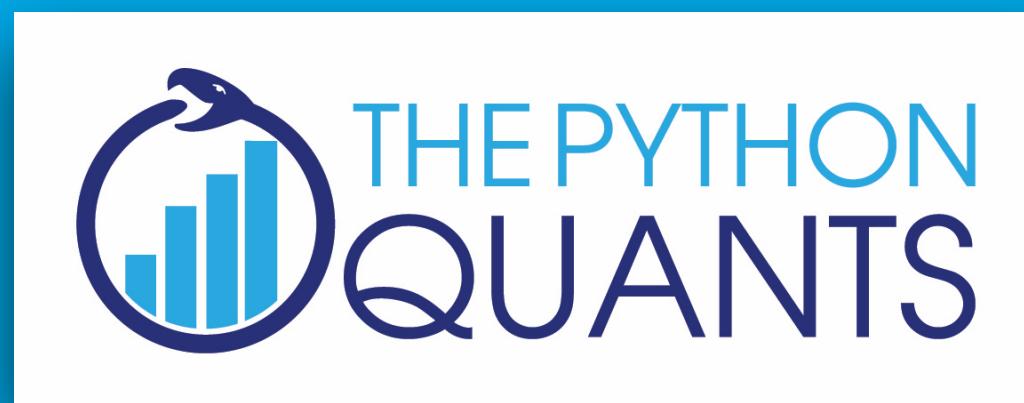


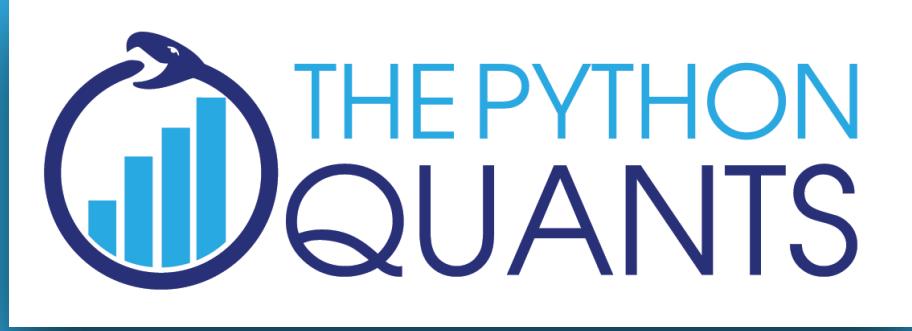
Reinforcement Learning— From Playing Games to Algorithmic Trading

Dr. Yves J. Hilpisch

CQF, Online, 16. May 2023



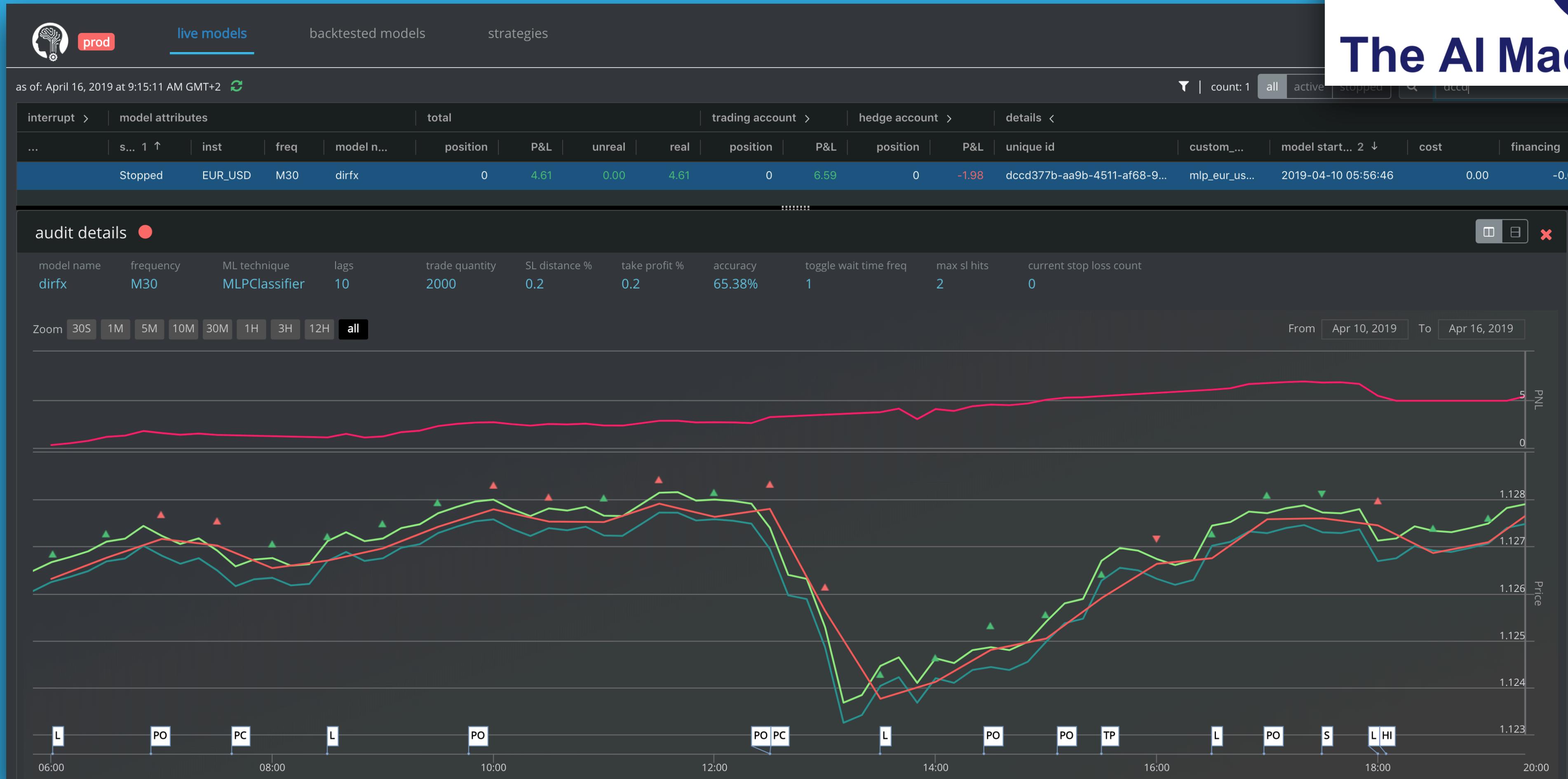
Introduction



<http://tpq.io>



The AI Machine



<http://aimachine.io>

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 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>):

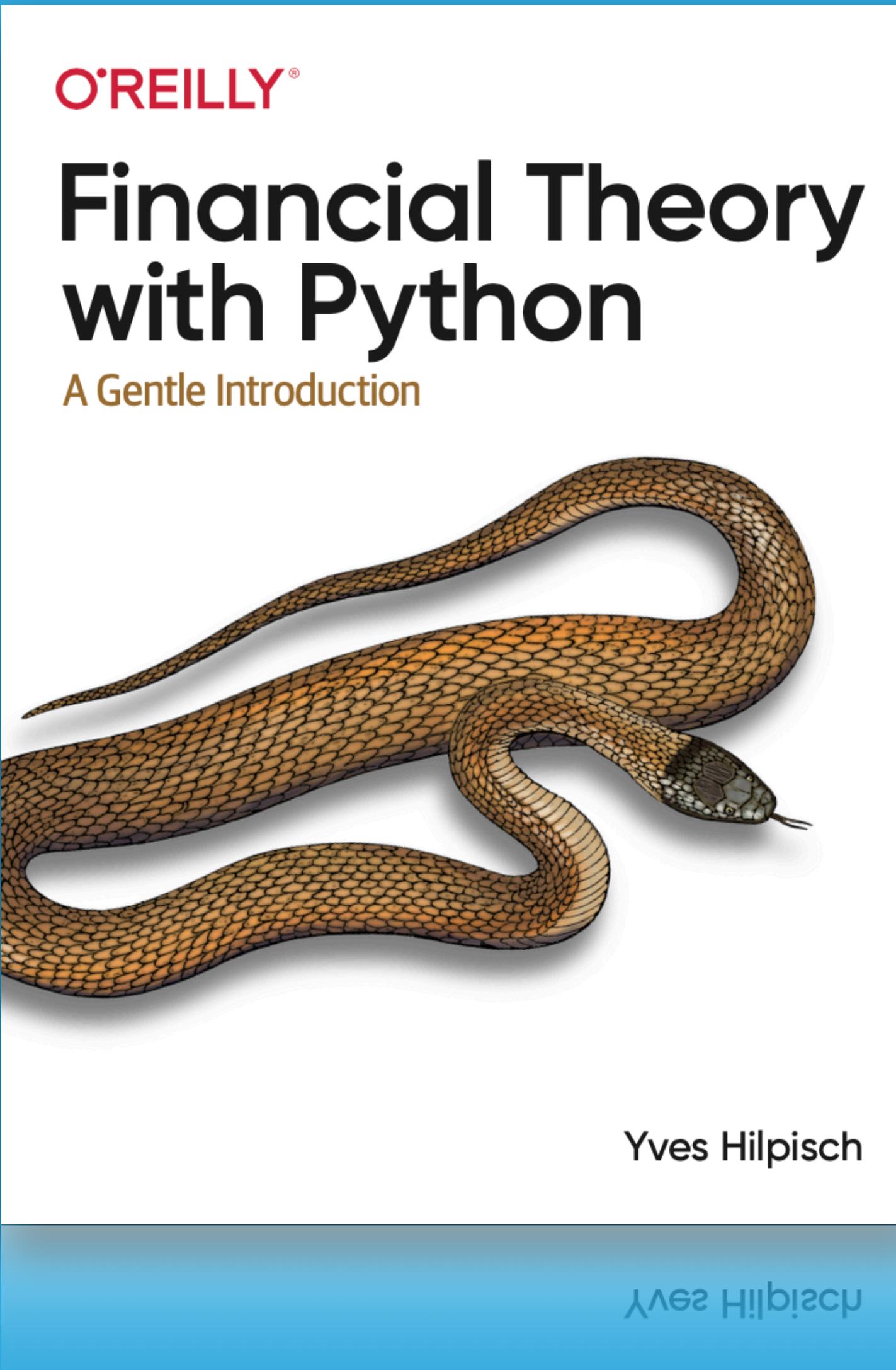
- * Financial Theory with Python (2021, O'Reilly)
- * Artificial Intelligence in Finance (2020, O'Reilly)
- * Python for Algorithmic Trading (2020, O'Reilly)
- * Python for Finance (2018, 2nd ed., O'Reilly)
- * Listed Volatility and Variance Derivatives (2017, Wiley Finance)
- * Derivatives Analytics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



Yves is the director of the first online training program leading to **University 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://cqd.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.

Financial Theory with Python – A Gentle Introduction



Finance with Python and Python environments

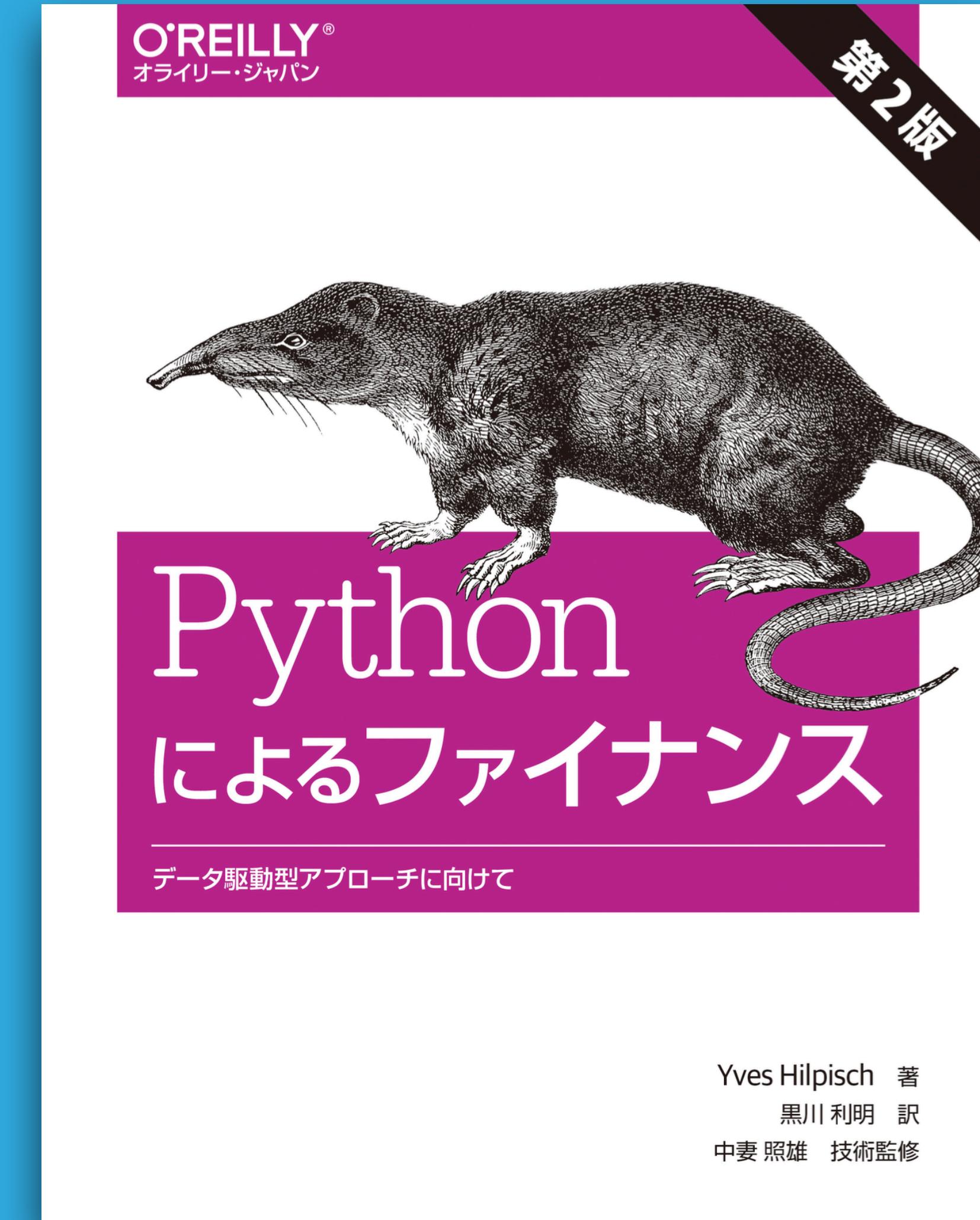
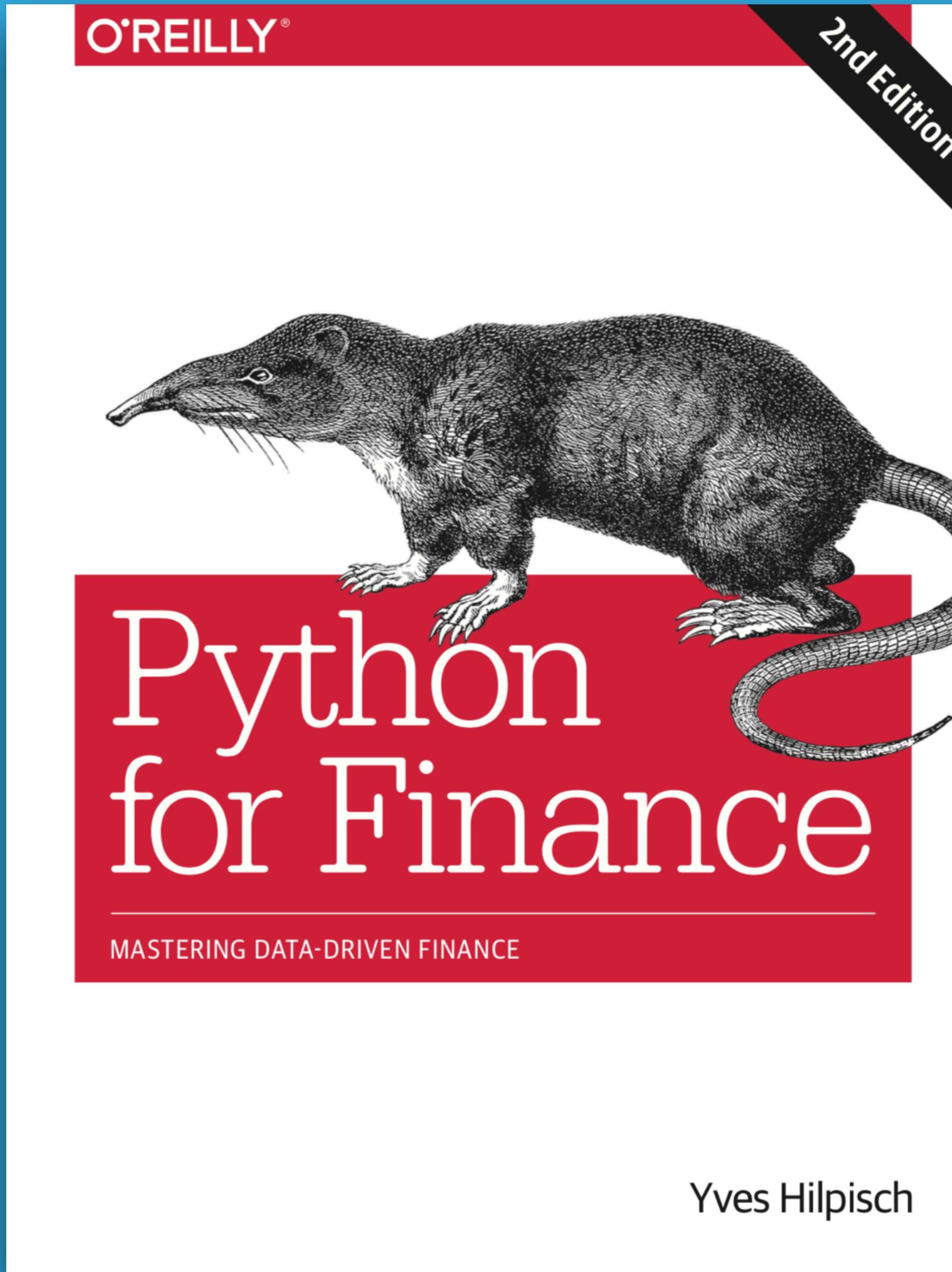
Basic Finance Concepts and Models:

- Risk–Return
- Arbitrage Pricing
- Expected Utility Theory
- Mean–Variance Portfolio Theory
- Capital Asset Pricing Model
- Portfolio Optimization

Basic Python Concepts and Packages:

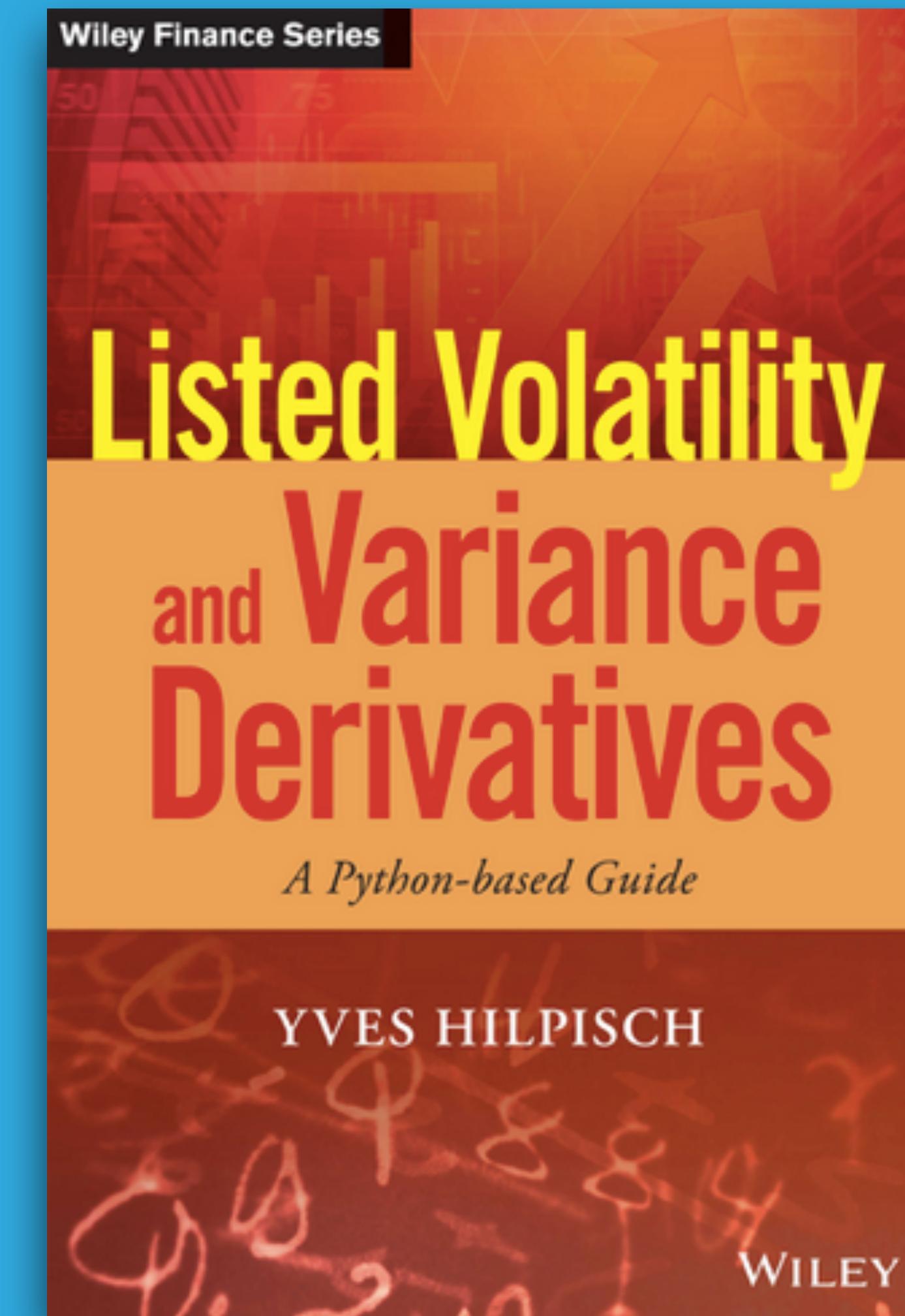
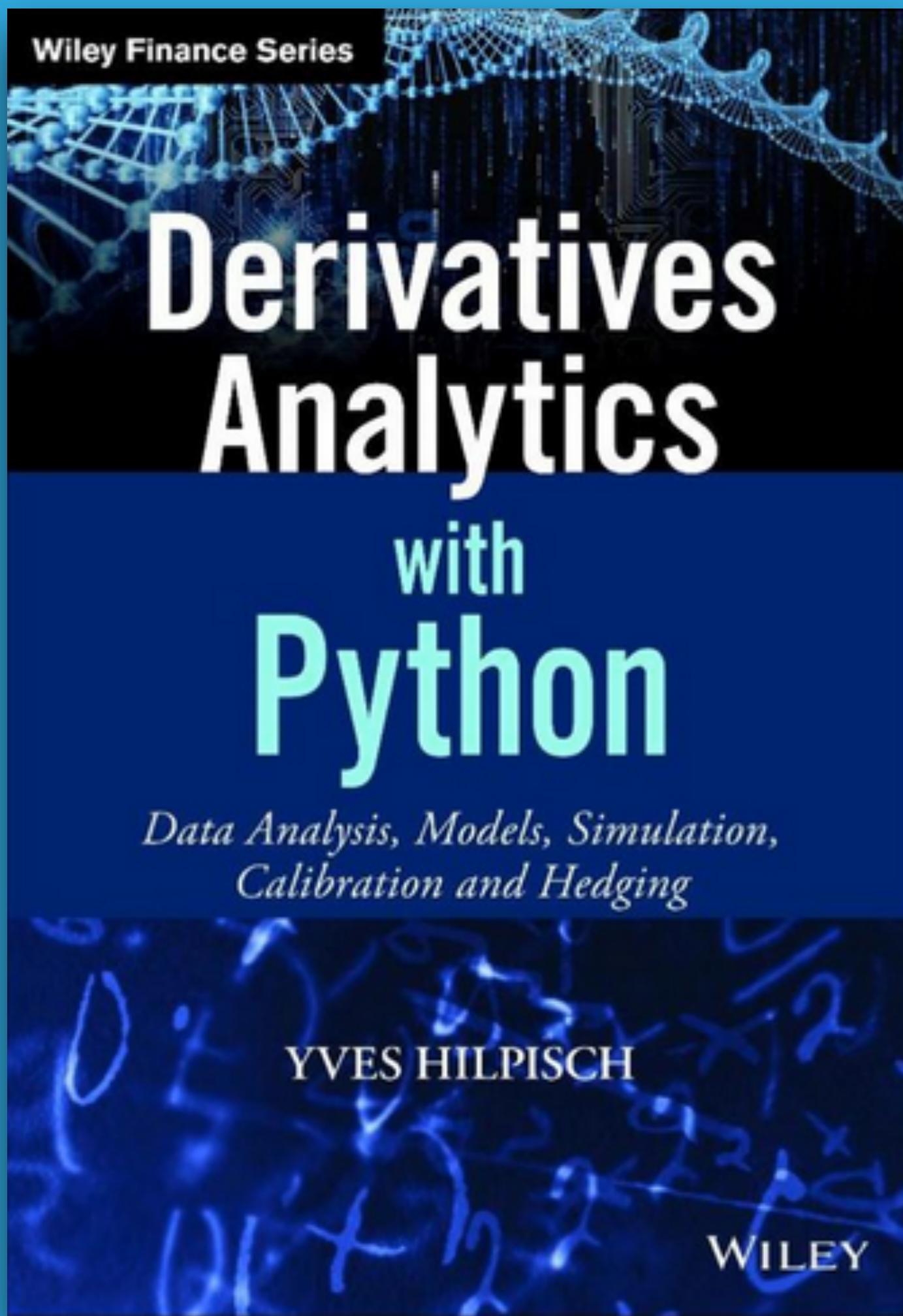
- Major Python Idioms
- NumPy Package
- SciPy & SymPy Packages

Python for Finance



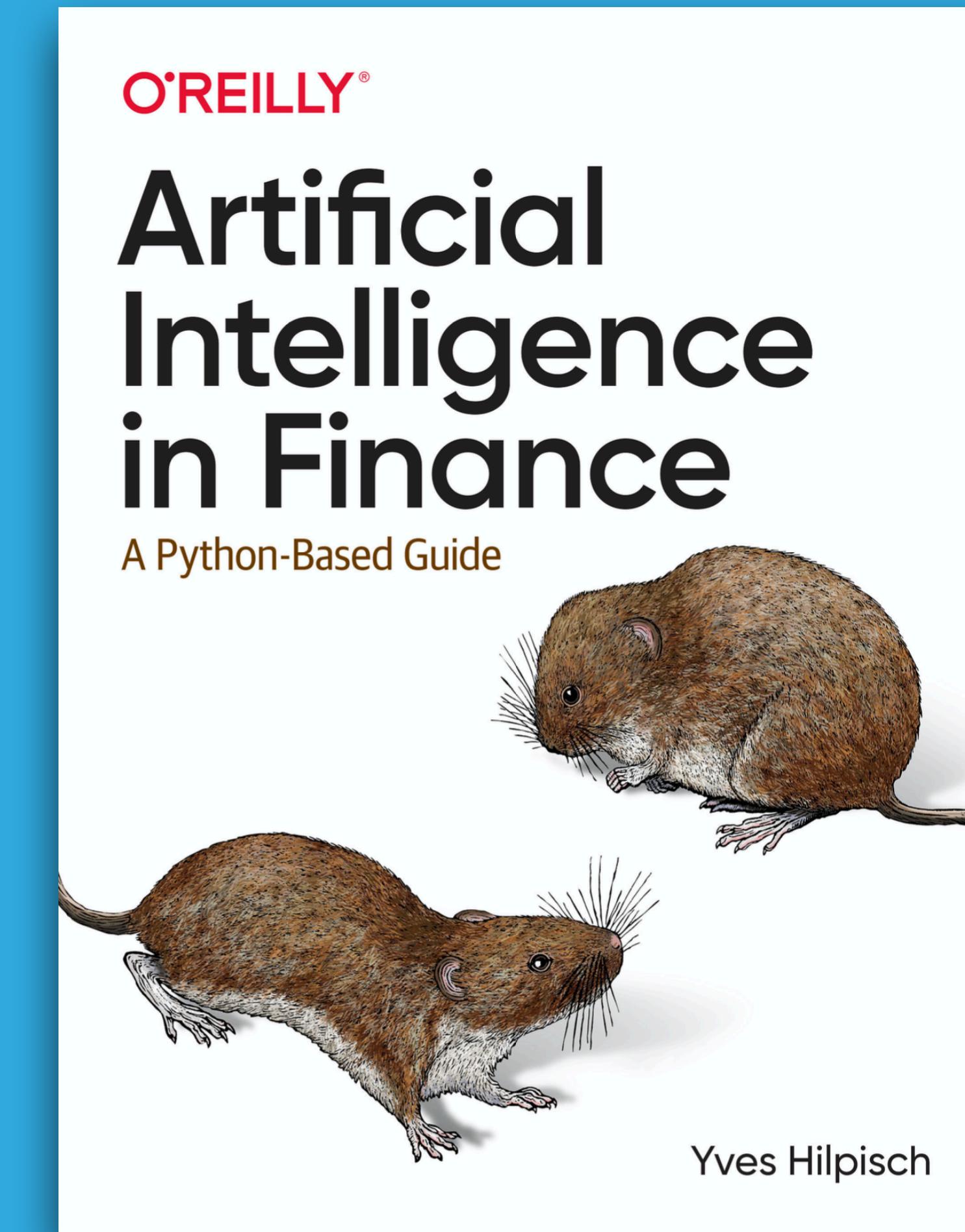
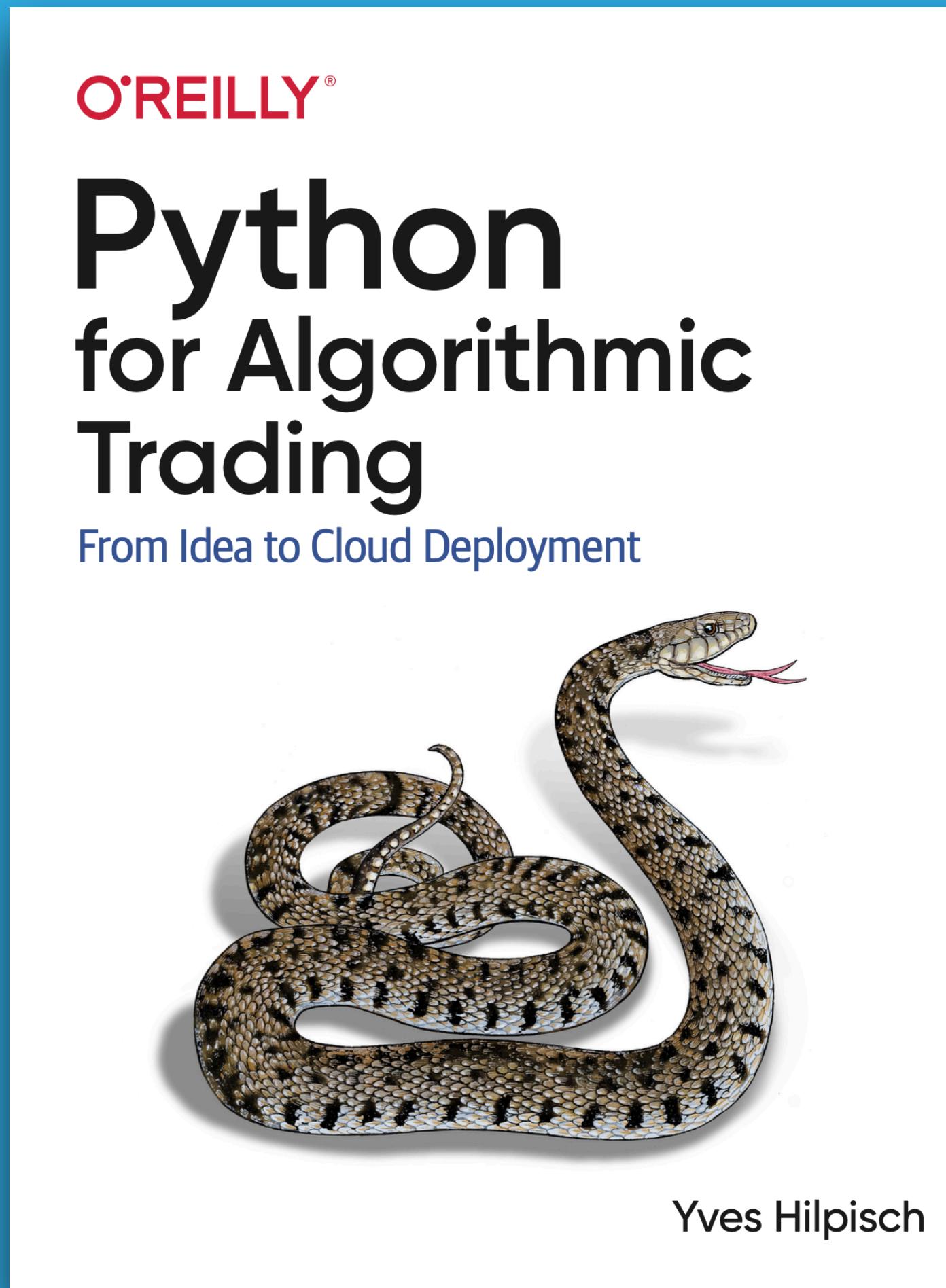
<http://books.tpq.io>

