Python for Algorithmic Trading

–Vectorized Backtesting, Object-Oriented Programming, Event-Based Backtesting, and Streaming Data with Python

Dr. Yves J. Hilpisch

Executive Program in Algorithmic Trading
September 2023

https://bit.ly/epat_sep_2023

Introduction

THE PYTHON QUANTS

SERVICES
for financial institutions globally

EVENTS
for Python quants & algorithmic traders

TRAINING
about Python for finance & algorithmic trading

CERTIFICATION
in cooperation with university

BOOKS
about Python and finance

PLATFORM
for browser-based data analytics

OPEN SOURCE
Python library for financial analytics

http://tpq.io

The AI Machine

http://aimachine.io

Dr. Yves J. Hilpisch is the 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 the founder and CEO of **The AI Machine** (http://aimachine.io), a company focused on AI-powered algorithmic trading based on a proprietary strategy execution platform.

Yves has a Diploma in Business Administration, a Ph.D. in Mathematical Finance, and is Adjunct Professor for Computational Finance.

Yves is the author of six books (https://home.tpq.io/books):

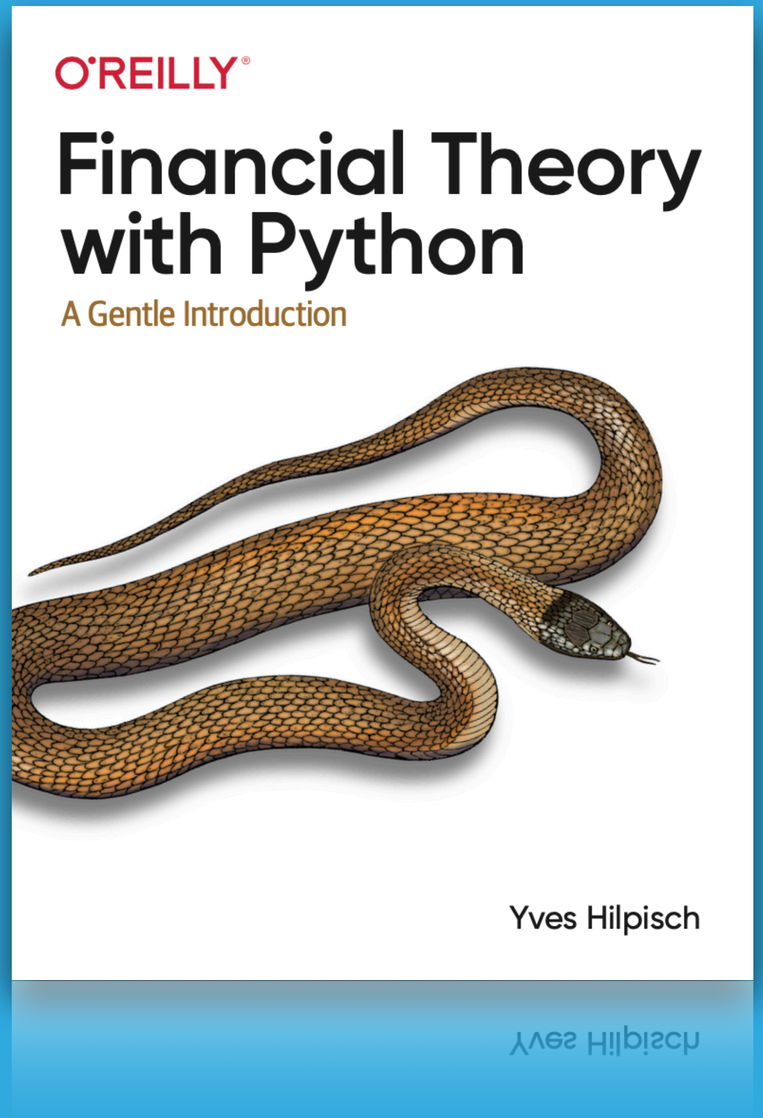
* Financial Theory with Python (2021, O'Reilly)
* Artificial Intelligence in Finance (2020, O'Reilly)
* Python for Algorithmic Trading (2020, O'Reilly)
* Python for Finance (2018, 2nd ed., O'Reilly)
* Listed Volatility and Variance Derivatives (2017, Wiley Finance)
* Derivatives Analytics with Python (2015, Wiley Finance)

Yves is the director of the first online training program leading to **Certificates in Python for Algorithmic Trading** (https://home.tpq.io/certificates/pyalgo), and **Computational Finance** (https://home.tpq.io/certificates/compfin). He also lectures on computational finance, machine learning, and algorithmic trading at the **CQF Program** (http://cqf.com).

Yves is the originator of the financial analytics library **DX Analytics** (http://dx-analytics.com) and organizes Meetup group **events, conferences, and bootcamps** about Python, artificial intelligence and algorithmic trading in London (http://pqf.tpq.io), New York (http://aifat.tpq.io), Frankfurt, Berlin, and Paris. He has given **keynote speeches** at technology conferences in the United States, Europe, and Asia.

