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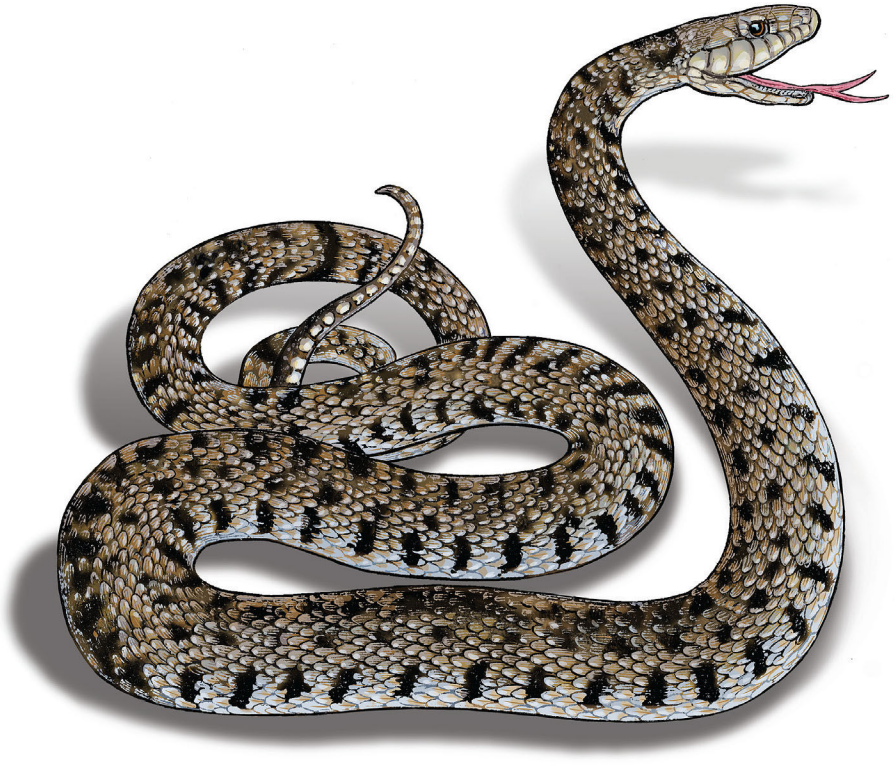
Python for Algorithmic Trading

From Idea to Cloud Deployment



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Yves Hilpisch

Beijing • Boston • Farnham • Sebastopol • Tokyo

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Preface

> Dataism says that the universe consists of data flows, and the value of any phenomenon or entity is determined by its contribution to data processing.…Dataism thereby collapses the barrier between animals [humans] and machines, and expects electronic algorithms to eventually decipher and outperform biochemical algorithms.[1]
>
> —Yuval Noah Harari

Finding the right algorithm to automatically and successfully trade in financial markets is the holy grail in finance. Not too long ago, algorithmic trading was only available and possible for institutional players with deep pockets and lots of assets under management. Recent developments in the areas of open source, open data, cloud compute, and cloud storage, as well as online trading platforms, have leveled the playing field for smaller institutions and individual traders, making it possible to get started in this fascinating discipline while equipped only with a typical notebook or desktop computer and a reliable internet connection.

Nowadays, Python and its ecosystem of powerful packages is the technology platform of choice for algorithmic trading. Among other things, Python allows you to do *efficient data analytics* (with, for example, `pandas` (*http://pandas.pydata.org*)), to apply *machine learning* to stock market prediction (with `scikit-learn` (*http://scikit-learn.org*), for example), or even to make use of Google's *deep learning* technology with `tensorflow` (*http://tensorflow.org*).

This is a book about Python *for* algorithmic trading, primarily in the context of *alpha generating strategies* (see Chapter 1). Such a book at the intersection of two vast and exciting fields can hardly cover all topics of relevance. However, it can cover a range of important meta topics in depth.

1 Harari, Yuval Noah. 2015. *Homo Deus: A Brief History of Tomorrow*. London: Harvill Secker.

These topics include:

Financial data
: Financial data is at the core of every algorithmic trading project. Python and packages like `NumPy` and `pandas` do a great job of handling and working with structured financial data of any kind (end-of-day, intraday, high frequency).

Backtesting
: There should be no automated algorithmic trading without a rigorous testing of the trading strategy to be deployed. The book covers, among other things, trading strategies based on simple moving averages, momentum, mean-reversion, and machine/deep-learning based prediction.