Quant Finance with Python



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Python & AI for Finance & Trading



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4 to 12 months
self-paced

250+ hours
of instruction

25,000+ lines
of code

2,500+ pages
HTML/PDF

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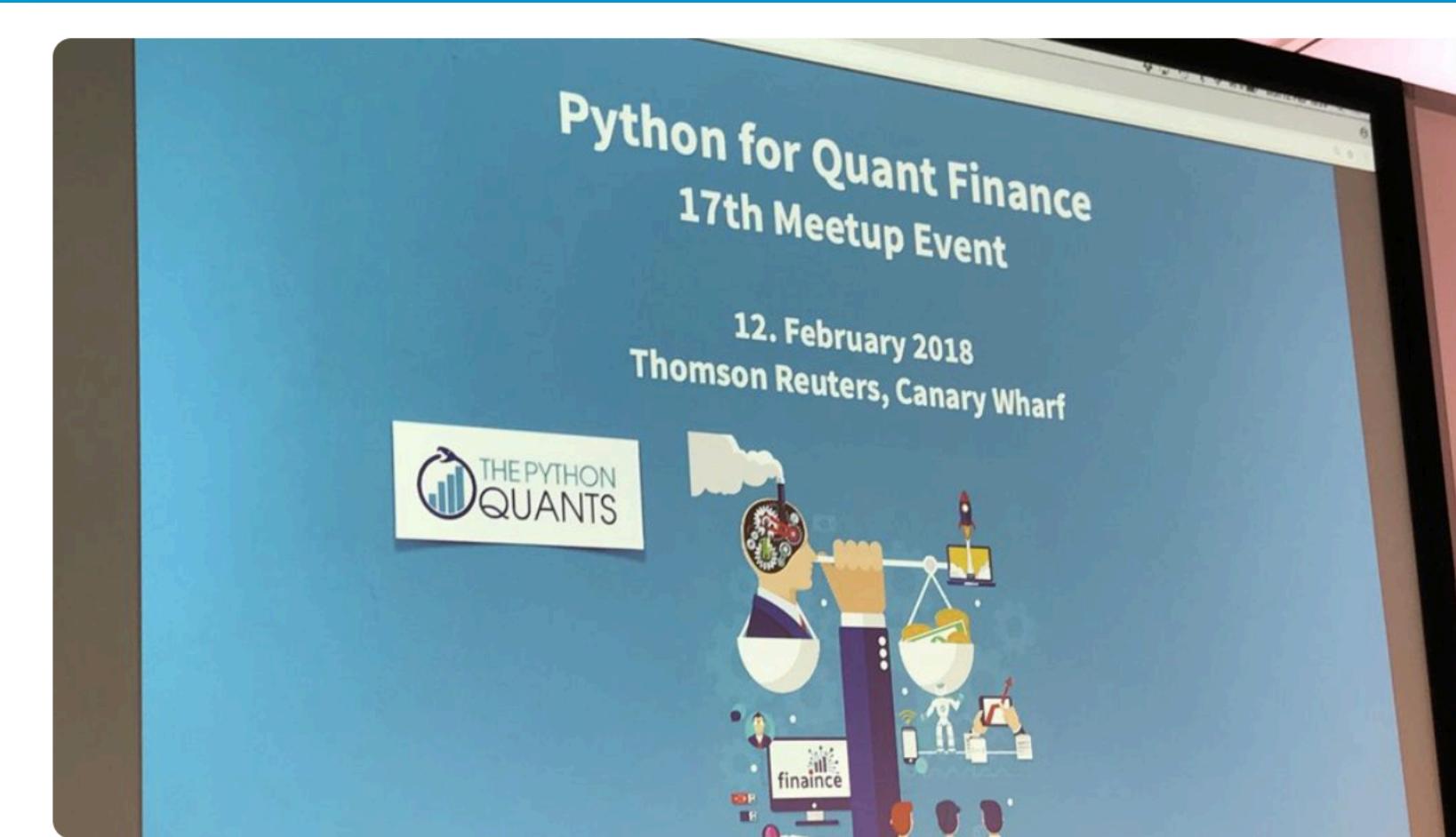
(pro)
quants@dev
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Community of
professional & aspiring
quant developers &
quant researchers.

750 Members
and growing.

Webinar series
“Reinforcement Learning
in Finance”

https://bit.ly/quants_dev



About Events Members Photos Discussions More

What we're about

This group is about the use of Python & AI for Quantitative Financial Applications, Algorithmic Trading and Interactive Financial Analytics.

Python for Quant Finance

London, United Kingdom
3,416 members · Public group
Organized by Yves H. and 2 others

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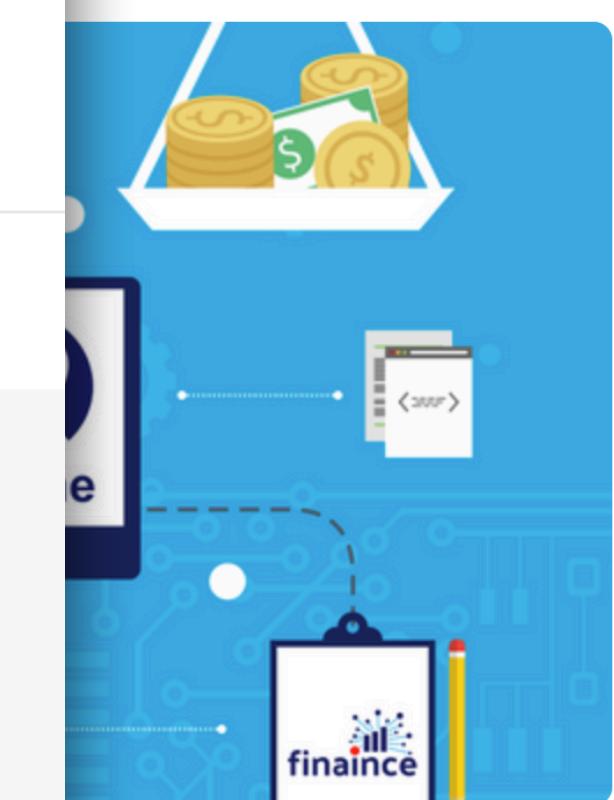
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Organizers



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What we're about

This Meetup group is concerned with data-driven and AI-first finance in general and algorithmic trading in particular. Its events cover the latest...

Artificial Intelligence in Finance & Algorithmic Trading

New York, NY
345 members · Public group
Organized by Yves Hilpisch

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 Yves Hilpisch
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Gist with Code Resources

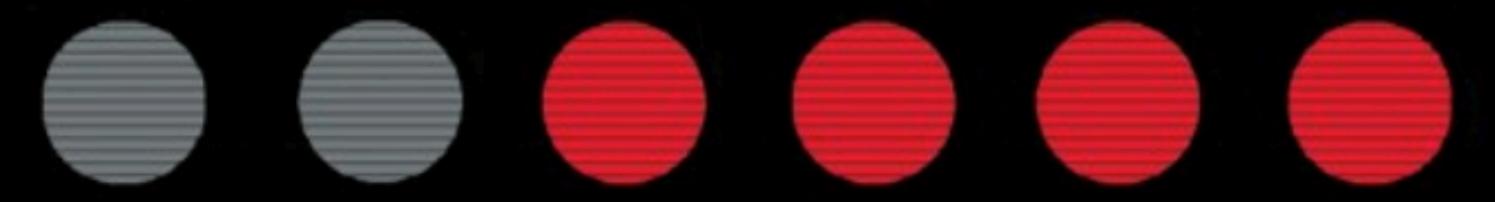
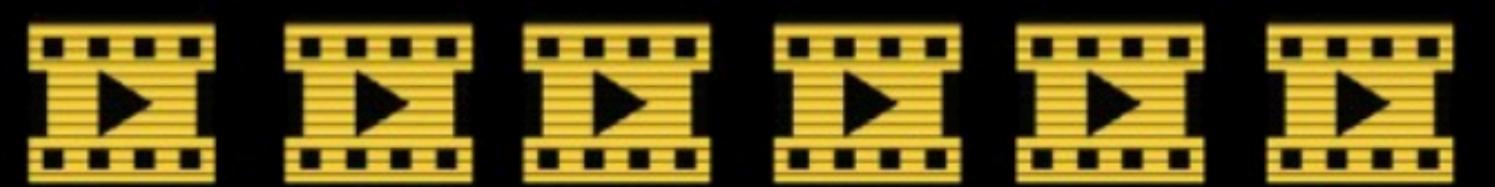
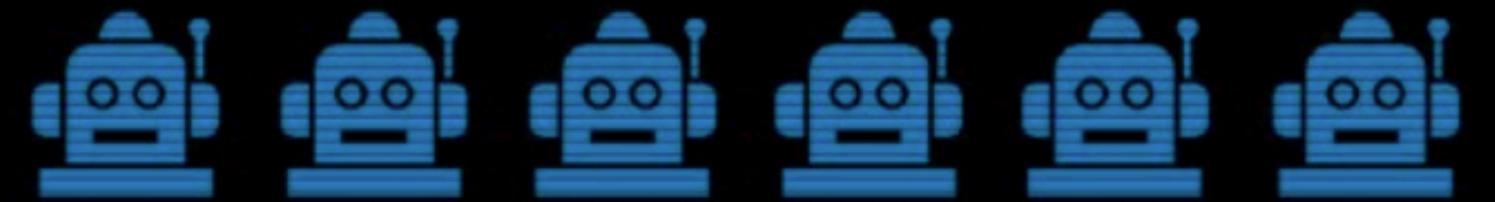
http://bit.ly/cqf_may_2023

AI-Powered Algorithmic Trading

1. AI Success Stories
2. Physics Envy & The Beauty Myth
3. Data-Driven Finance
4. Efficient Markets
5. AI-First Finance
6. Dynamic Programming
7. Reinforcement Learning
8. Conclusions

AI Success Stories

SEAN GERRISH



HOW SMART
MACHINES THINK

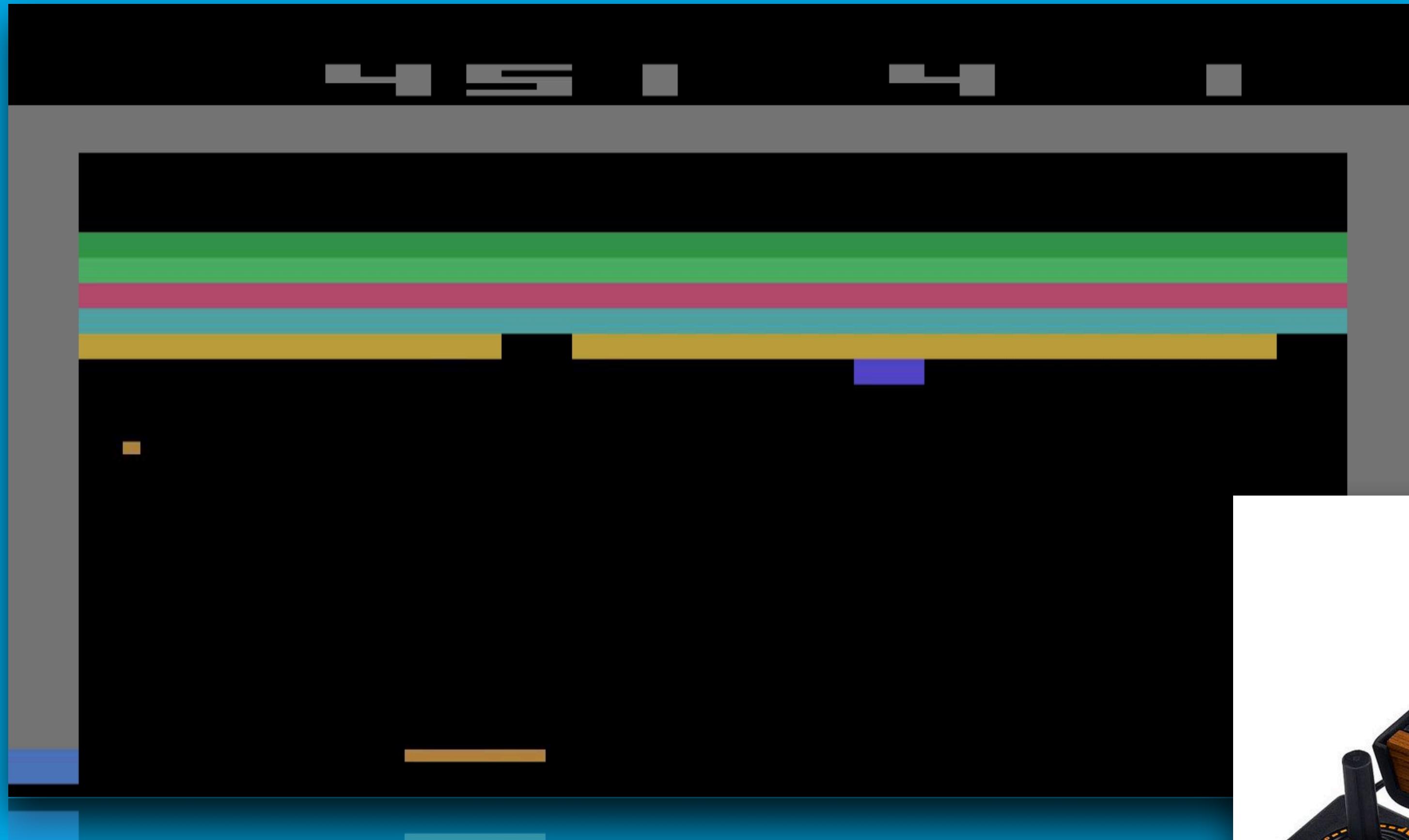


Success Stories about Deep Learning and Deep Reinforcement Learning:

- Self-Driving Cars
- Recommendation Engines
- Playing Atari Games
- Image Recognition & Classification
- Speech Recognition
- Playing the Game of Go

AI Success Stories

–Atari Games and Reinforcement Learning



“We present the first deep learning model to successfully learn control policies directly from high-dimensional sensory input using reinforcement learning. The model is a convolutional neural network, trained with a variant of Q-learning, whose input is raw pixels and whose output is a value function estimating future rewards. We apply our method to seven Atari 2600 games from the Arcade Learning Environment, with no adjustment of the architecture or learning algorithm. We find that it outperforms all previous approaches on six of the games and surpasses a human expert on three of them.”

