothing Techniques Need Tuning Reducing Distributions to Quantiles When Not to Smooth Facilitating Meaningful Comparisons Emphasize the Important Difference Ordering Groups Avoid Stacking Selecting a Color Palette	235 236 237 239 241 242 245 245 245 245 247 250 252 254 254 254 256 258 260
11.	Data Visualization. Choosing Scale to Reveal Structure Filling the Data Region Including Zero Revealing Shape Through Transformations Banking to Decipher Relationships Revealing Relationships Through Straightening Smoothing and Aggregating Data Smoothing Techniques to Uncover Shape Smoothing Techniques to Uncover Relationships and Trends Smoothing Techniques Need Tuning Reducing Distributions to Quantiles When Not to Smooth Facilitating Meaningful Comparisons Emphasize the Important Difference Ordering Groups Avoid Stacking Selecting a Color Palette Guidelines for Comparisons in Plots	235 236 237 239 241 242 245 245 245 245 247 249 250 252 254 254 254 254 254 256 258 260 262

	Data Collected Over Time	263
	Observational Studies	265
	Unequal Sampling	266
	Geographic Data	267
	Adding Context	268
	Example: 100m Sprint Times	269
	Creating Plots Using plotly	270
	Figure and Trace Objects	271
	Modifying Layout	273
	Plotting Functions	274
	Annotations	277
	Other Tools for Visualization	278
	matplotlib	278
	Grammar of Graphics	278
	Summary	279
12.	Case Study: How Accurate Are Air Quality Measurements?	281
	Question, Design, and Scope	282
	Finding Collocated Sensors	284
	Wrangling the List of AQS Sites	284
	Wrangling the List of PurpleAir Sites	286
	Matching AQS and PurpleAir Sensors	288
	Wrangling and Cleaning AQS Sensor Data	290
	Checking Granularity	291
	Removing Unneeded Columns	292
	Checking the Validity of Dates	292
	Checking the Quality of PM2.5 Measurements	293
	Checking the Quality of PM2.5 Measurements Wrangling PurpleAir Sensor Data	293 294
	Checking the Quality of PM2.5 Measurements Wrangling PurpleAir Sensor Data Checking the Granularity	293 294 296
	Checking the Quality of PM2.5 Measurements Wrangling PurpleAir Sensor Data Checking the Granularity Handling Missing Values	293 294 296 300
	Checking the Quality of PM2.5 Measurements Wrangling PurpleAir Sensor Data Checking the Granularity Handling Missing Values Exploring PurpleAir and AQS Measurements	293 294 296 300 302
	Checking the Quality of PM2.5 Measurements Wrangling PurpleAir Sensor Data Checking the Granularity Handling Missing Values Exploring PurpleAir and AQS Measurements Creating a Model to Correct PurpleAir Measurements	293 294 296 300 302 308
	Checking the Quality of PM2.5 Measurements Wrangling PurpleAir Sensor Data Checking the Granularity Handling Missing Values Exploring PurpleAir and AQS Measurements Creating a Model to Correct PurpleAir Measurements Summary	293 294 296 300 302 308 310

Part IV. Other Data Sources

13.	Working with Text	315
	Examples of Text and Tasks	316
	Convert Text into a Standard Format	316
	Extract a Piece of Text to Create a Feature	316

	Transform Text into Features	317
	Text Analysis	317
	String Manipulation	318
	Converting Text to a Standard Format with Python String Methods	318
	String Methods in pandas	319
	Splitting Strings to Extract Pieces of Text	320
	Regular Expressions	321
	Concatenation of Literals	322
	Quantifiers	324
	Alternation and Grouping to Create Features	326
	Reference Tables	327
	Text Analysis	329
	Summary	334
14.	Data Exchange	335
	NetCDF Data	336
	JSON Data	341
	HTTP	345
	REST	349
	XML, HTML, and XPath	353
	Example: Scraping Race Times from Wikipedia	356
	XPath	358
	Example: Accessing Exchange Rates from the ECB	360
	Summary	363