Real-time data
: Algorithmic trading requires dealing with real-time data, online algorithms based on it, and visualization in real time. The book provides an introduction to socket programming with `ZeroMQ` and streaming visualization.

Online platforms
: No trading can take place without a trading platform. The book covers two popular electronic trading platforms: Oanda (*http://oanda.com*) and FXCM (*http://fxcm.com*).

Automation
: The beauty, as well as some major challenges, in algorithmic trading results from the automation of the trading operation. The book shows how to deploy Python in the cloud and how to set up an environment appropriate for automated algorithmic trading.

The book offers a unique learning experience with the following features and benefits:

Coverage of relevant topics
: This is the only book covering such a breadth and depth with regard to relevant topics in Python for algorithmic trading (see the following).

Self-contained code base
: The book is accompanied by a Git repository with all codes in a self-contained, executable form. The repository is available on the Quant Platform (*http://py4at.pqp.io*).

Real trading as the goal
: The coverage of two different online trading platforms puts the reader in the position to start both paper and live trading efficiently. To this end, the book equips the reader with relevant, practical, and valuable background knowledge.

Do-it-yourself and self-paced approach
: Since the material and the codes are self-contained and only rely on standard Python packages, the reader has full knowledge of and full control over what is going on, how to use the code examples, how to change them, and so on. There is no need to rely on third-party platforms, for instance, to do the backtesting or to connect to the trading platforms. With this book, the reader can do all this on their own at a convenient pace and has every single line of code to do so.

User forum
: Although the reader should be able to follow along seamlessly, the author and The Python Quants are there to help. The reader can post questions and comments in the user forum on the Quant Platform (*http://home.tpq.io/pqp*) at any time (accounts are free).

Online/video training (paid subscription)
: The Python Quants offer comprehensive online training programs (*https://oreil.ly/Qy90w*) that make use of the contents presented in the book and that add additional content, covering important topics such as financial data science, artificial intelligence in finance, Python for Excel and databases, and additional Python tools and skills.

Contents and Structure

Here's a quick overview of the topics and contents presented in each chapter.

Chapter 1
: The first chapter is an introduction to the topic of algorithmic trading—that is, the automated trading of financial instruments based on computer algorithms. It discusses fundamental notions in this context and also addresses, among other things, what the expected prerequisites for reading the book are.

Chapter 2
: This chapter lays the technical foundations for all subsequent chapters in that it shows how to set up a proper Python environment. This chapter mainly uses `conda` as a package and environment manager. It illustrates Python deployment via Docker (*http://docker.com*) containers and in the cloud.

Chapter 3
: Financial times series data is central to every algorithmic trading project. This chapter shows you how to retrieve financial data from different public data and proprietary data sources. It also demonstrates how to store financial time series data efficiently with Python.

Chapter 4

Vectorization is a powerful approach in numerical computation in general and for financial analytics in particular. This chapter introduces vectorization with `NumPy` and `pandas` and applies that approach to backtesting SMA-based, momentum, and mean-reversion strategies.

Chapter 5

This chapter is dedicated to generating market predictions by the use of machine learning and deep learning approaches. By mainly relying on past return observations as features, approaches are presented for predicting tomorrow's market direction by using such Python packages as `tensorflow` (*https://oreil.ly/B44Fb*) and `scikit-learn` (*http://scikit-learn.org/*).

Chapter 6

While vectorized backtesting has advantages when it comes to conciseness of code and performance, it's limited with regard to the representation of certain market features of trading strategies. On the other hand, event-based backtesting, technically implemented by the use of object oriented programming, allows for a rather granular and more realistic modeling of such features. This chapter presents and explains in detail a base class as well as two classes for the backtesting of long-only and long-short trading strategies.

Chapter 7

Needing to cope with real-time or streaming data is a reality even for the ambitious individual algorithmic trader. The tool of choice is socket programming, for which this chapter introduces `ZeroMQ` (*http://zeromq.org*) as a lightweight and scalable technology. The chapter also illustrates how to make use of Plotly (*http://plot.ly*) to create nice looking, interactive streaming plots. It also presents a wrapper class that simplifies the creation of such plots in cases where multiple data streams need to be visualized simultaneously (for example, in a dashboard-like manner).

Chapter 8

Oanda (*http://oanda.com*) is a foreign exchange (forex) and Contracts for Difference (CFD) trading platform offering a broad set of tradable instruments, such as those based on foreign exchange pairs, stock indices, commodities, or rates instruments (benchmark bonds). This chapter provides guidance on how to implement automated algorithmic trading strategies with Oanda, making use of the Python wrapper package `tpqoa` (*http://github.com/yhilpisch/tpqoa*).

