
Table of Contents

Preface	xi
1. Preliminaries	1
What Is This Book About?	1
Why Python for Data Analysis?	2
Python as Glue	2
Solving the “Two-Language” Problem	2
Why Not Python?	3
Essential Python Libraries	3
NumPy	4
pandas	4
matplotlib	5
IPython	5
SciPy	6
Installation and Setup	6
Windows	7
Apple OS X	9
GNU/Linux	10
Python 2 and Python 3	11
Integrated Development Environments (IDEs)	11
Community and Conferences	12
Navigating This Book	12
Code Examples	13
Data for Examples	13
Import Conventions	13
Jargon	13
Acknowledgements	14
2. Introductory Examples	17
1.usa.gov data from bit.ly	18
Counting Time Zones in Pure Python	19

Counting Time Zones with pandas	21
MovieLens 1M Data Set	26
Measuring rating disagreement	30
US Baby Names 1880-2010	32
Analyzing Naming Trends	36
Conclusions and The Path Ahead	43
3. IPython: An Interactive Computing and Development Environment	45
IPython Basics	46
Tab Completion	47
Introspection	48
The %run Command	49
Executing Code from the Clipboard	50
Keyboard Shortcuts	52
Exceptions and Tracebacks	53
Magic Commands	54
Qt-based Rich GUI Console	55
Matplotlib Integration and Pylab Mode	56
Using the Command History	58
Searching and Reusing the Command History	58
Input and Output Variables	58
Logging the Input and Output	59
Interacting with the Operating System	60
Shell Commands and Aliases	60
Directory Bookmark System	62
Software Development Tools	62
Interactive Debugger	62
Timing Code: %time and %timeit	67
Basic Profiling: %prun and %run -p	68
Profiling a Function Line-by-Line	70
IPython HTML Notebook	72
Tips for Productive Code Development Using IPython	72
Reloading Module Dependencies	74
Code Design Tips	74
Advanced IPython Features	76
Making Your Own Classes IPython-friendly	76
Profiles and Configuration	77
Credits	78
4. NumPy Basics: Arrays and Vectorized Computation	79
The NumPy ndarray: A Multidimensional Array Object	80
Creating ndarrays	81
Data Types for ndarrays	83

Operations between Arrays and Scalars	85
Basic Indexing and Slicing	86
Boolean Indexing	89
Fancy Indexing	92
Transposing Arrays and Swapping Axes	93
Universal Functions: Fast Element-wise Array Functions	95
Data Processing Using Arrays	97
Expressing Conditional Logic as Array Operations	98
Mathematical and Statistical Methods	100
Methods for Boolean Arrays	101
Sorting	101
Unique and Other Set Logic	102
File Input and Output with Arrays	103
Storing Arrays on Disk in Binary Format	103
Saving and Loading Text Files	104
Linear Algebra	105
Random Number Generation	106
Example: Random Walks	108
Simulating Many Random Walks at Once	109
5. Getting Started with pandas	111
Introduction to pandas Data Structures	112
Series	112
DataFrame	115
Index Objects	120
Essential Functionality	122
Reindexing	122
Dropping entries from an axis	125
Indexing, selection, and filtering	125
Arithmetic and data alignment	128
Function application and mapping	132
Sorting and ranking	133
Axis indexes with duplicate values	136
Summarizing and Computing Descriptive Statistics	137
Correlation and Covariance	139
Unique Values, Value Counts, and Membership	141
Handling Missing Data	142
Filtering Out Missing Data	143
Filling in Missing Data	145
Hierarchical Indexing	147
Reordering and Sorting Levels	149
Summary Statistics by Level	150
Using a DataFrame's Columns	150

Other pandas Topics	151
Integer Indexing	151
Panel Data	152
6. Data Loading, Storage, and File Formats	155
Reading and Writing Data in Text Format	155
Reading Text Files in Pieces	160
Writing Data Out to Text Format	162
Manually Working with Delimited Formats	163
JSON Data	165
XML and HTML: Web Scraping	166
Binary Data Formats	171
Using HDF5 Format	171
Reading Microsoft Excel Files	172
Interacting with HTML and Web APIs	173
Interacting with Databases	174
Storing and Loading Data in MongoDB	176
7. Data Wrangling: Clean, Transform, Merge, Reshape	177
Combining and Merging Data Sets	177
Database-style DataFrame Merges	178
Merging on Index	182
Concatenating Along an Axis	185
Combining Data with Overlap	188
Reshaping and Pivoting	189
Reshaping with Hierarchical Indexing	190
Pivoting “long” to “wide” Format	192
Data Transformation	194
Removing Duplicates	194
Transforming Data Using a Function or Mapping	195
Replacing Values	196
Renaming Axis Indexes	197
Discretization and Binning	199
Detecting and Filtering Outliers	201
Permutation and Random Sampling	202
Computing Indicator/Dummy Variables	203
String Manipulation	205
String Object Methods	206
Regular expressions	207
Vectorized string functions in pandas	210
Example: USDA Food Database	212