http://hilpisch.com

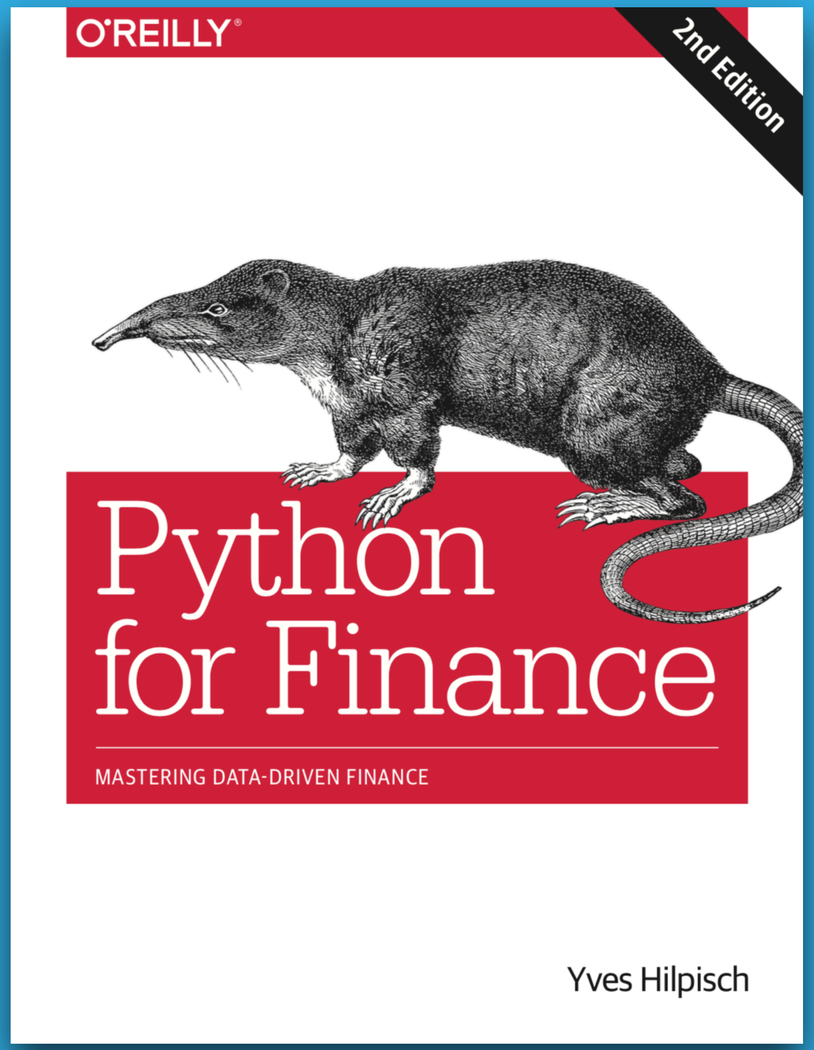
Financial Theory with Python – A Gentle Introduction



Finance with Python and Python environments
Basic Finance Concepts and Models:
- **Risk–Return**
- **Pricing of Instruments**
- **Expected Utility Theory**
- **Mean–Variance Portfolio Theory**
- **Capital Asset Pricing Model**
- **Portfolio Optimization**

Basic Python Concepts and Packages:
- **Major Python Idioms**
- **NumPy Package**
- **SciPy & SymPy Packages**

Python for Finance



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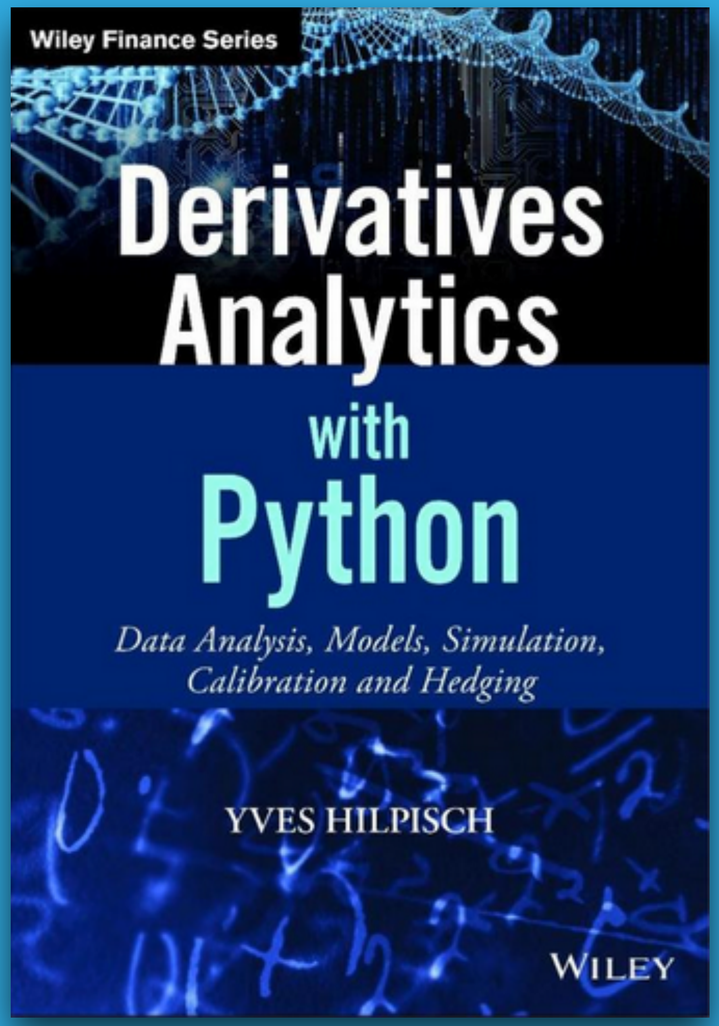
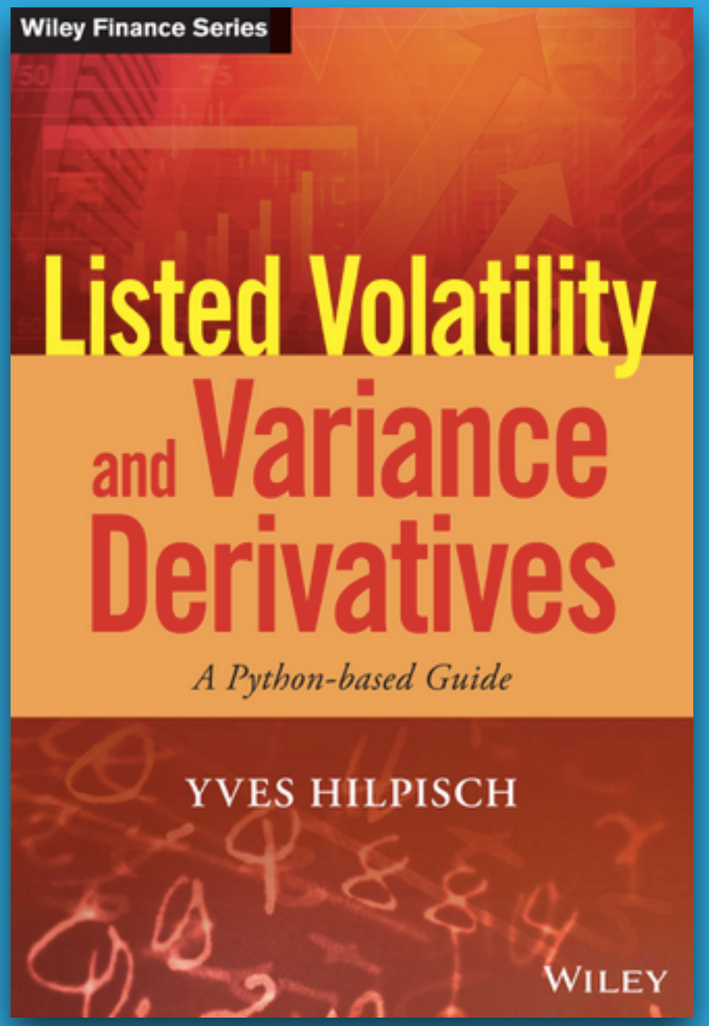
Quant Finance with Python