Mnih, V. (2013): “Playing Atari with Deep Reinforcement Learning”. <https://arxiv.org/pdf/1312.5602v1.pdf>

arXiv:1312.5602v1 [cs.LG] 19 Dec 2013

Playing Atari with Deep Reinforcement Learning

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Daan Wierstra Martin Riedmiller
DeepMind Technologies
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Abstract

We present the first deep learning model to successfully learn control policies directly from high-dimensional sensory input using reinforcement learning. The model is a convolutional neural network, trained with a variant of Q-learning, whose input is raw pixels and whose output is a value function estimating future rewards. We apply our method to seven Atari 2600 games from the Arcade Learning Environment, with no adjustment of the architecture or learning algorithm. We find that it outperforms all previous approaches on six of the games and surpasses a human expert on three of them.

1 Introduction

Learning to control agents directly from high-dimensional sensory inputs like vision and speech is one of the long-standing challenges of reinforcement learning (RL). Most successful RL applications that operate on these domains have relied on hand-crafted features combined with linear value functions or policy representations. Clearly, the performance of such systems heavily relies on the quality of the feature representation.

Recent advances in deep learning have made it possible to extract high-level features from raw sensory data, leading to breakthroughs in computer vision [11, 22, 16] and speech recognition [6, 7]. These methods utilise a range of neural network architectures, including convolutional networks, multilayer perceptrons, restricted Boltzmann machines and recurrent neural networks, and have exploited both supervised and unsupervised learning. It seems natural to ask whether similar techniques could also be beneficial for RL with sensory data.

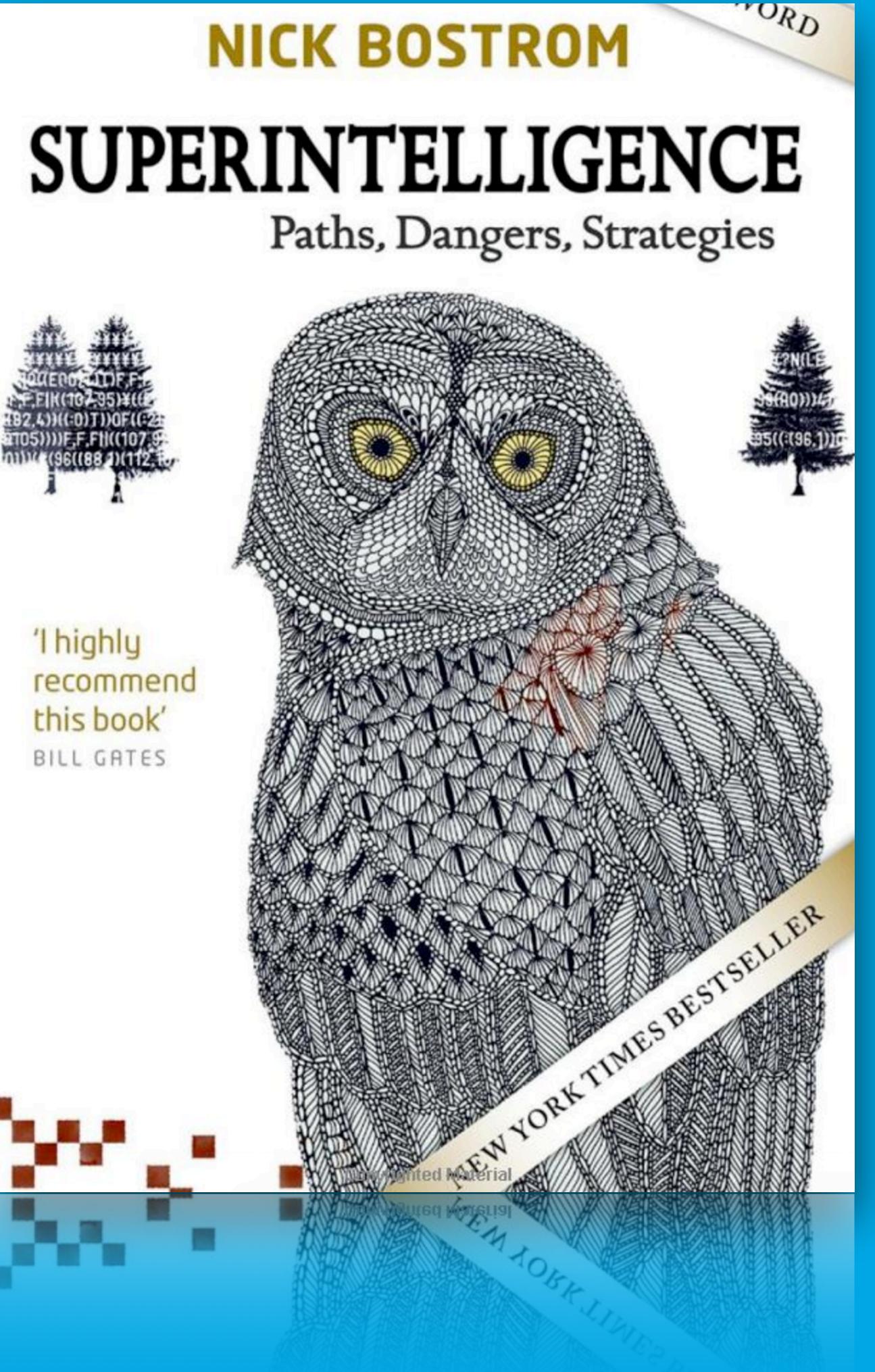
However reinforcement learning presents several challenges from a deep learning perspective. Firstly, most successful deep learning applications to date have required large amounts of hand-labelled training data. RL algorithms, on the other hand, must be able to learn from a scalar reward signal that is frequently sparse, noisy and delayed. The delay between actions and resulting rewards, which can be thousands of timesteps long, seems particularly daunting when compared to the direct association between inputs and targets found in supervised learning. Another issue is that most deep learning algorithms assume the data samples to be independent, while in reinforcement learning one typically encounters sequences of highly correlated states. Furthermore, in RL the data distribution changes as the algorithm learns new behaviours, which can be problematic for deep learning methods that assume a fixed underlying distribution.

This paper demonstrates that a convolutional neural network can overcome these challenges to learn successful control policies from raw video data in complex RL environments. The network is trained with a variant of the Q-learning [26] algorithm, with stochastic gradient descent to update the weights. To alleviate the problems of correlated data and non-stationary distributions, we use

1

AI Success Stories

—Go and AlphaGo



“Go-playing programs have been improving at a rate of about 1 dan/year in recent years. If this rate of improvement continues, they might beat the human world champion in about a decade.”

Nick Bostrom (2014): Superintelligence.

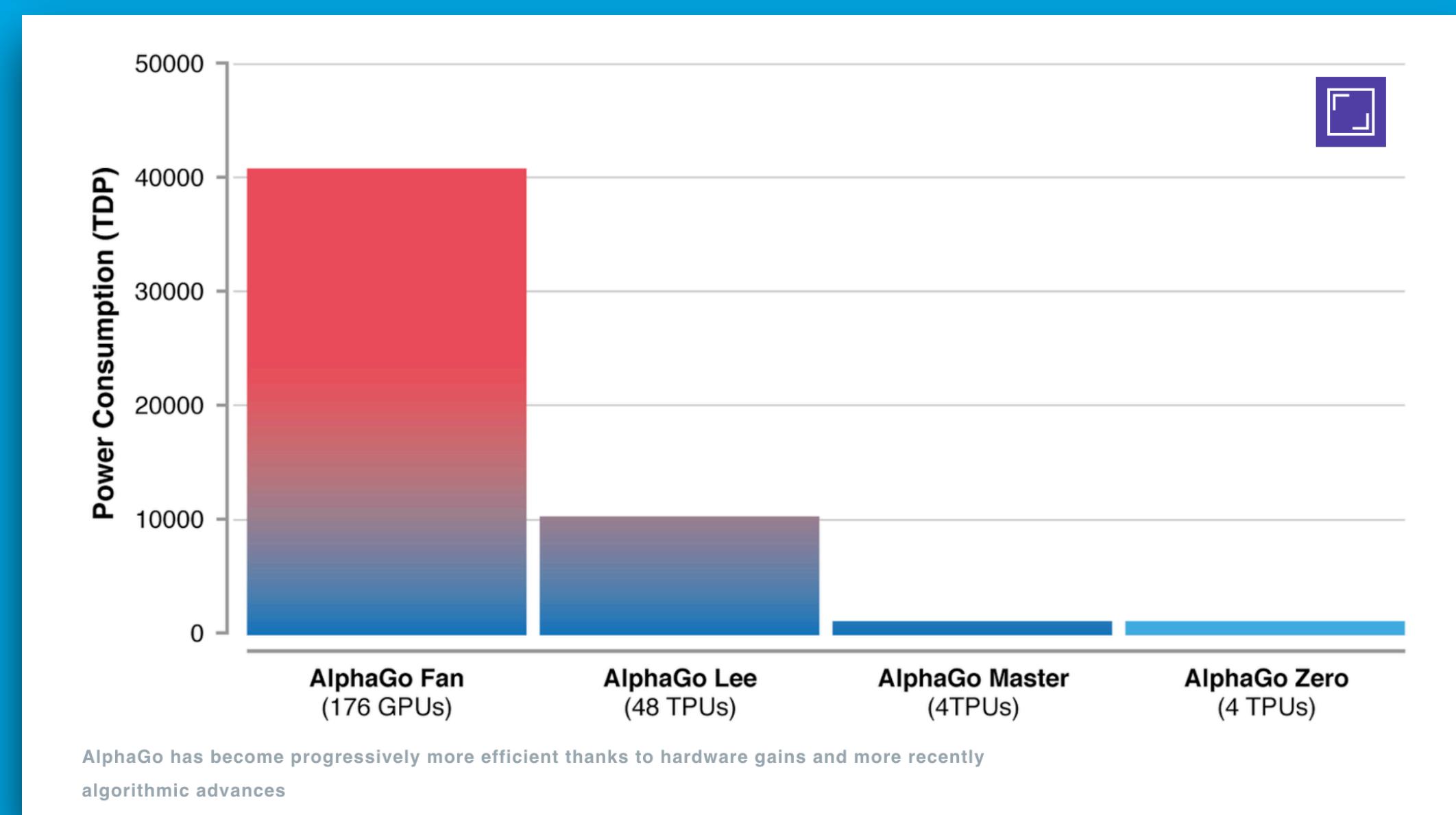
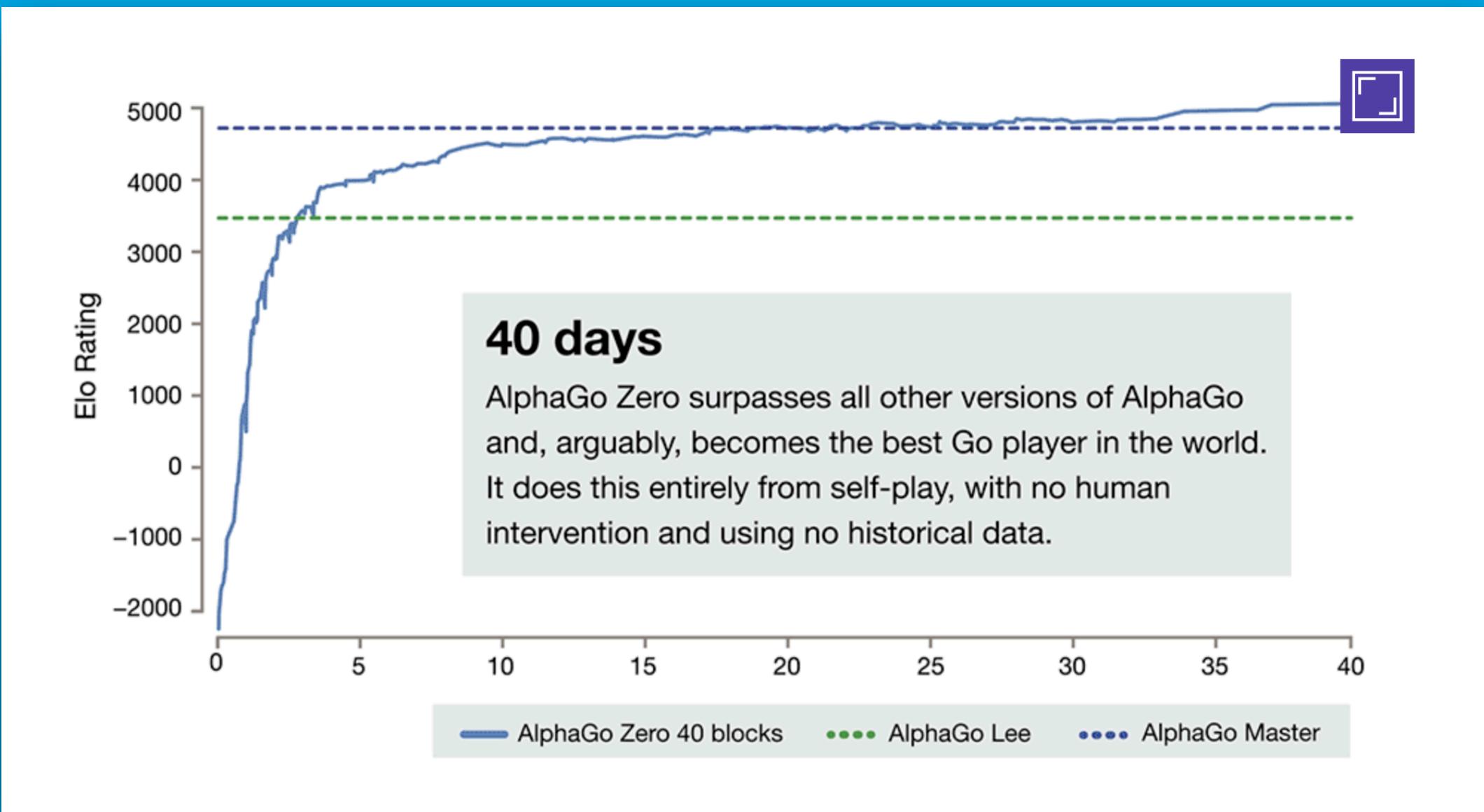
The story of AlphaGo so far

AlphaGo is the first computer program to defeat a professional human Go player, the first program to defeat a Go world champion, and arguably the strongest Go player in history.