Part V. Linear Modeling

15.	Linear Models	367
	Simple Linear Model	368
	Example: A Simple Linear Model for Air Quality	372
	Interpreting Linear Models	374
	Assessing the Fit	375
	Fitting the Simple Linear Model	377
	Multiple Linear Model	379
	Fitting the Multiple Linear Model	384
	Example: Where Is the Land of Opportunity?	388
	Explaining Upward Mobility Using Commute Time	389
	Relating Upward Mobility Using Multiple Variables	392
	Feature Engineering for Numeric Measurements	396
	Feature Engineering for Categorical Measurements	400

Summary

Example: Energy Consumption Train-Test Split Cross-Validation Regularization Model Bias and Variance Summary	410 410 415 419 424 425 429 431 431 433 435 439
Train-Test Split Cross-Validation Regularization Model Bias and Variance Summary	410 415 419 424 425 429 431 431 433 435 439
Cross-Validation Regularization Model Bias and Variance Summary	413 419 424 425 429 431 431 433 435 439
Regularization Model Bias and Variance Summary	419 424 425 429 431 431 433 435 439
Model Bias and Variance Summary	424 425 429 431 431 433 435 439
Summary	429 429 431 431 433 435 439
17 Theory for Informer and Prediction	429 431 433 435 439
17 Theory for Informer and Drediction	431 433 435 439
	431 433 435 439
Distributions: Population, Empirical, Sampling	433 435 439
Basics of Hypothesis Testing	435 439
Example: A Rank Test to Compare Productivity of	435 439
Wikipedia Contributors	439
Example: A Test of Proportions for Vaccine Efficacy	440
Bootstrapping for Inference	442
Basics of Confidence Intervals	446
Basics of Prediction Intervals	450
Example: Predicting Bus Lateness	450
Example: Predicting Crab Size	451
Example: Predicting the Incremental Growth of a Crab	453
Probability for Inference and Prediction	455
Formalizing the Theory for Average Rank Statistics	456
General Properties of Random Variables	459
Probability Behind Testing and Intervals	462
Probability Behind Model Selection	465
Summary	467
18 Case Study: How to Weigh a Donkey	471
Donkey Study Ouestion and Scope	471
Wrangling and Transforming	472
Exploring	478
Modeling a Donkey's Weight	481
A Loss Function for Prescribing Anesthetics	481
Fitting a Simple Linear Model	482
Fitting a Multiple Linear Model	484
Bringing Qualitative Features into the Model	485
Model Assessment	488
Summary	490

Part VI. Classification

19.	Classification	495
	Example: Wind-Damaged Trees	496
	Modeling and Classification	498
	A Constant Model	498
	Examining the Relationship Between Size and Windthrow	499
	Modeling Proportions (and Probabilities)	501
	A Logistic Model	502
	Log Odds	504
	Using a Logistic Curve	505
	A Loss Function for the Logistic Model	505
	From Probabilities to Classification	509
	The Confusion Matrix	511
	Precision Versus Recall	512
	Summary	515
20.	Numerical Optimization	517
	Gradient Descent Basics	518
	Minimizing Huber Loss	520
	Convex and Differentiable Loss Functions	522
	Variants of Gradient Descent	524
	Stochastic Gradient Descent	525
	Mini-Batch Gradient Descent	525
	Newton's Method	526
	Summary	527
21	Case Study: Detecting Fake News	529
	Question and Scope	530
	Obtaining and Wrangling the Data	531
	Exploring the Data	535
	Exploring the Publishers	536
	Exploring Publication Date	538
	Exploring Words in Articles	540
	Modeling	542
	A Single-Word Model	542
	Multiple-Word Model	544
	Predicting with the tf-idf Transform	546
	Summary	549

Additional Material	551
Data Sources	557
Index	561

.