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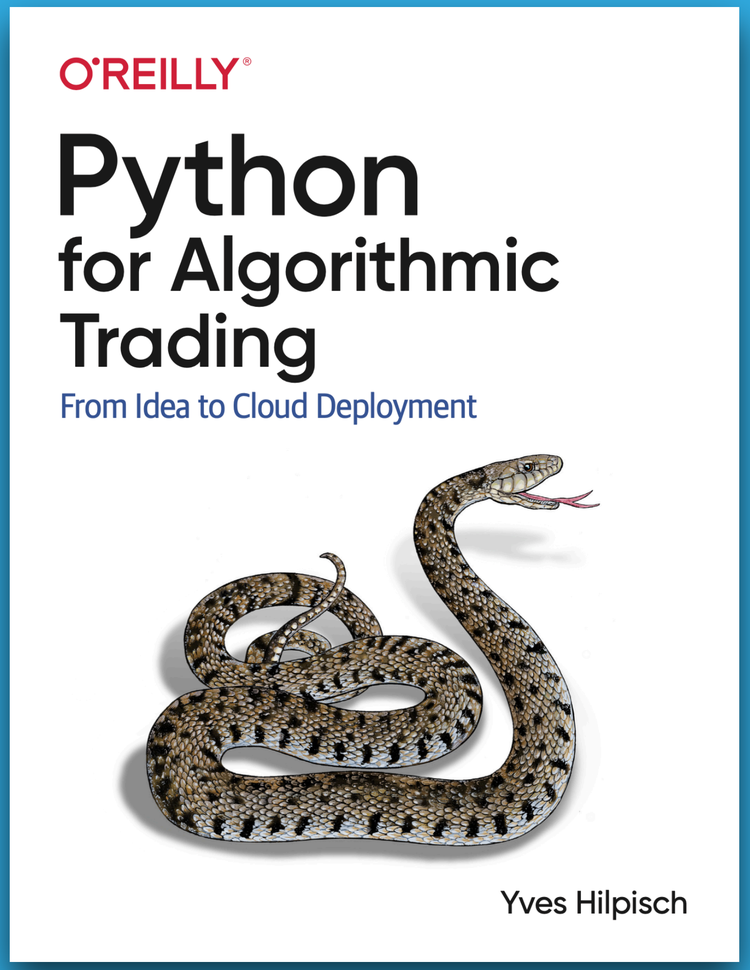
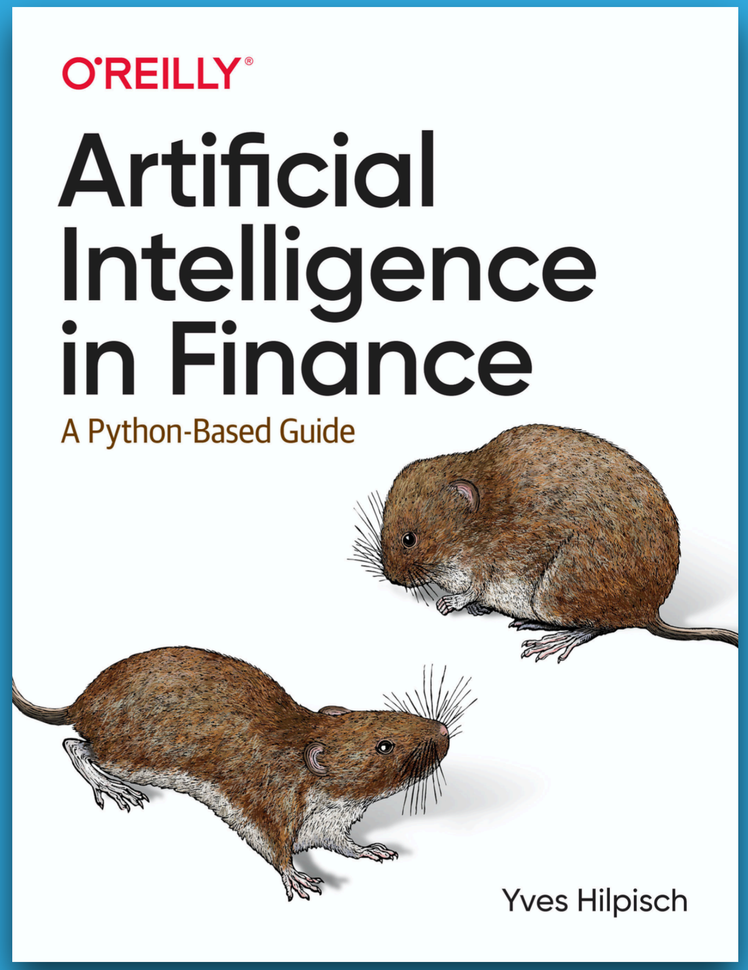
Python & AI for Finance & Trading