8. Plotting and Visualization	219
A Brief matplotlib API Primer	219
Figures and Subplots	220
Colors, Markers, and Line Styles	224
Ticks, Labels, and Legends	225
Annotations and Drawing on a Subplot	228
Saving Plots to File	231
matplotlib Configuration	231
Plotting Functions in pandas	232
Line Plots	232
Bar Plots	235
Histograms and Density Plots	238
Scatter Plots	239
Plotting Maps: Visualizing Haiti Earthquake Crisis Data	241
Python Visualization Tool Ecosystem	247
Chaco	248
mayavi	249
Other Packages	249
The Future of Visualization Tools?	249
 9. Data Aggregation and Group Operations	 251
GroupBy Mechanics	252
Iterating Over Groups	255
Selecting a Column or Subset of Columns	256
Grouping with Dicts and Series	257
Grouping with Functions	258
Grouping by Index Levels	259
Data Aggregation	259
Column-wise and Multiple Function Application	262
Returning Aggregated Data in “unindexed” Form	264
Group-wise Operations and Transformations	264
Apply: General split-apply-combine	266
Quantile and Bucket Analysis	268
Example: Filling Missing Values with Group-specific Values	270
Example: Random Sampling and Permutation	271
Example: Group Weighted Average and Correlation	273
Example: Group-wise Linear Regression	274
Pivot Tables and Cross-Tabulation	275
Cross-Tabulations: Crosstab	277
Example: 2012 Federal Election Commission Database	278
Donation Statistics by Occupation and Employer	280
Bucketing Donation Amounts	283
Donation Statistics by State	285

10. Time Series	289
Date and Time Data Types and Tools	290
Converting between string and datetime	291
Time Series Basics	293
Indexing, Selection, Subsetting	294
Time Series with Duplicate Indices	296
Date Ranges, Frequencies, and Shifting	297
Generating Date Ranges	298
Frequencies and Date Offsets	299
Shifting (Leading and Lagging) Data	301
Time Zone Handling	303
Localization and Conversion	304
Operations with Time Zone-aware Timestamp Objects	305
Operations between Different Time Zones	306
Periods and Period Arithmetic	307
Period Frequency Conversion	308
Quarterly Period Frequencies	309
Converting Timestamps to Periods (and Back)	311
Creating a PeriodIndex from Arrays	312
Resampling and Frequency Conversion	312
Downsampling	314
Upsampling and Interpolation	316
Resampling with Periods	318
Time Series Plotting	319
Moving Window Functions	320
Exponentially-weighted functions	324
Binary Moving Window Functions	324
User-Defined Moving Window Functions	326
Performance and Memory Usage Notes	327
 11. Financial and Economic Data Applications	 329
Data Munging Topics	329
Time Series and Cross-Section Alignment	330
Operations with Time Series of Different Frequencies	332
Time of Day and “as of” Data Selection	334
Splicing Together Data Sources	336
Return Indexes and Cumulative Returns	338
Group Transforms and Analysis	340
Group Factor Exposures	342
Decile and Quartile Analysis	343
More Example Applications	345
Signal Frontier Analysis	345
Future Contract Rolling	347

Rolling Correlation and Linear Regression	350
---	-----

12. Advanced NumPy	353
ndarray Object Internals	353
NumPy dtype Hierarchy	354
Advanced Array Manipulation	355
Reshaping Arrays	355
C versus Fortran Order	356
Concatenating and Splitting Arrays	357
Repeating Elements: Tile and Repeat	360
Fancy Indexing Equivalents: Take and Put	361
Broadcasting	362
Broadcasting Over Other Axes	364
Setting Array Values by Broadcasting	367
Advanced ufunc Usage	367
ufunc Instance Methods	368
Custom ufuncs	370
Structured and Record Arrays	370
Nested dtypes and Multidimensional Fields	371
Why Use Structured Arrays?	372
Structured Array Manipulations: numpy.lib.recfunctions	372
More About Sorting	373
Indirect Sorts: argsort and lexsort	374
Alternate Sort Algorithms	375
numpy.searchsorted: Finding elements in a Sorted Array	376
NumPy Matrix Class	377
Advanced Array Input and Output	379
Memory-mapped Files	379
HDF5 and Other Array Storage Options	380
Performance Tips	380
The Importance of Contiguous Memory	381
Other Speed Options: Cython, f2py, C	382
Appendix: Python Language Essentials	385
Index	433