AlphaGo's first formal match was against the reigning 3-times European Champion, Mr Fan Hui, in October 2015. Its 5-0 win was the first ever against a Go professional, and the results were published in full technical detail in the international journal, [Nature](#). AlphaGo then went on to compete against legendary player Mr Lee Sedol, winner of 18 world titles and widely considered to be the greatest player of the past decade.

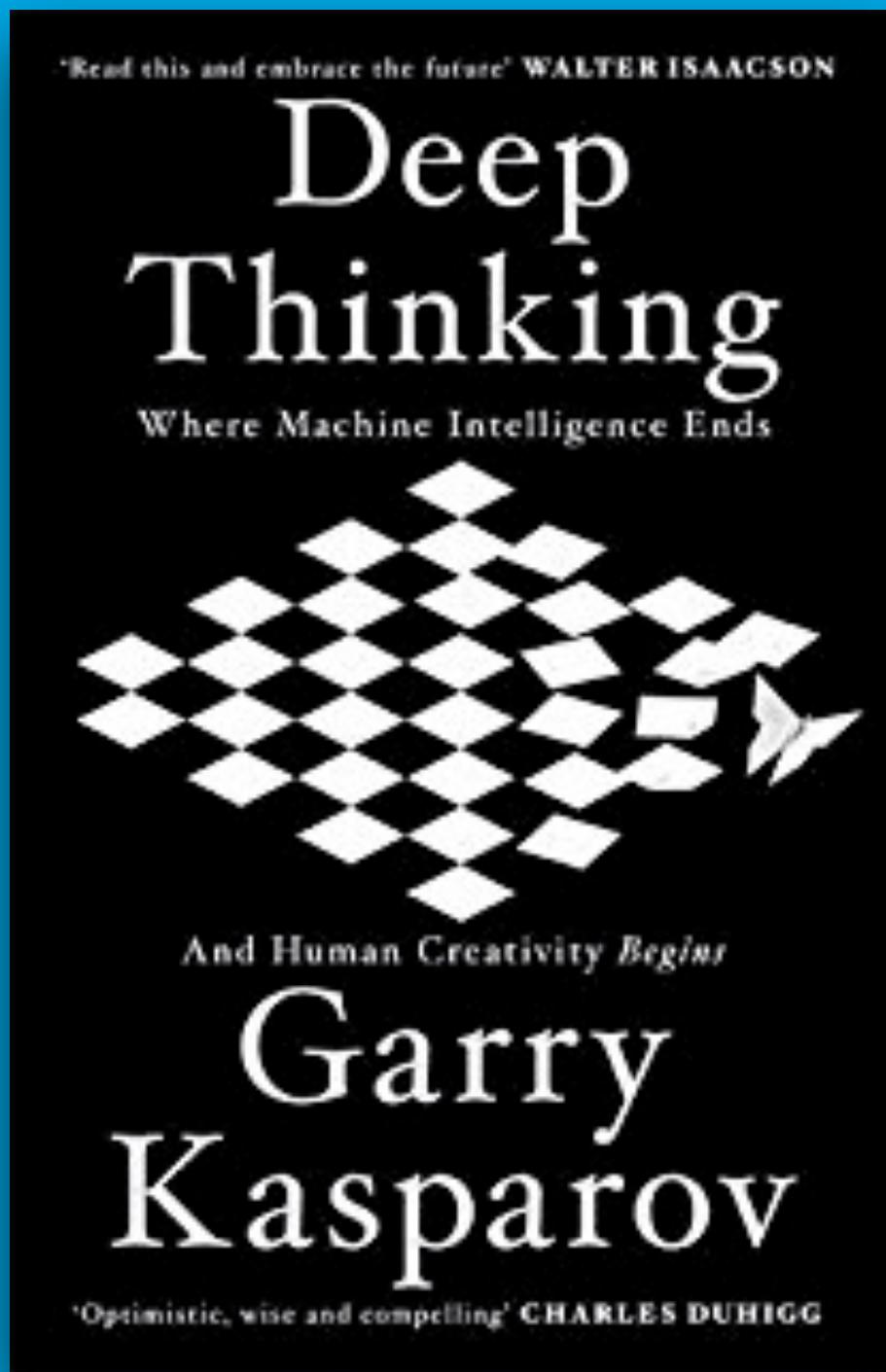
AlphaGo's 4-1 victory in Seoul, South Korea, in March 2016 was watched by over 200 million people worldwide. It was a landmark achievement that experts agreed was a decade ahead of its time, and earned AlphaGo a 9 dan professional ranking (the highest certification) - the first time a computer Go player had ever received the accolade.

During the games, AlphaGo played a handful of [highly inventive winning moves](#), several of which - including move 37 in game two - were so surprising they overturned hundreds of years of received wisdom, and have since been examined extensively by players of all levels. In the course of winning, AlphaGo somehow taught the world completely new knowledge about perhaps the most studied and contemplated game in history.



AI Success Stories

–Chess, Deep Blue & AlphaZero



“It was a pleasant day in Hamburg in June 6, 1985, ... Each of my opponents, all thirty-two of them, was a computer. ... it didn’t come as much of a surprise, ..., when I achieved a perfect 32–0 score.”

“Twelve years later I was in New York City fighting for my chess life. Against just one machine, a \$10 million IBM supercomputer nicknamed ‘Deep Blue’.”

“Jump forward another 20 years to today, to 2017, and you can download any number of free chess apps for your phone that rival any human Grandmaster.”



AlphaZero: Shedding new light on the grand games of chess, shogi and Go

“Traditional chess engines – including the world computer chess champion Stockfish and IBM’s ground-breaking Deep Blue – rely on **thousands of rules and heuristics handcrafted by strong human players** that try to account for every eventuality in a game. ...

AlphaZero takes a totally different approach, replacing these hand-crafted rules with a **deep neural network and general purpose algorithms** that know nothing about the game beyond the basic rules.”

“The amount of **training** the network needs depends on the style and complexity of the game, taking **approximately 9 hours for chess**, 12 hours for shogi, and 13 days for Go.”

“In Chess, for example, it searches **only 60 thousand positions** per second in chess, compared to roughly 60 million for Stockfish.”

Source: <http://deepmind.com>

AI Success Stories

—GPT 4.0, ChatGPT & LLMs

Sparks of Artificial General Intelligence: Early experiments with GPT-4

Sébastien Bubeck Varun Chandrasekaran Ronen Eldan Johannes Gehrke
Eric Horvitz Ece Kamar Peter Lee Yin Tat Lee Yuanzhi Li Scott Lundberg
Harsha Nori Hamid Palangi Marco Tulio Ribeiro Yi Zhang
Microsoft Research

Abstract

Artificial intelligence (AI) researchers have been developing and refining large language models (LLMs) that exhibit remarkable capabilities across a variety of domains and tasks, challenging our understanding of learning and cognition. The latest model developed by OpenAI, GPT-4 [Ope23], was trained using an unprecedented scale of compute and data. In this paper, we report on our investigation of an early version of GPT-4, when it was still in active development by OpenAI. We contend that (this early version of) GPT-4 is part of a new cohort of LLMs (along with ChatGPT and Google's PaLM for example) that exhibit more general intelligence than previous AI models. We discuss the rising capabilities and implications of these models. We demonstrate that, beyond its mastery of language, GPT-4 can solve novel and difficult tasks that span mathematics, coding, vision, medicine, law, psychology and more, without needing any special prompting. Moreover, in all of these tasks, GPT-4's performance is strikingly close to human-level performance, and often vastly surpasses prior models such as ChatGPT. Given the breadth and depth of GPT-4's capabilities, we believe that it could reasonably be viewed as an early (yet still incomplete) version of an artificial general intelligence (AGI) system. In our exploration of GPT-4, we put special emphasis on discovering its limitations, and we discuss the challenges ahead for advancing towards deeper and more comprehensive versions of AGI, including the possible need for pursuing a new paradigm that moves beyond next-word prediction. We conclude with reflections on societal influences of the recent technological leap and future research directions.

Contents

1	Introduction	4
1.1	Our approach to studying GPT-4's intelligence	6
1.2	Organization of our demonstration	8
2	Multimodal and interdisciplinary composition	13
2.1	Integrative ability	13
2.2	Vision	16
2.2.1	Image generation beyond memorization	16
2.2.2	Image generation following detailed instructions (à la Dall-E)	17
2.2.3	Possible application in sketch generation	18
2.3	Music	19
3	Coding	21
3.1	From instructions to code	21
3.1.1	Coding challenges	21
3.1.2	Real world scenarios	22
3.2	Understanding existing code	26

HI

How can I implement the Black-Scholes option pricing formula for a European call option in concise Python code?



You can implement the Black-Scholes option pricing formula for a European call option in a more concise manner using Python and the `scipy.stats` library as shown below:

python

Copy code

```
import numpy as np
from scipy.stats import norm

def black_scholes_call(S, K, T, r, sigma):
    d1 = (np.log(S / K) + (r + 0.5 * sigma**2) * T) / (sigma * np.sqrt(T))
    d2 = d1 - sigma * np.sqrt(T)
    return S * norm.cdf(d1) - K * np.exp(-r * T) * norm.cdf(d2)

S, K, T, r, sigma = 100, 110, 1, 0.05, 0.25
print("Call price:", black_scholes_call(S, K, T, r, sigma))
```

This implementation calculates the price of a European call option using the Black-Scholes formula in a more concise way. The function `black_scholes_call` takes the same input parameters as before (stock price, strike price, time to maturity, risk-free interest rate, and stock volatility) and returns the option price. The example usage demonstrates how to call this function and print the resulting call price.

Physics Envy & The Beauty Myth

WARNING: Physics Envy May Be Hazardous To Your Wealth!*

Andrew W. Lo[†] and Mark T. Mueller[‡]

This Draft: March 19, 2010

Abstract

The quantitative aspirations of economists and financial analysts have for many years been based on the belief that it should be possible to build models of economic systems—and financial markets in particular—that are as predictive as those in physics. While this perspective has led to a number of important breakthroughs in economics, “physics envy” has also created a false sense of mathematical precision in some cases. We speculate on the origins of physics envy, and then describe an alternate perspective of economic behavior based on a new taxonomy of uncertainty. We illustrate the relevance of this taxonomy with two concrete examples: the classical harmonic oscillator with some new twists that make physics look more like economics, and a quantitative equity market-neutral strategy. We conclude by offering a new interpretation of tail events, proposing an “uncertainty checklist” with which our taxonomy can be implemented, and considering the role that quants played in the current financial crisis.

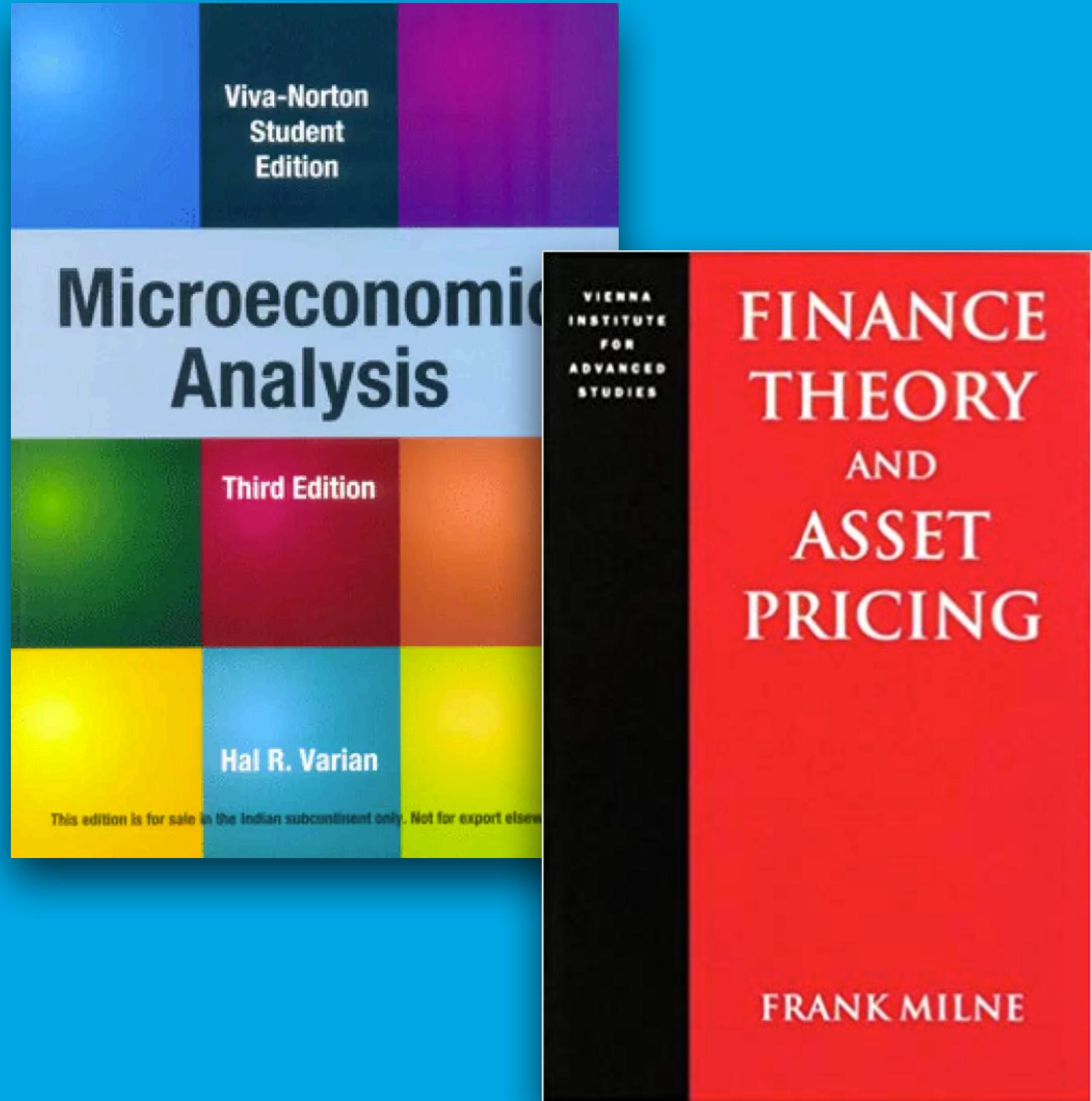
Keywords: Quantitative Finance; Efficient Markets; Financial Crisis; History of Economic Thought.