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Community of
professional & aspiring
quant developers &
quant researchers.

850+ Members
and growing.

Webinar series
“Reinforcement Learning
in Finance” on
https://youtube.com/@dyjh

https://bit.ly/quants_dev

Data-Driven Finance

FINANCIAL TIMES

COP clock runs down

Protest legacy

Huge Hong Kong police population keeps itself busy

Iran impasse

Long wait for liberty goes on

Briefing

Xi cements grip on China after vote puts him on par with Mao

Party says nation 'rejuvenated' • Third five-year term likely • New emphasis on socialism

Datawatch

Johnson's £4m outside earnings open him to charges of hypocrisy from MPs

De Klerk, last president of apartheid era, dies at 85

World Markets

Wilshire

Investing for a better future

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What's News

Business & Finance

World-Wide

GE Breakup Marks End of an Era

Company that symbolized U.S. manufacturing power to split into three parts

By Thomas Gryta

Over the past four decades, GE's revenue swelled and ebbed under four CEOs as it focused on different businesses, including a shift away from consumer goods and a bet on finance.

GE's revenue by segment

$74.37B

$224.19B

$84.83B

Share and index performance since 1980

Tax Bill Looms as Musk Eyes Share Sale

Facebook Rife With Stolen Content

the facebook files

Latest in a series

Meta Curbs Targeted Ads

A $115,000 USC Degree Yields Low Pay, Huge Debts

Elite school hired for-profit firm to woo students to social-work master's

THE FUTURE OF EVERYTHING

THE (ALMOST) CAR-FREE CITY

Democracy Loses Favor

Is Santa

From print …

... to the Web ...

Financial Times

ft.com

FTSE 100 -0.01% | S&P 500 -0.00% | Euro/Dollar +0.04% | Pound/Dollar +0.25% | Brent Crude Oil +0.96% | 10 Year US Gov +2.50% | Visit Markets Data

FINANCIAL TIMES

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Portfolio Settings & Account

US-China relations

Biden urges Xi not to allow competition to 'veer into conflict'

Leaders hold first virtual meeting as ties between US and China fray over Taiwan

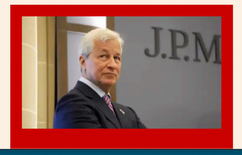
UPDATED 43 MINUTES AGO

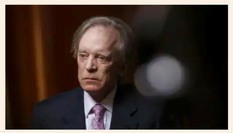
- Biden and Xi to tackle Taiwan and nuclear build-up in virtual meeting
- Australia vows to help US defend Taiwan from Chinese attacks
- Joe Biden and Xi Jinping to hold virtual summit on Monday

The Big Read

Investors pivot to India after China's tech crackdown

4 HOURS AGO





Feedback

About WSJ

Dow 29808.12 0.11% ▲ | U.S. 10 Yr 1/32 Yield 1.616% ▲ | Crude Oil 81.53 0.80% ▲ | Euro 1.1373 0.05% ▲ | DJIA 36087.45 0.04% ▼

THE WALL STREET JOURNAL.

Yves Hilpisch

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Virtual Meeting

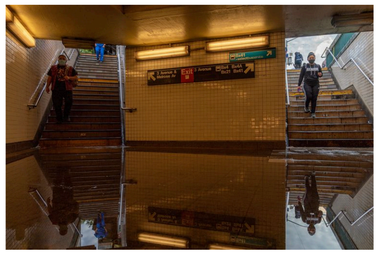
The White House said the U.S. and Chinese presidents discussed a variety of topics including Afghanistan, North Korea and Iran, as well as human rights, climate change and concerns over Taiwan. 492 7 min read

▶ How U.S. Plays Catch-Up on China's Push for Influence

President Signs Infrastructure Bill Into Law

The passage of the $1 trillion bill to repair roads and bridges, upgrade the electrical grid and expand access to broadband internet marks a rare bipartisan policy win for the White House. 6 min read

- What's in the Bill? From Amtrak to Roads to Water Systems



America's Infrastructure Struggles With New Weather Forecast

Historically anomalous heat and rain have overwhelmed systems designed to withstand old meteorological patterns, and climatologists expect still worse with climate change. "We've never seen destruction like this before."