Chapter 9

FXCM (*http://fxcm.co.uk*) is another forex and CFD trading platform that has recently released a modern RESTful API for algorithmic trading. Available instruments span multiple asset classes, such as forex, stock indices, or

commodities. A Python wrapper package that makes algorithmic trading based on Python code rather convenient and efficient is available (*http://fxcmpy.tpq.io*).

Chapter 10
: This chapter deals with capital management, risk analysis and management, as well as with typical tasks in the technical automation of algorithmic trading operations. It covers, for instance, the Kelly criterion for capital allocation and leverage in detail.

Appendix
: This appendix provides a concise introduction to the most important Python, `NumPy`, and `pandas` topics in the context of the material presented in the main chapters. It represents a starting point from which one can add to one's own Python knowledge over time.

Figure P-1 shows the layers related to algorithmic trading that the chapters cover from the bottom to the top. It necessarily starts with the Python infrastructure (Chapter 2), and adds financial data (Chapter 3), strategy, and vectorized backtesting code (Chapter 4 and Chapter 5). Until that point, data sets are used and manipulated as a whole. Event-based backtesting for the first time introduces the idea that data in the real world arrives incrementally (Chapter 6). It is the bridge that leads to the connecting code layer that covers socket communication and real-time data handling (Chapter 7). On top of that, trading platforms and their APIs are required to be able to place orders (Chapter 8 and Chapter 9). Finally, important aspects of automation and deployment are covered (Chapter 10). In that sense, the main chapters of the book relate to the layers as seen in Figure P-1, which provide a natural sequence for the topics to be covered.

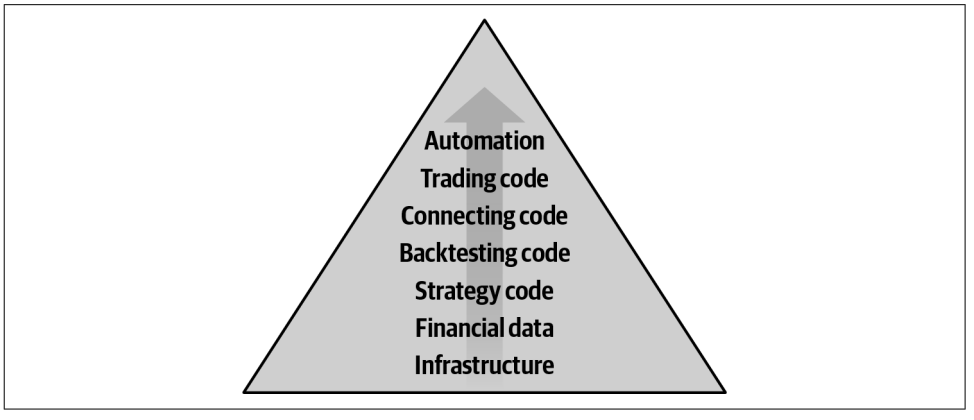

Figure P-1. The layers of Python for algorithmic trading

Who This Book Is For

This book is for students, academics, and practitioners alike who want to apply Python in the fascinating field of algorithmic trading. The book assumes that the reader has, at least on a fundamental level, background knowledge in both Python programming and in financial trading. For reference and review, the Appendix introduces important Python, `NumPy`, `matplotlib`, and `pandas` topics. The following are good references to get a sound understanding of the Python topics important for this book. Most readers will benefit from having at least access to Hilpisch (2018) for reference. With regard to the machine and deep learning approaches applied to algorithmic trading, Hilpisch (2020) provides a wealth of background information and a larger number of specific examples. Background information about Python as applied to finance, financial data science, and artificial intelligence can be found in these books:

Hilpisch, Yves. 2018. *Python for Finance: Mastering Data-Driven Finance*. 2nd ed. Sebastopol: O'Reilly.

———. 2020. *Artificial Intelligence in Finance: A Python-Based Guide*. Sebastopol: O'Reilly.

McKinney, Wes. 2017. *Python for Data Analysis: Data Wrangling with Pandas, NumPy, and IPython*. 2nd ed. Sebastopol: O'Reilly.

Ramalho, Luciano. 2021. *Fluent Python: Clear, Concise, and Effective Programming*. 2nd ed. Sebastopol: O'Reilly.

VanderPlas, Jake. 2016. *Python Data Science Handbook: Essential Tools for Working with Data*. Sebastopol: O'Reilly.