JEL Classification: G01, G12, B16, C00

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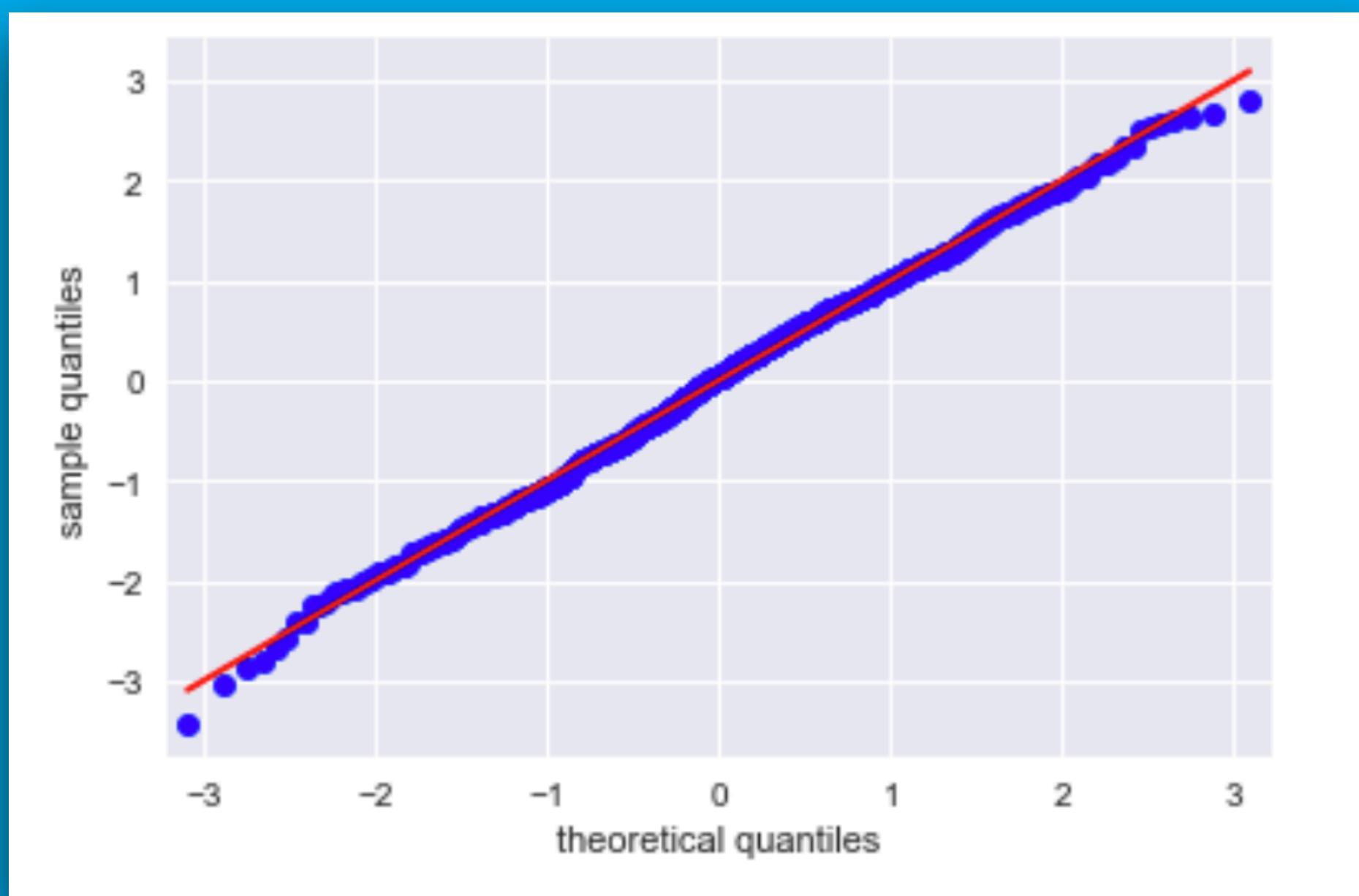
[†]Harris & Harris Group Professor, MIT Sloan School of Management, and Chief Investment Strategist, AlphaSimplex Group, LLC. Please direct all correspondence to: MIT Sloan School, 50 Memorial Drive, E52–454, Cambridge, MA 02142–1347, [alo@mit.edu](mailto:a.lo@mit.edu) (email).

[‡]Senior Lecturer, MIT Sloan School of Management, and Visiting Scientist, MIT Department of Physics, Center for Theoretical Physics, 77 Massachusetts Avenue, Cambridge, MA 02142–1347, mark.t.mueller@mac.com (email).

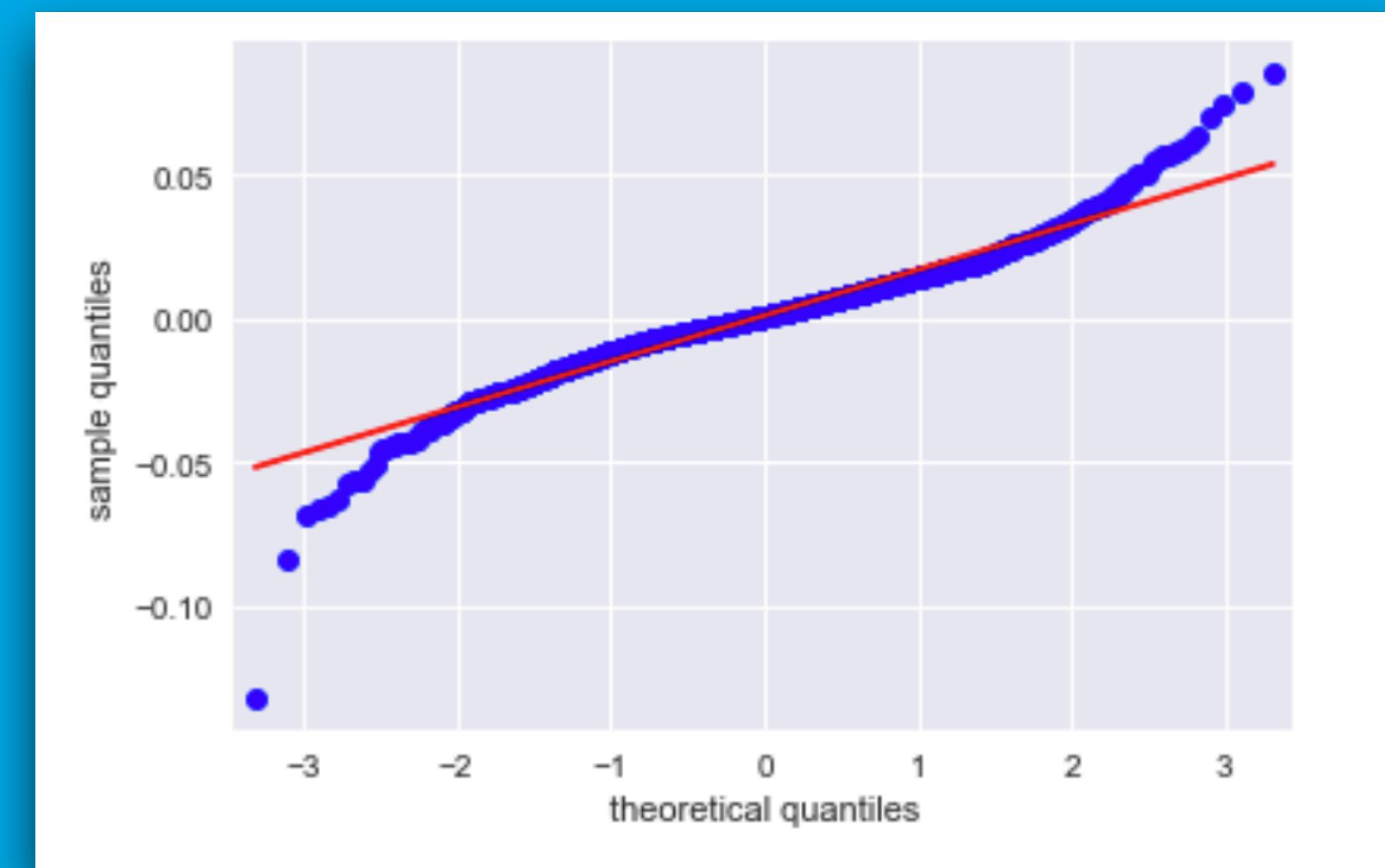


- ## Cornerstones of Economics
- A. Arbitrage Pricing (✓)
 - B. Expected Utility (✗)
 - C. Equilibrium Theory (✗)
 - D. Normal Distributions (✗)
 - E. Linear Relationships (✗)
 - F. Efficient Markets (✓)

Theory



Reality



The Journal of FINANCE

VOL. XIX

SEPTEMBER 1964

No. 3

CAPITAL ASSET PRICES: A THEORY OF MARKET EQUILIBRIUM UNDER CONDITIONS OF RISK*

WILLIAM F. SHARPE†

I. INTRODUCTION

ONE OF THE PROBLEMS which has plagued those attempting to predict the behavior of capital markets is the absence of a body of positive micro-economic theory dealing with conditions of risk. Although many useful insights can be obtained from the traditional models of investment under conditions of certainty, the pervasive influence of risk in financial transactions has forced those working in this area to adopt models of price behavior which are little more than assertions. A typical classroom explanation of the determination of capital asset prices, for example, usually begins with a careful and relatively rigorous description of the process through which individual preferences and physical relationships interact to determine an equilibrium pure interest rate. This is generally followed by the assertion that somehow a market risk-premium is also determined, with the prices of assets adjusting accordingly to account for differences in their risk.

A useful representation of the view of the capital market implied in such discussions is illustrated in Figure 1. In equilibrium, capital asset prices have adjusted so that the investor, if he follows rational procedures (primarily diversification), is able to attain any desired point along a *capital market line*.¹ He may obtain a higher expected rate of return on his holdings only by incurring additional risk. In effect, the market presents him with two prices: the *price of time*, or the pure interest rate (shown by the intersection of the line with the horizontal axis) and the *price of risk*, the additional expected return per unit of risk borne (the reciprocal of the slope of the line).

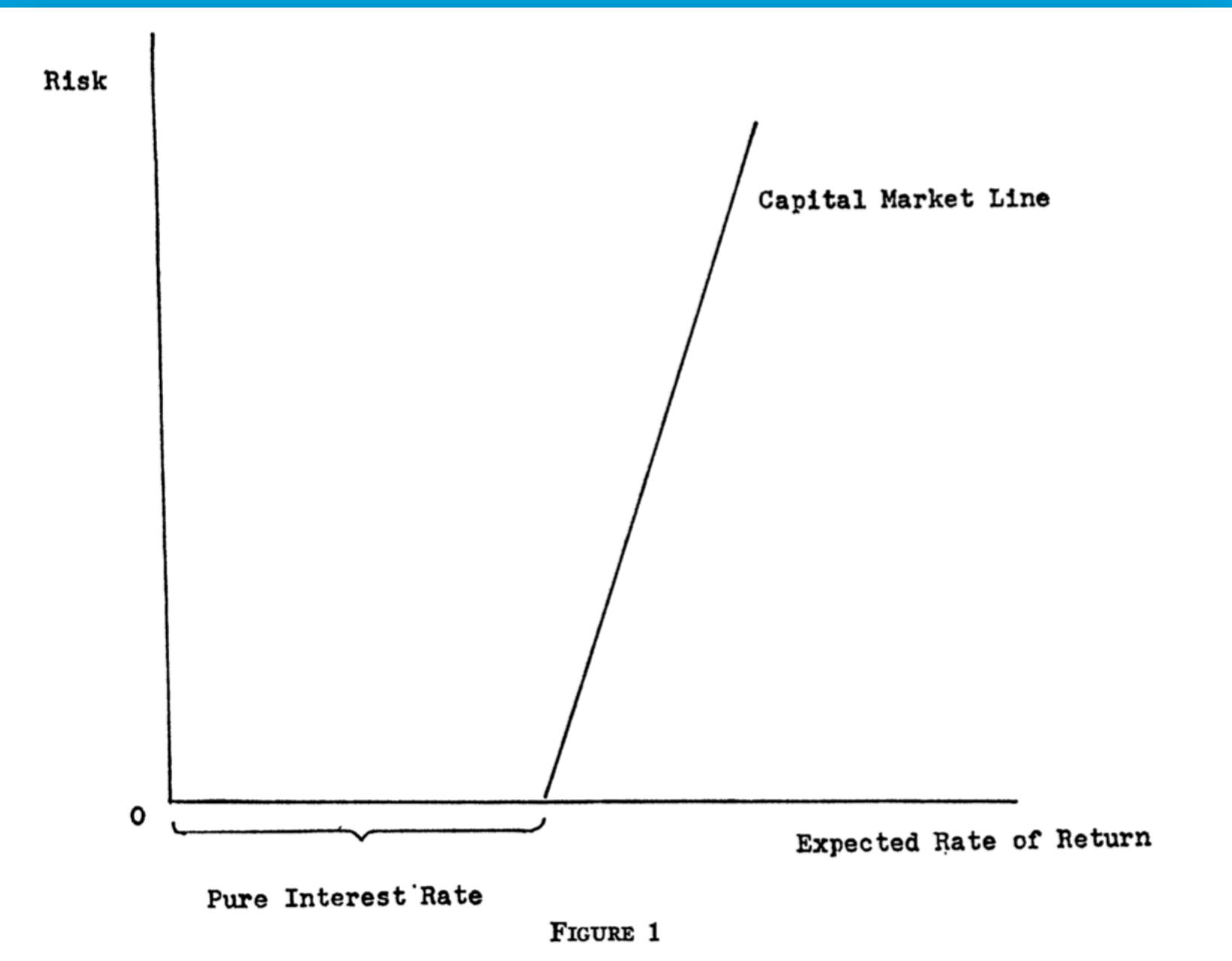
* A great many people provided comments on early versions of this paper which led to major improvements in the exposition. In addition to the referees, who were most helpful, the author wishes to express his appreciation to Dr. Harry Markowitz of the RAND Corporation, Professor Jack Hirshleifer of the University of California at Los Angeles, and to Professors Yoram Barzel, George Brabb, Bruce Johnson, Walter Oi and R. Haney Scott of the University of Washington.

† Associate Professor of Operations Research, University of Washington.

1. Although some discussions are also consistent with a non-linear (but monotonic) curve.

$$\mu_i = r + \beta_i(\mu_M - r)$$

“Market Risk” “Idiosyncratic Risk”



“The attraction of the CAPM is that it offers powerful and intuitively pleasing predictions about how to measure risk and the relation between expected return and risk.”

“The version of the CAPM developed by Sharpe (1964) and Lintner (1965) has never been an empirical success. . . . The problems are serious enough to invalidate most applications of the CAPM.”

Fama and French (2004):
“The Capital Asset Pricing Model: Theory and Evidence.”

Data-Driven Finance

FINANCIAL TIMES

FRIDAY 12 NOVEMBER 2021

NEWS PROVIDER OF THE YEAR

UK £190 Channel Islands £130 Republic of Ireland £120

COP clock runs down

- Summit's 'blah blah blah' is welcomed — GILLIAN TETT, PAGE 25
- Business climate pledges' credibility gap — BIG READ, PAGE 23
- The struggle to write the carbon market rule book — PAGE 4

Protest legacy

Huge Hong Kong police population keeps itself busy — NOTEBOOK, PAGE 24

Iran impasse Long wait for liberty goes on

Richard Ratcliffe holds up a picture of his wife, Nazanin Zaghari-Ratcliffe, the British-Iranian woman who has been imprisoned by Tehran since 2010.

Ratcliffe has been on hunger strike outside the Foreign, Commonwealth and Development Office for 19 days, trying to put pressure on the government to do more to secure his wife's release.

Talks between British officials and Iran's foreign minister yesterday — principally to discuss reviving the nuclear deal with the Islamic republic — had raised hopes of a possible breakthrough.

However, Ratcliffe said he had been left "deflated" after speaking to James Cleverly, the foreign minister involved in the negotiations.