523 Long read

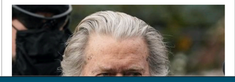
Shell to Move Headquarters to London Amid

Beto O'Rourke Announces Bid for Texas Governor

4 min read

Kyle Rittenhouse Homicide Trial Wraps Up

5 min read



US EUROPE ASIA FX RATES FUTURES

1D 5D 3M 6M 1Y

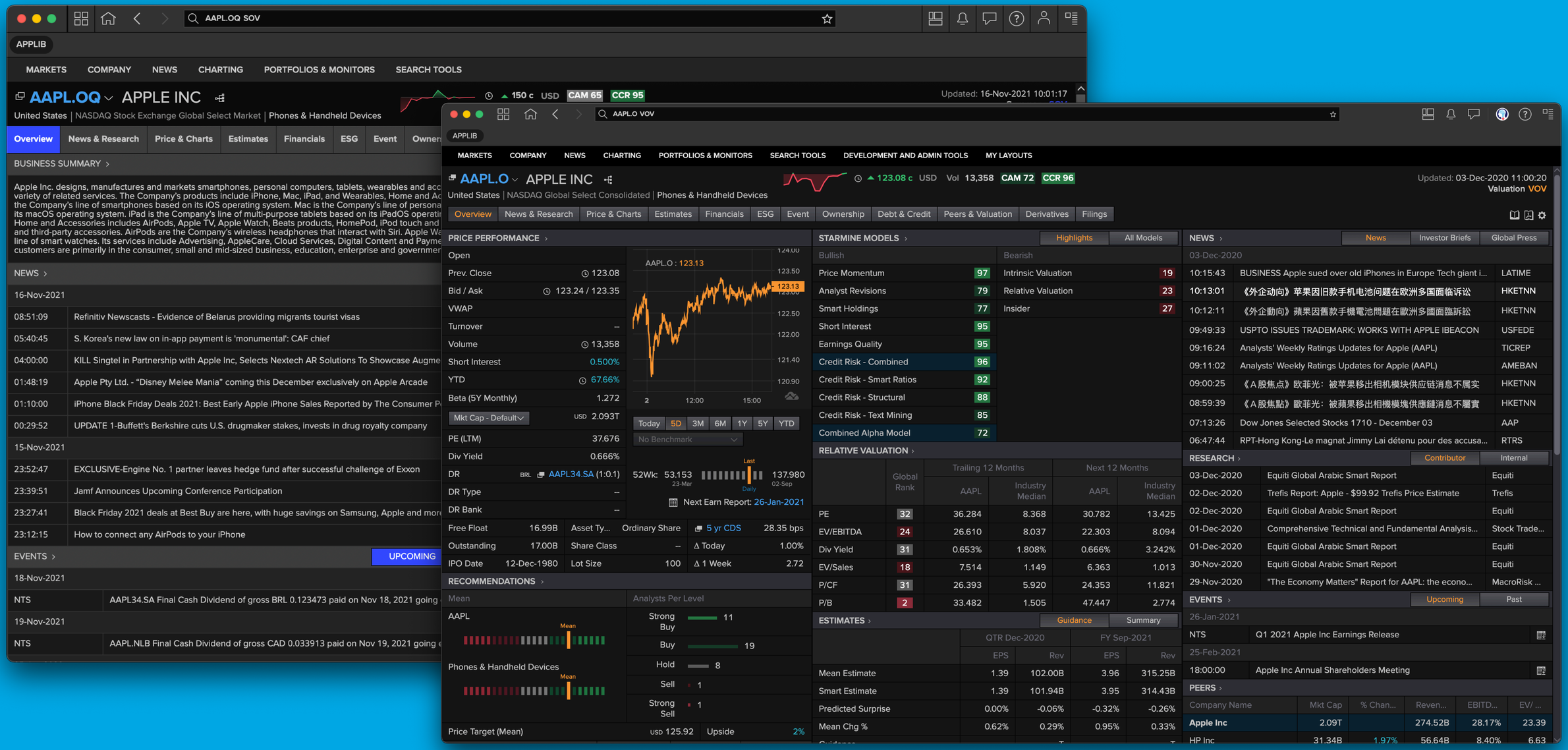
DJIA	36087.45	-12.86	-0.04%
S&P 500	4682.80	-0.05	-0.00%
Nasdaq	15853.85	-7.11	-0.04%
Russell 2000	2400.93	-10.84	-0.45%
DJ Total Mkt	48582.45	-17.28	-0.04%

View Watchlist View All Market Data →

OPINION

America Will Be Number One—in Taxes

By The Editorial Board | Review & Outlook



... to the Terminal ...

Tick Data

[4]:
```
%%time
data = ek.get_timeseries('AAPL.O',
                         start_date='2021-11-15 15:00:00',
                         end_date='2021-11-15 15:30:00',
                         interval='tick',
                         fields=['*'])
```

```
CPU times: user 120 ms, sys: 14.5 ms, total: 135 ms
Wall time: 2.7 s
```

[5]:
```
data.info()
```

```
<class 'pandas.core.frame.DataFrame'>
DatetimeIndex: 41213 entries, 2021-11-15 15:00:00.004000 to 2021-11-15 15:29:59.936000
Data columns (total 2 columns):
 #   Column  Non-Null Count  Dtype
---  ------  --------------  -----
 0   VALUE   41145 non-null  Float64
 1   VOLUME  41213 non-null  Int64
dtypes: Float64(1), Int64(1)
memory usage: 1.0 MB
```

[14]:
```
data.tail()
```

[14]:

AAPL.O	VALUE	VOLUME
Date		
2021-11-15 15:29:59.134	150.4456	10
2021-11-15 15:29:59.313	150.445	1
2021-11-15 15:29:59.588	150.4409	150
2021-11-15 15:29:59.745	150.445	1
2021-11-15 15:29:59.936	150.4488	5

... to powerful APIs.

Apple Event on 18. October 2021 (https://www.apple.com/de/apple-events/october-2021/).