Background information about algorithmic trading can be found, for instance, in these books:

Chan, Ernest. 2009. *Quantitative Trading: How to Build Your Own Algorithmic Trading Business*. Hoboken et al: John Wiley & Sons.

Chan, Ernest. 2013. *Algorithmic Trading: Winning Strategies and Their Rationale*. Hoboken et al: John Wiley & Sons.

Kissel, Robert. 2013. *The Science of Algorithmic Trading and Portfolio Management*. Amsterdam et al: Elsevier/Academic Press.

Narang, Rishi. 2013. *Inside the Black Box: A Simple Guide to Quantitative and High Frequency Trading*. Hoboken et al: John Wiley & Sons.

Enjoy your journey through the algorithmic trading world with Python and get in touch by emailing *pyalgo@tpq.io* if you have questions or comments.

Conventions Used in This Book

The following typographical conventions are used in this book:

Italic
: Indicates new terms, URLs, email addresses, filenames, and file extensions.

`Constant width`
: Used for program listings, as well as within paragraphs, to refer to program elements such as variable or function names, databases, data types, environment variables, statements, and keywords.

`Constant width bold`
: Shows commands or other text that should be typed literally by the user.

`Constant width italic`
: Shows text that should be replaced with user-supplied values or by values determined by context.

This element signifies a tip or suggestion.

This element signifies a general note.

This element indicates a warning or caution.

Using Code Examples

You can access and execute the code that accompanies the book on the Quant Platform at *https://py4at.pqp.io*, for which only a free registration is required.

If you have a technical question or a problem using the code examples, please send email to *bookquestions@oreilly.com*.

This book is here to help you get your job done. In general, if example code is offered with this book, you may use it in your programs and documentation. You do not

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I want to thank the technical reviewers—Hugh Brown, McKlayne Marshall, Ramanathan Ramakrishnamoorthy, and Prem Jebaseelan—who provided helpful comments that led to many improvements of the book's content.

As usual, a special thank you goes to Michael Schwed, who supports me in all technical matters, simple and highly complex, with his broad and in-depth technology know-how.

Delegates of the Certificate Programs in Python for Computational Finance and Algorithmic Trading also helped improve this book. Their ongoing feedback has enabled me to weed out errors and mistakes and refine the code and notebooks used in our online training classes and now, finally, in this book.

I would also like to thank the whole team at O'Reilly Media—especially Michelle Smith, Michele Cronin, Victoria DeRose, and Danny Elfanbaum—for making it all happen and helping me refine the book in so many ways.

Of course, all remaining errors are mine alone.

Furthermore, I would also like to thank the team at Refinitiv—in particular, Jason Ramchandani—for providing ongoing support and access to financial data. The major data files used throughout the book and made available to the readers were received in one way or another from Refinitiv's data APIs.

To my family with love. I dedicate this book to my father Adolf whose support for me and our family now spans almost five decades.

About the Author

Dr. Yves J. Hilpisch is founder and CEO of The Python Quants (*http://tpq.io*), a group focusing on the use of open source technologies for financial data science, artificial intelligence, algorithmic trading, and computational finance. He is also founder and CEO of The AI Machine (*http://aimachine.io*), a company focused on AI-powered algorithmic trading via a proprietary strategy execution platform.

In addition to this book, he is the author of the following books:

- *Artificial Intelligence in Finance* (*https://aiif.tpq.io*) (O'Reilly, 2020)
- *Python for Finance* (*https://py4fi.tpq.io*) (2nd ed., O'Reilly, 2018)
- *Derivatives Analytics with Python* (*https://dawp.tpq.io*) (Wiley, 2015)
- *Listed Volatility and Variance Derivatives* (*https://lvvd.tpq.io*) (Wiley, 2017)

Yves is an adjunct professor of computational finance and lectures on algorithmic trading at the CQF Program (*http://cqf.com*). He is also the director of the first online training programs leading to university certificates in Python for Algorithmic Trading (*http://certificate.tpq.io*) and Python for Computational Finance (*http://compfinance.tpq.io*).

Yves wrote the financial analytics library DX Analytics (*http://dx-analytics.com*) and organizes meetups, conferences, and bootcamps about Python for quantitative finance and algorithmic trading in London, Frankfurt, Berlin, Paris, and New York. He has given keynote speeches at technology conferences in the United States, Europe, and Asia.

Colophon

The animal on the cover of *Python for Algorithmic Trading* is a Common Barred Grass Snake (*Natrix helvetica*).

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