GW/iran talks page 2

Briefing

» NHS waiting list soars to almost 6m

New data have shown 5.5m people were waiting for hospital care in England in September, up by more than 1m in a year. Medical bodies said the figures were "unustainable" and "shocking" — PAGE 1

» Wall St cashes in on GE's decline and fall General Electric has paid more than \$7bn in fees to banks since 2009 as lenders required rescues from the fizzled de-risking that culminated in a falling share price and the break-up of the group — PAGE +

» Johnson Matthey cuts battery chemicals The 204-year-old company has laid a blow to UK ambitions to develop a national champion in the race to power electric cars with a decision to stop making chemicals for batteries — PAGE 16, LEX, PAGE 20

» Uber chief flies in to fix London crisis

Dara Khosrowshahi has told the FT that resolving a shortage of 200,000 drivers in the UK was a priority. The taxi company has raised fares and pay, and offered incentives — PAGE 11

» Race to feed Afghans as winter looms

Aid agencies have said they have weeks to supply food to remote regions before winter cuts them off for months, as Afghanistan faces the world's worst humanitarian crisis — PAGE 8, FT VIEW page 24

» Lukashenko threatens EU gas supplies The Belarusian president has threatened to cut the transit of gas and goods to Europe if the EU imposes further sanctions on his regime over the migrant crisis on his country's border with Poland — PAGE 4

» Foreign buyers triple house ownership The number of homes in England and Wales owned by overseas buyers has tripled in the past decade, with cities outside London also their target. Foreign ownership in Liverpool has risen fourfold — PAGE 1

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

FT REPORTERS

China's Communist party has passed its first "historical resolution" in 40 years, paving the way for President Xi Jinping to stay in office until at least 2022.

The resolution, formally adopted by the party's central committee at the end of its annual meeting, or plenum, yesterday, declared that Xi's leadership was "the key to the great rejuvenation of the Chinese nation," according to the official Xinhua news agency.

This week's annual plenum is particularly significant as it comes just a year before a party congress is to appoint a new leadership team to serve until 2027.

Communist China's two most-revered leaders, Mao Zedong and Deng Xiaoping, used similar resolutions to secure

their grip on power in 1945 and 1951, respectively. By declaring "the great rejuvenation of the Chinese nation has entered an irreversible historical process" under Xi's leadership, the party has in effect honoured him as an equal of Mao and Deng, eclipsing his predecessors like Jiang Zemin and Hu Jintao.

Xi, the plenum said, had "resolved many problems that [the party] failed to address for a long time despite intending-to-do-so."

He and Jiang presided over peaceful and orderly transitions of power, with their successors identified five years in advance. Xi is expected to dispense with that tradition and secure a third five-year term as the party's general secretary late next year. Xi did not identify a successor at the start of his second term

in 2017. His third term as president would begin in March 2023.

"The central purpose of the plenum is to cement Xi as [China's] most important leader since Mao and Deng," said Henry Gan, a China expert at Singapore Management University.

Xi led the party to its revolutionary victory in 1949, while Deng set it on course to a global economic power with his "reforms and opening" policies introduced in the early 1980s.

But Xi has discarded what many regard as Deng's greatest accomplishments, such as the introduction of a two-term limit on the presidency and clearer party-state divisions, while emphasising the egalitarian ideals of the revolution and Mao's early years in power.

"The plenum's message is the reform

Xi Jinping's leadership was declared to have "resolved many problems that [the party] failed to address for a long time."

era has reached such a stage that the party can embark on the construction of a "socialist modern country", and the emphasis here is on "country", Gan said.

The plenum declared that "the Chinese people are not only good at destroying old worlds but also good at building new worlds". "Only socialism", it added, "can save and develop China".

Xi orchestrated similar moves to reinforce his power near the end of his first term. A plenum in 2016 declared him "the core" of the party leadership. In 2018, he won approval to remove the two-term limit on the presidency, with the potential to stay in power for life.

Reporting by Tom Mitchell in Beijing, Sue Tsui in Shanghai and Xiong Lin in Beijing; 80 words of directions page 8

Metabook page 24

Datawatch

Coffee hit

A change in foot traffic to Starbucks in 500 coffee shops compared with Sept 2020

2020 2021 2022
Loc. America
- Home
- Chicago
- New York City
- San Francisco

Visit to Starbucks coffee near offices in US city centres compared up earlier in the year last June - dropped sharply since July 2020. Data is for Dallas variant of Covid-19 cases. New York booked the most but has not improved much since July

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

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

P W de Klerk, who shared the Nobel Peace Prize with Nelson Mandela for dismantling apartheid, has died at the age of 85. As South African president he had the courage to realise that the country's experiment in social engineering had not worked and that black majority rule was inevitable. But his rationale seemed more practical than moral and, having left politics, he often attracted outrage for his defence of a separate but equal society.

Obituary — PAGE 4

"double生活" an earlier visit as MP from 2002 to 2004 with the leadership of the Spectator magazine for four years. Johnson has not declared any new sources of private income since becoming prime minister in July 2019. Downing Street has not denied claims that the prime minister has continued to work on a Shakespeare biography.

Johnson is at the centre of a bizarre scandal that began last week when he whipped Tory MPs to replace the existing standards system in a move designed to benefit Owen Paterson, a former Conservative minister.

Paterson had been found to have broken lobbying rules in an "egregious case of paid advocacy". Johnson has since dropped the proposals, prompting Paterson's resignation — but his party is now caught in a new row over whether MPs should hold second jobs. On Wednesday

he sought to regain public trust as he insisted that MPs who broke parliamentary rules "should be punished".

"You must put your job as an MP first and you must devote yourself primarily and above all to your constituents," he told them.

Some Tory MPs accused Johnson of hypocrisy, given his past private interests. "Owen was literally editing the Spectator while he was an MP," said one.

Nic Alstair Graham, former chair of the Committee on Standards in Public Life, told the FT that Johnson did not have "the ideal track record" to be the person in charge of implementing a public desire for improved standards.

Not only had Johnson made millions through private work while in politics but he had also tried to "subvert" the system and was himself the subject of up-to-date probes, Graham said.

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THE WALL STREET JOURNAL.

DOW JONES | News Corp ****

WEDNESDAY, NOVEMBER 10, 2021 ~ VOL. CCLXXVIII NO. 112

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★★★★ \$5.00

DJIA 36319.98 ▼ 112.24 0.3%

NASDAQ 15886.54 ▼ 0.6%

STOXX 600 482.71 ▼ 0.2%

10-YR.TREAS. ▲ 19/32, yield 1.431%

OIL \$84.15 ▲ \$2.22

GOLD \$1,830.20 ▲ \$2.80

EURO \$1.1596

YEN 112.88

What's News

Business & Finance

General Electric, the company that for more than a century stood as a beacon of U.S. manufacturing might and management prowess, will split into three public companies, drawing the curtain on an era of business—the dominance of industrial conglomerates. **A1, A12, A13**

◆ **U.S. stocks fell back**, from record levels, with the Nasdaq, S&P 500 and Dow declining 0.6%, 0.4% and 0.3%, respectively. **B12**

◆ **Rivian priced** its highly anticipated IPO at \$78 a share, well above its raised expectations, valuing the electric-vehicle maker at more than \$77 billion on a fully diluted basis. **BI**

◆ **Panera plans** to go public and has secured an unconventional investment from restaurateur Danny Meyer's SPAC. **BI**

◆ **Semiconductor** makers have earmarked less than 17% of the roughly \$146 billion the industry will devote to capital spending this year to legacy chips, Gartner estimates. **BI**

◆ **Hertz**, which emerged from bankruptcy this summer, listed on the Nasdaq, with shares closing down nearly 10% in the first day of trading. **BI**

◆ **DoorDash** said it agreed to acquire European food-delivery company Wolt in a deal valued at over \$8 billion. **B3**

◆ **Presto** is close to a deal to combine with a SPAC and go public in a merger that would value the restaurant-technology firm at about \$1 billion. **B3**

◆ **Videogame company** Unity agreed to pay \$1.63 billion for major parts of visual-effects studio Weta. **B4**

World-Wide

◆ **Nicaragua**, after a presidential election the U.S. called fraudulent, is now widely seen to have become Latin America's third dictatorship and part of a broader trend of democratic backsliding across the region, U.S. officials and political analysts said. **A1**

◆ **Ports snarled** with supply-chain problems will be able to redirect money from other federally funded projects to help ease the logjams under a plan outlined by the Biden administration. **A2**

◆ **The Oklahoma Supreme Court** overturned a ruling that held J&J liable for contributing to the state's opioid-addiction crisis. **A2**

◆ **Pfizer and partner BioNTech** asked U.S. health regulators to expand the authorization of their Covid-19 booster to people as young as 18 years old. **A3**

◆ **A federal judge** said records from the Trump White House can be turned over to the House committee investigating

GE Breakup Marks End of an Era

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

Adjusted for inflation

Notes: Segment categorizations for GE's annual revenue were taken as initially reported in the company's annual reports from 1980 to 2020 and adjusted for inflation. The graphic excludes corporate items and eliminations that GE reported in some years. Revenue from GE Capital is included starting in 1988 when GE began reporting consolidated revenues that included the finance business in its annual report. In prior years, GE reported earnings from the subsidiary, which was called GE Credit Corp.

Sources: SEC filings, staff reports (revenue); FactSet (share price)

Elliot Bentley, Erik Brynildsen and Luis Santiago/
THE WALL STREET JOURNAL

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

BY THOMAS GRYTA

General Electric Co., the company that for more than a century stood as a beacon of U.S. manufacturing might and management prowess, will split into three public companies, drawing the curtain on an era of business—the dominance of industrial conglomerates.

The decision, announced Tuesday by Chief Executive Larry Culp, ends the myth that GE wielded a magic touch to run companies better, and make everyone richer, through its management of varied enterprises around the world.

When Mr. Culp took over as CEO of a wounded GE three years ago, he faced calls from inside and outside to break it apart. He resisted the idea, saying he wanted to fix GE and just needed more time. He repaired company finances, but ultimately concluded that investors wanted a simpler structure. "It was clear this

Please turn to page A13

◆ General Electric through the years in photos A12-13
◆ Heard on the Street: GE sheds conglomerate label B13

Tax Bill Looms as Musk Eyes Share Sale

Elon Musk's pledge to sell 10% of his Tesla Inc. stock highlights the complex financial web the world's richest man has spun around his personal fortune.

By Rebecca Elliott,
Richard Rubin
and Theo Francis

Selling a stake valued at about \$17 billion could provide Mr. Musk, who has at times said he was cash-poor, with a sizable liquidity infusion. It could also go a long way toward helping the billionaire pay a bill likely coming due from the Internal Revenue Service. Completing these moves before year-end would help Mr. Musk avoid a possible tax increase.

Mr. Musk is worth about \$300 billion on paper, according to the Bloomberg Billionaires Index, with the majority of that wealth tied up in Tesla and his rocket company, Space Explorations.

Please turn to page A2

◆ Tesla's valuation punishes the wary B1
◆ James Mackintosh: Own Tesla stock? Do like Musk B11

Facebook Rife With Stolen Content

By KEACH HAGEY
AND JEFF HORWITZ

Facebook has allowed plagiarized and recycled content to flourish on its platform despite having policies against it, the tech giant's researchers warned in internal memos.

About 40% of the traffic to Facebook pages at one point in 2018 went to pages that stole or repurposed most of their content, according to a research report that year by Facebook senior data scientist Jeff Allen, one of a dozen internal communications re-

viewed by The Wall Street Journal. Pages are used by businesses and organizations to disseminate content on Facebook, while individual users put content on what Facebook calls "profiles."

The researchers also wrote Facebook has been slow to crack down on copyright infringement for fear of opening itself to legal liability.

"What's the easiest (lowest

the facebook files

Latest in a series

ings simply had to ask one question of the content they were considering recirculating: "Has it gone viral in the past?"

Posting unoriginal content continues to be a formula for success on Facebook, according to data the company has

Please turn to page A6

Meta Curbs Targeted Ads

Personalized advertising on politics is dropped A6

THE
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OF
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THE (ALMOST)
CAR-FREE CITY
R1-10

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

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

By LISA BANNON AND ANDREA FULLER

Over the past decade, the University of Southern California has used a for-profit company to help enroll thousands of students in its online social-work master's program.

The nonprofit school used its status-symbol image to attract students across the country, including low-income minority students it targeted for recruitment, often with aggressive tactics. Most students piled on debt to afford the tuition, which last year

reached \$115,000 for the two-year degree. The majority never set foot on the posh Los Angeles campus but paid the same rate for online classes as in-person students.

Recent USC social-work graduates who took out federal loans borrowed a median \$112,000. Half of them were earning \$52,000 or less annually two years later, a Wall Street Journal analysis of newly released U.S. Education Department data found. Compared with other master's-degree programs

Please turn to page A14

Democracy Loses Favor

Is Santa

From print ...

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

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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

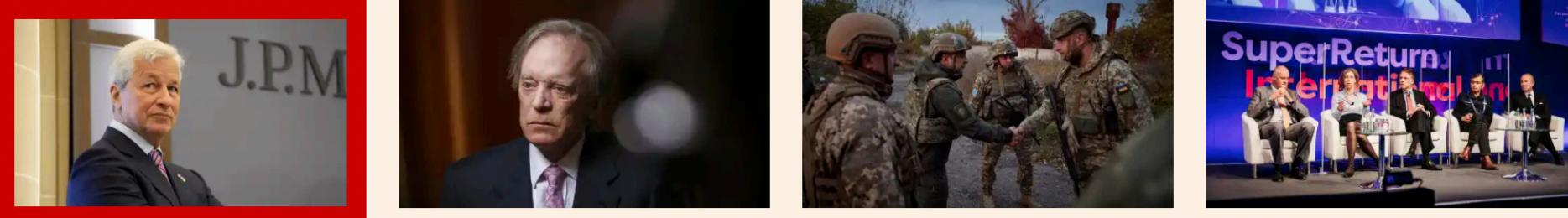
- Biden and Xi to tackle Taiwan and nuclear build-up in virtual meeting
- Australia vows to help US defend Taiwan from Chinese attacks
- Joe Biden and Xi Jinping to hold virtual summit on Monday



The Big Read

Investors pivot to India after China's tech crackdown

4 HOURS AGO



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

... to the Web ...

... to the Web ...

Feedback 

Market Data  About WSJ

S&P 500 **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% ▼ Yves Hilpisch ▾

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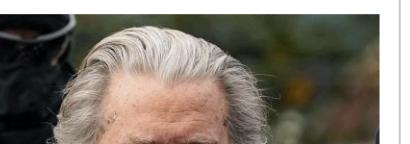
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Beto O'Rourke Announces Bid for Texas Governor
④ 4 min read


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


Kyle Rittenhouse Homicide Trial Wraps Up ⑤ 5 min read


Shell to Move Headquarters to London Amid

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%

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OPINION 

America Will Be Number One—in Taxes
By The Editorial Board | Review & Outlook

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United States | NASDAQ Stock Exchange Global Select Market | Phones & Handheld Devices

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BUSINESS SUMMARY >

Apple Inc. designs, manufactures and markets smartphones, personal computers, tablets, wearables and a variety of related services. The Company's products include iPhone, Mac, iPad, and Wearables, Home and Auto. The Company's line of smartphones based on its iOS operating system. Mac is the Company's line of personal computers based on its macOS operating system. iPad is the Company's line of multi-purpose tablets based on its iPadOS operating system. Home and Accessories includes AirPods, Apple TV, Apple Watch, Beats products, HomePod, iPod touch and third-party accessories. AirPods are the Company's wireless headphones that interact with Siri. Apple Watch is the Company's line of smart watches. Its services include Advertising, AppleCare, Cloud Services, Digital Content and Payment. Customers are primarily in the consumer, small and mid-sized business, education, enterprise and government sectors.