[9]:
```
headlines = ek.get_news_headlines(query='R:AAPL.O macbook',
                                  count=5,
                                  date_from='2021-10-18',
                                  date_to='2021-10-19')
```

[10]:
```
headlines
```

[10]:

	versionCreated	text	storyId	sourceCode
2021-10-18 23:30:18.401	2021-10-18 23:30:18.401000+00:00	Apple is finally fixing the things people hate...	urn:newsml:reuters.com:20211018:nNRAh2psl1:1	NS:WASHPO
2021-10-18 23:10:18.012	2021-10-18 23:10:18.012000+00:00	Apple event – live: Macbook Pro and other new ...	urn:newsml:reuters.com:20211018:nNRAh2kj3a:1	NS:INDEPE
2021-10-18 21:41:19.927	2021-10-18 21:41:19.927000+00:00	New MacBook Pro features ultra-fast chips, ret...	urn:newsml:reuters.com:20211018:nNRAh2u38b:1	NS:EFEING
2021-10-18 21:33:50.860	2021-10-18 21:33:50.860000+00:00	Apple Event: MacBook Pro 2021 alleged pictures...	urn:newsml:reuters.com:20211018:nNRAh2u1wj:1	NS:TIMIND
2021-10-18 21:33:50.623	2021-10-18 21:33:50.623000+00:00	Apple launches new MacBook Pro: Price, specs a...	urn:newsml:reuters.com:20211018:nNRAh2u1vv:1	NS:TIMIND

... to powerful APIs.

```
[11]: story = headlines.iloc[0]

[12]: story

[12]: versionCreated                     2021-10-18 23:30:18.401000+00:00
      text              Apple is finally fixing the things people hate...
      storyId                urn:newsml:reuters.com:20211018:nNRAh2psl1:1
      sourceCode                                                   NS:WASHPO
      Name: 2021-10-18 23:30:18.401000, dtype: object

[13]: news_text = ek.get_news_story(story['storyId'])

[14]: from IPython.display import HTML

[15]: HTML(news_text)
```

[15]: The demise of MagSafe charging. An inelegant Touch Bar. Limited selection of ports. The laundry list of complaints about Apple's laptops has steadily grown over the past five years. Now, Apple is finally walking back those changes.

On Monday, the Cupertino, Calif., company unveiled a pair of new MacBook Pro laptops, powered by its latest homegrown processors and free of the many limitations that plagued earlier models. It also showed off a set of updated AirPods and colorful HomePod mini smart speakers. Riding high from record Mac sales last year, Apple made sure to make its new MacBooks the star of its virtual event Monday.

Still, computers that run Apple's MacOS software account for only a fraction of the overall PC landscape — just over 7 percent as of the end of the second quarter, according to market research firm IDC. Its market share has slipped from 8 percent in the first quarter and 7.6 percent a year earlier, IDC data showed. The changes on display Monday seem to be geared more toward

... to powerful APIs.

Infrastructure

IP[y]:
IPython

NumPy

matplotlib

pandas

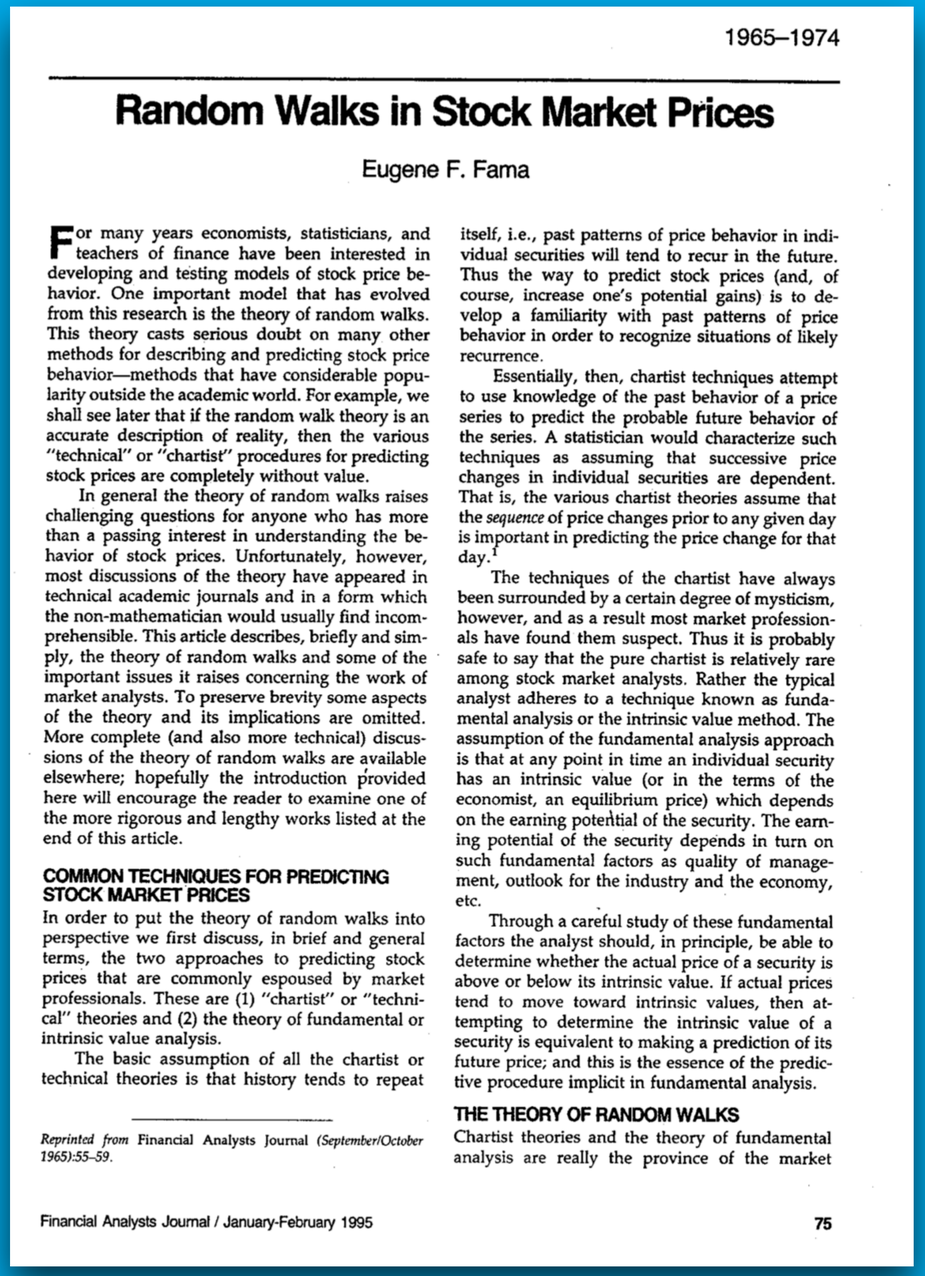
$$y_i t = \beta' x_{it} + \mu_i + \epsilon_{it}$$

