
Table of Contents

Preface	xiii
1. Exploratory Data Analysis	1
Elements of Structured Data	2
Further Reading	4
Rectangular Data	5
Data Frames and Indexes	6
Nonrectangular Data Structures	7
Further Reading	8
Estimates of Location	8
Mean	9
Median and Robust Estimates	10
Example: Location Estimates of Population and Murder Rates	12
Further Reading	13
Estimates of Variability	13
Standard Deviation and Related Estimates	14
Estimates Based on Percentiles	17
Example: Variability Estimates of State Population	18
Further Reading	19
Exploring the Data Distribution	19
Percentiles and Boxplots	20
Frequency Table and Histograms	21
Density Estimates	24
Further Reading	26
Exploring Binary and Categorical Data	26
Mode	28
Expected Value	28
Further Reading	29

Correlation	29
Scatterplots	32
Further Reading	34
Exploring Two or More Variables	34
Hexagonal Binning and Contours (Plotting Numeric versus Numeric Data)	34
Two Categorical Variables	37
Categorical and Numeric Data	38
Visualizing Multiple Variables	40
Further Reading	42
Summary	42
2. Data and Sampling Distributions.....	43
Random Sampling and Sample Bias	44
Bias	46
Random Selection	47
Size versus Quality: When Does Size Matter?	48
Sample Mean versus Population Mean	49
Further Reading	49
Selection Bias	50
Regression to the Mean	51
Further Reading	53
Sampling Distribution of a Statistic	53
Central Limit Theorem	55
Standard Error	56
Further Reading	57
The Bootstrap	57
Resampling versus Bootstrapping	60
Further Reading	60
Confidence Intervals	61
Further Reading	63
Normal Distribution	64
Standard Normal and QQ-Plots	65
Long-Tailed Distributions	67
Further Reading	69
Student's t-Distribution	69
Further Reading	72
Binomial Distribution	72
Further Reading	74
Poisson and Related Distributions	74
Poisson Distributions	75
Exponential Distribution	75
Estimating the Failure Rate	76

Weibull Distribution	76
Further Reading	77
Summary	77
3. Statistical Experiments and Significance Testing.....	79
A/B Testing	80
Why Have a Control Group?	82
Why Just A/B? Why Not C, D...?	83
For Further Reading	84
Hypothesis Tests	85
The Null Hypothesis	86
Alternative Hypothesis	86
One-Way, Two-Way Hypothesis Test	87
Further Reading	88
Resampling	88
Permutation Test	88
Example: Web Stickiness	89
Exhaustive and Bootstrap Permutation Test	92
Permutation Tests: The Bottom Line for Data Science	93
For Further Reading	93
Statistical Significance and P-Values	93
P-Value	96
Alpha	96
Type 1 and Type 2 Errors	98
Data Science and P-Values	98
Further Reading	99
t-Tests	99
Further Reading	101
Multiple Testing	101
Further Reading	104
Degrees of Freedom	104
Further Reading	106
ANOVA	106
F-Statistic	109
Two-Way ANOVA	110
Further Reading	111
Chi-Square Test	111
Chi-Square Test: A Resampling Approach	112
Chi-Squared Test: Statistical Theory	114
Fisher's Exact Test	115
Relevance for Data Science	117
Further Reading	118

Multi-Arm Bandit Algorithm	119
Further Reading	122
Power and Sample Size	122
Sample Size	123
Further Reading	125
Summary	125
4. Regression and Prediction.....	127
Simple Linear Regression	127
The Regression Equation	129
Fitted Values and Residuals	131
Least Squares	132
Prediction versus Explanation (Profiling)	133
Further Reading	134
Multiple Linear Regression	134
Example: King County Housing Data	135
Assessing the Model	136
Cross-Validation	138
Model Selection and Stepwise Regression	139
Weighted Regression	141
Prediction Using Regression	142
The Dangers of Extrapolation	143
Confidence and Prediction Intervals	143
Factor Variables in Regression	145
Dummy Variables Representation	145
Factor Variables with Many Levels	147
Ordered Factor Variables	149
Interpreting the Regression Equation	150
Correlated Predictors	150
Multicollinearity	151
Confounding Variables	152
Interactions and Main Effects	153
Testing the Assumptions: Regression Diagnostics	155
Outliers	156
Influential Values	158
Heteroskedasticity, Non-Normality and Correlated Errors	161
Partial Residual Plots and Nonlinearity	164
Polynomial and Spline Regression	166
Polynomial	167
Splines	168
Generalized Additive Models	170
Further Reading	172

Summary	172
5. Classification.....	173
Naive Bayes	174
Why Exact Bayesian Classification Is Impractical	175
The Naive Solution	176
Numeric Predictor Variables	178
Further Reading	178
Discriminant Analysis	179
Covariance Matrix	180
Fisher’s Linear Discriminant	180
A Simple Example	181
Further Reading	183
Logistic Regression	184
Logistic Response Function and Logit	184
Logistic Regression and the GLM	186
Generalized Linear Models	187
Predicted Values from Logistic Regression	188
Interpreting the Coefficients and Odds Ratios	188
Linear and Logistic Regression: Similarities and Differences	190
Assessing the Model	191
Further Reading	194
Evaluating Classification Models	194
Confusion Matrix	195
The Rare Class Problem	196
Precision, Recall, and Specificity	197
ROC Curve	198
AUC	200
Lift	201
Further Reading	202
Strategies for Imbalanced Data	203
Undersampling	204
Oversampling and Up/Down Weighting	204
Data Generation	205
Cost-Based Classification	206
Exploring the Predictions	206
Further Reading	208
Summary	208
6. Statistical Machine Learning.....	209
K-Nearest Neighbors	210
A Small Example: Predicting Loan Default	211

Distance Metrics	213
One Hot Encoder	214
Standardization (Normalization, Z-Scores)	215
Choosing K	217
KNN as a Feature Engine	218
Tree Models	219
A Simple Example	221
The Recursive Partitioning Algorithm	222
Measuring Homogeneity or Impurity	224
Stopping the Tree from Growing	225
Predicting a Continuous Value	227
How Trees Are Used	227
Further Reading	228
Bagging and the Random Forest	228
Bagging	230
Random Forest	230
Variable Importance	233
Hyperparameters	236
Boosting	237
The Boosting Algorithm	238
XGBoost	239
Regularization: Avoiding Overfitting	241
Hyperparameters and Cross-Validation	245
Summary	247
7. Unsupervised Learning.....	249
Principal Components Analysis	250
A Simple Example	251
Computing the Principal Components	254
Interpreting Principal Components	254
Further Reading	257
K-Means Clustering	257
A Simple Example	258
K-Means Algorithm	260
Interpreting the Clusters	261
Selecting the Number of Clusters	263
Hierarchical Clustering	265
A Simple Example	266
The Dendrogram	266
The Agglomerative Algorithm	268
Measures of Dissimilarity	268
Model-Based Clustering	270

Multivariate Normal Distribution	270
Mixtures of Normals	272
Selecting the Number of Clusters	274
Further Reading	276
Scaling and Categorical Variables	276
Scaling the Variables	277
Dominant Variables	278
Categorical Data and Gower's Distance	280
Problems with Clustering Mixed Data	283
Summary	284
Bibliography.....	285
Index.....	287