Keras

Resources & Links

https://bit.ly/epat_sep_2023

Efficient Markets



1965–1974

Random Walks in Stock Market Prices

Eugene F. Fama

For many years economists, statisticians, and teachers of finance have been interested in developing and testing models of stock price behavior. One important model that has evolved from this research is the theory of random walks. This theory casts serious doubt on many other methods for describing and predicting stock price behavior—methods that have considerable popularity outside the academic world. For example, we shall see later that if the random walk theory is an accurate description of reality, then the various "technical" or "chartist" procedures for predicting stock prices are completely without value.

In general the theory of random walks raises challenging questions for anyone who has more than a passing interest in understanding the behavior of stock prices. Unfortunately, however, most discussions of the theory have appeared in technical academic journals and in a form which the non-mathematician would usually find incomprehensible. This article describes, briefly and simply, the theory of random walks and some of the important issues it raises concerning the work of market analysts. To preserve brevity some aspects of the theory and its implications are omitted. More complete (and also more technical) discussions of the theory of random walks are available elsewhere; hopefully the introduction provided here will encourage the reader to examine one of the more rigorous and lengthy works listed at the end of this article.

COMMON TECHNIQUES FOR PREDICTING STOCK MARKET PRICES

In order to put the theory of random walks into perspective we first discuss, in brief and general terms, the two approaches to predicting stock prices that are commonly espoused by market professionals. These are (1) "chartist" or "technical" theories and (2) the theory of fundamental or intrinsic value analysis.

The basic assumption of all the chartist or technical theories is that history tends to repeat itself, i.e., past patterns of price behavior in individual securities will tend to recur in the future. Thus the way to predict stock prices (and, of course, increase one's potential gains) is to develop a familiarity with past patterns of price behavior in order to recognize situations of likely recurrence.

Essentially, then, chartist techniques attempt to use knowledge of the past behavior of a price series to predict the probable future behavior of the series. A statistician would characterize such techniques as assuming that successive price changes in individual securities are dependent. That is, the various chartist theories assume that the *sequence* of price changes prior to any given day is important in predicting the price change for that day.[1]

The techniques of the chartist have always been surrounded by a certain degree of mysticism, however, and as a result most market professionals have found them suspect. Thus it is probably safe to say that the pure chartist is relatively rare among stock market analysts. Rather the typical analyst adheres to a technique known as fundamental analysis or the intrinsic value method. The assumption of the fundamental analysis approach is that at any point in time an individual security has an intrinsic value (or in the terms of the economist, an equilibrium price) which depends on the earning potential of the security. The earning potential of the security depends in turn on such fundamental factors as quality of management, outlook for the industry and the economy, etc.

Through a careful study of these fundamental factors the analyst should, in principle, be able to determine whether the actual price of a security is above or below its intrinsic value. If actual prices tend to move toward intrinsic values, then attempting to determine the intrinsic value of a security is equivalent to making a prediction of its future price; and this is the essence of the predictive procedure implicit in fundamental analysis.

THE THEORY OF RANDOM WALKS

Chartist theories and the theory of fundamental analysis are really the province of the market

Reprinted from Financial Analysts Journal *(September/October 1965):55–59.*

Financial Analysts Journal / January-February 1995 75

Eugene F. Fama (1965):

"For many years, economists, statisticians, and teachers of finance have been interested in developing and testing models of stock price behavior. One important model that has evolved from this research is the theory of random walks. This theory casts serious doubt on many other methods for describing and predicting stock price behavior—methods that have considerable popularity outside the academic world. For example, we shall see later that, if the random-walk theory is an accurate description of reality, then the various "technical" or "chartist" procedures for predicting stock prices are completely without value."—Eugene F. Fama (1965): "Random Walks in Stock Market Prices"

Michael Jensen (1978): “Some Anomalous Evidence Regarding Market Efficiency”:

“A market is efficient with respect to an information set S if it is impossible to make economic profits by trading on the basis of information set S.”

Efficient Markets—Simple Illustration

If a stock price follows a (simple) random walk (no drift & normally distributed returns), then it rises and falls with the same probability of 50% (“toss of a coin”).

In such a case, the best predictor of tomorrow’s stock price — in a least-squares sense — is today’s stock price.

"… the existence of a single successful prediction model is sufficient to demonstrate violation of the EMH.

Acknowledging this point, we provide suggestions to the sort of forecasting procedure that could work even if the EMH is correct.

Consideration needs to be turned to quickly changing models that can detect and utilize any instances of temporary forecastability that might arise and quickly disappear as learning opportunities arise and close down."

Timmermann, Allan and Clive Granger (2004): "Efficient Market Hypothesis and Forecasting."

“A market is efficient with respect to the information set, S(t), search technologies, T(t), and forecasting models, M(t), if it is impossible to make economic profits by trading on the basis of signals produced from a forecasting model in M(t) defined over predictor variables in the information set S(t) and selected using a search technology in T(t).”

Timmermann, Allan and Clive Granger (2004): “Efficient Market Hypothesis and Forecasting.”

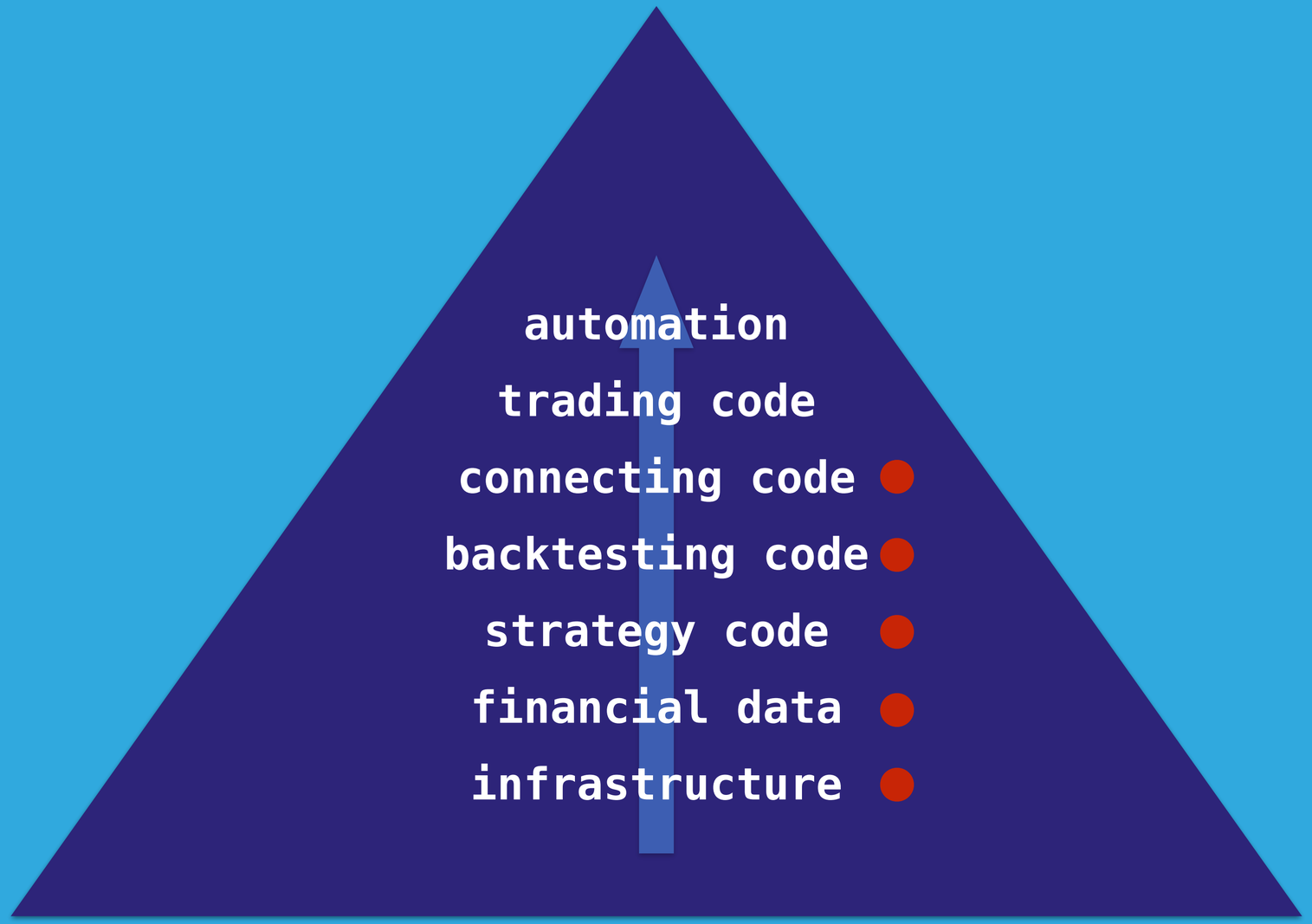
Overview

INFRASTRUCTURE
Python environment, Jupyter Lab,
first steps, efficient markets

VECTORIZED BACKTESTING
interactive code,
OOP and Python classes

EVENT-BASED BACKTESTING
base backtesting class,
strategy backtesting class

REAL-TIME DATA
simulated streaming (“real-time”) data,
data processing, online algorithms


automation
trading code
connecting code
backtesting code
strategy code
financial data
infrastructure

Why Object Orientation?

Some human aspects:

- natural way of thinking
  - a “house”
  - a “person”
  - a “person” in a “house”
- mastering complexity
- nicer user interfaces
- pythonic way …

Some technical aspects:

- abstraction
- modularity
- re-usability
  - inheritance
  - composition
  - aggregation
  - polymorphism
- non-redundancy

Free e-book about OOP in general

Lecture Notes on Object-Oriented Programming

Free e-book about Python programming & OOP

http://python-textbok.readthedocs.io/en/1.0/

Fluent Python (O'Reilly)

https://learning.oreilly.com

The Python Quants GmbH

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@dyjh