NEWS > 16-Nov-2021 08:51:09 05:40:45 04:00:00 01:48:19 01:10:00 00:29:52

Refinitiv Newscasts - Evidence of Belarus providing migrants tourist visas S. Korea's new law on in-app payment is 'monumental': CAF chief KILL Singtel in Partnership with Apple Inc, Selects Nextech AR Solutions To Showcase Augmented Reality Apple Pty Ltd. - "Disney Melee Mania" coming this December exclusively on Apple Arcade iPhone Black Friday Deals 2021: Best Early Apple iPhone Sales Reported by The Consumer Project UPDATE 1-Buffett's Berkshire cuts U.S. drugmaker stakes, invests in drug royalty company

15-Nov-2021 23:52:47 23:39:51 23:27:41 23:12:15 EVENTS > UPCOMING

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18-Nov-2021 NTS AAPL34.SA Final Cash Dividend of gross BRL 0.123473 paid on Nov 18, 2021 going ex- 19-Nov-2021 NTS AAPLNLB Final Cash Dividend of gross CAD 0.033913 paid on Nov 19, 2021 going ex-

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PRICE PERFORMANCE >

Open Prev. Close ① 123.08 Bid / Ask ① 123.24 / 123.35 VWAP Turnover Volume ① 13,358 Short Interest YTD Beta (5Y Monthly) Mkt Cap - Default ① USD 2.093T PE (LTM) 37.676 Div Yield 0.666% DR BRL AAPL34.SA (1:0.1) DR Type DR Bank 52Wk: 53.153 23-Mar Daily Last 137.980 02-Sep

52Wk: 53.153 23-Mar Daily Last 137.980 02-Sep

Next Earnings Report: 26-Jan-2021

RECOMMENDATIONS >

Mean AAPL Strong Buy 11 Buy 19 Hold 8 Sell 1 Strong Sell 1

Price Target (Mean) USD 125.92 Upside 2%

STARMINER MODELS >

Bullish Price Momentum ⑨7 Analyst Revisions ⑦9 Smart Holdings ⑦7 Short Interest ⑨5 Earnings Quality ⑨5 Credit Risk - Combined ⑨6 Credit Risk - Smart Ratios ⑨2 Credit Risk - Structural ⑧8 Credit Risk - Text Mining ⑧5 Combined Alpha Model ⑦2

Highlights All Models

NEWS > 03-Dec-2020 10:15:43 BUSINESS Apple sued over old iPhones in Europe Tech giant i... LATIME 10:13:01 《外企動向》蘋果因舊款手機電池問題在歐洲多國面臨訴訟 HKETNN 10:12:11 《外企動向》蘋果因舊款手機電池問題在歐洲多國面臨訴訟 HKETNN 09:49:33 USPTO ISSUES TRADEMARK: WORKS WITH APPLE IBEACON USFED 09:16:24 Analysts' Weekly Ratings Updates for Apple (AAPL) TICREP 09:11:02 Analysts' Weekly Ratings Updates for Apple (AAPL) AMEBAN 09:00:25 《A股焦点》欧菲光：被苹果移出相机模块供应链消息不属实 HKETNN 08:59:39 《A股焦点》欧菲光：被苹果移出相机模块供应链消息不属实 HKETNN 07:13:26 Dow Jones Selected Stocks 1710 - December 03 AAP 06:47:44 RPT-Hong Kong-Le magnat Jimmy Lai détenu pour des accusa... RTRS

RESEARCH > Contributor Internal

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EVENTS > Upcoming Past

26-Jan-2021 NTS Q1 2021 Apple Inc Earnings Release 25-Feb-2021 18:00:00 Apple Inc Annual Shareholders Meeting PEERS >

Company Name Mkt Cap % Chan... Reven... EBITD... EV/ ...

Apple Inc 2.09T 274.52B 28.17% 23.39 HP Inc 31.34B 1.97% 56.64B 8.40% 6.63

... 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.0 macbook',
                                         count=5,
                                         date_from='2021-10-18',
                                         date_to='2021-10-19')
```

```
[10]: headlines
```

	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.



EXPERT OPINION

Contact Editor: Brian Brannon, bbrannon@computer.org

The Unreasonable Effectiveness of Data

Alon Halevy, Peter Norvig, and Fernando Pereira, Google

Eugene Wigner's article "The Unreasonable Effectiveness of Mathematics in the Natural Sciences"¹ examines why so much of physics can be neatly explained with simple mathematical formulas

such as $f = ma$ or $e = mc^2$. Meanwhile, sciences that involve human beings rather than elementary particles have proven more resistant to elegant mathematics. Economists suffer from physics envy over their inability to neatly model human behavior. An informal, incomplete grammar of the English language runs over 1,700 pages.² Perhaps when it comes to natural language processing and related fields, we're doomed to complex theories that will never have the elegance of physics equations. But if that's so, we should stop acting as if our goal is to author extremely elegant theories, and instead embrace complexity and make use of the best ally we have: the unreasonable effectiveness of data.

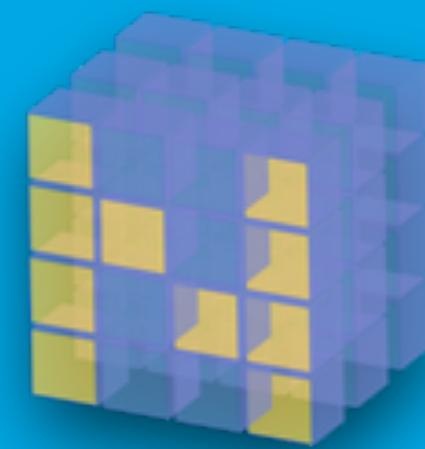
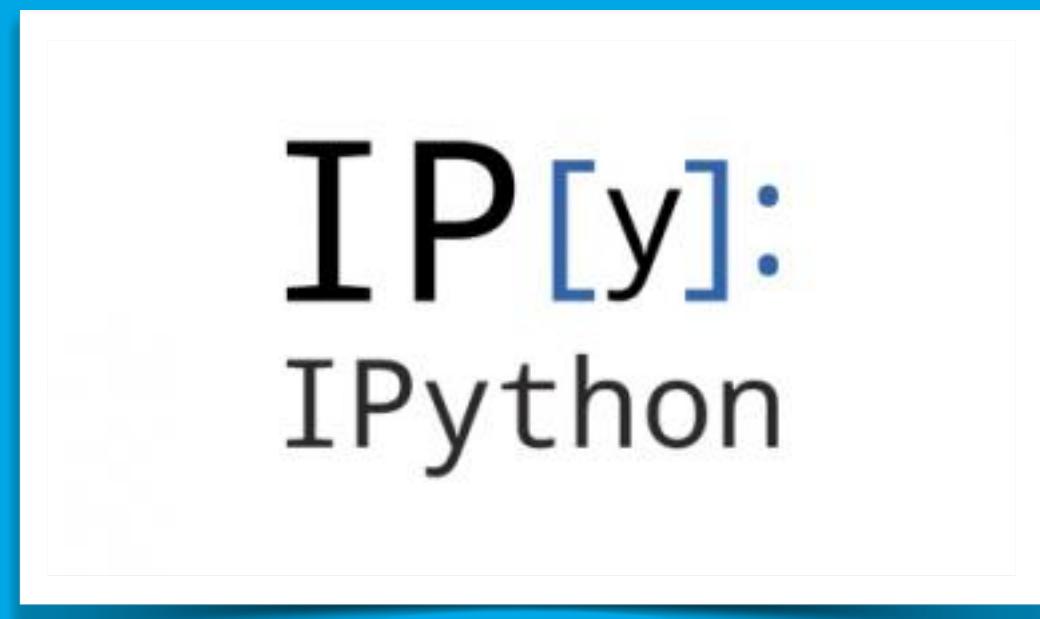
One of us, as an undergraduate at Brown University, remembers the excitement of having access to the Brown Corpus, containing one million English words.³ Since then, our field has seen several notable corpora that are about 100 times larger, and in 2006, Google released a trillion-word corpus with frequency counts for all sequences up to five words long.⁴ In some ways this corpus is a step backwards from the Brown Corpus: it's taken from unfiltered Web pages and thus contains incomplete sentences, spelling errors, grammatical errors, and all sorts of other errors. It's not annotated with carefully hand-corrected part-of-speech tags. But the fact that it's a million times larger than the Brown Corpus outweighs these drawbacks. A trillion-word corpus—along with other Web-derived corpora of millions, billions, or trillions of links, videos, images, tables, and user interactions—captures even very rare aspects of human

behavior. So, this corpus could serve as the basis of a complete model for certain tasks—if only we knew how to extract the model from the data.

Learning from Text at Web Scale

The biggest successes in natural-language-related machine learning have been statistical speech recognition and statistical machine translation. The reason for these successes is not that these tasks are easier than other tasks; they are in fact much harder than tasks such as document classification that extract just a few bits of information from each document. The reason is that translation is a natural task routinely done every day for a real human need (think of the operations of the European Union or of news agencies). The same is true of speech transcription (think of closed-caption broadcasts). In other words, a large training set of the input-output behavior that we seek to automate is available to us *in the wild*. In contrast, traditional natural language processing problems such as document classification, part-of-speech tagging, named-entity recognition, or parsing are not routine tasks, so they have no large corpus available in the wild. Instead, a corpus for these tasks requires skilled human annotation. Such annotation is not only slow and expensive to acquire but also difficult for experts to agree on, being bedeviled by many of the difficulties we discuss later in relation to the Semantic Web. The first lesson of Web-scale learning is to use available large-scale data rather than hoping for annotated data that isn't available. For instance, we find that useful semantic relationships can be automatically learned from the statistics of search queries and the corresponding results⁵ or from the accumulated evidence of Web-based text patterns and formatted tables,⁶ in both cases without needing any manually annotated data.

"Eugene Wigner's article "The Unreasonable Effectiveness of Mathematics in the Natural Sciences" examines why so much of physics can be neatly explained with simple mathematical formulas such as $f = ma$ or $e = mc^2$. Meanwhile, sciences that involve human beings rather than elementary particles have proven more resistant to elegant mathematics. Economists suffer from physics envy over their inability to neatly [and successfully] model human behavior. An informal, incomplete grammar of the English language runs over 1,700 pages. Perhaps when it comes to natural language processing and related fields, we're doomed to complex theories that will never have the elegance of physics equations. But if that's so, we should stop acting as if our goal is to author extremely elegant theories, and instead embrace complexity and make use of the best ally we have: the unreasonable effectiveness of data."



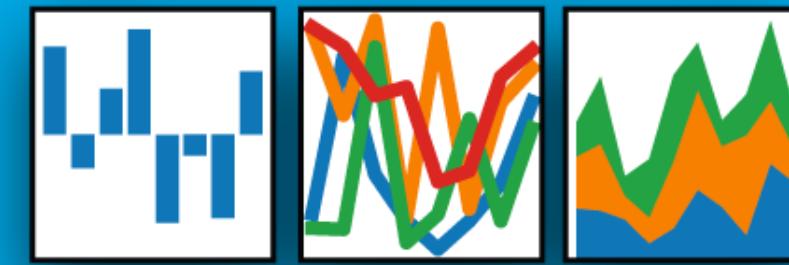
NumPy

matplotlib



pandas

$$y_{it} = \beta' x_{it} + \mu_i + \epsilon_{it}$$



Keras

Efficient Markets

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.

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.”

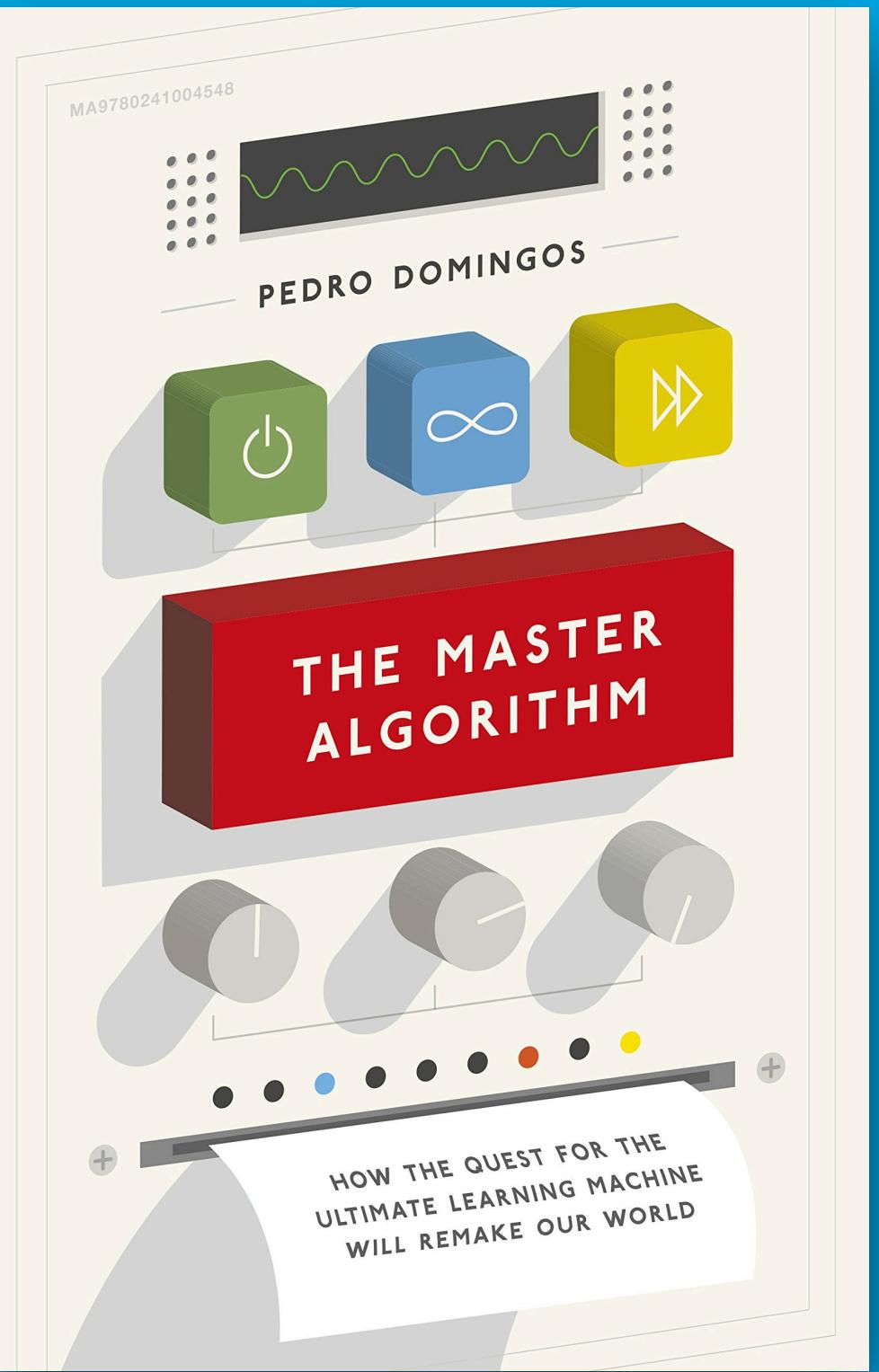
AI-First Finance

scientific method

noun

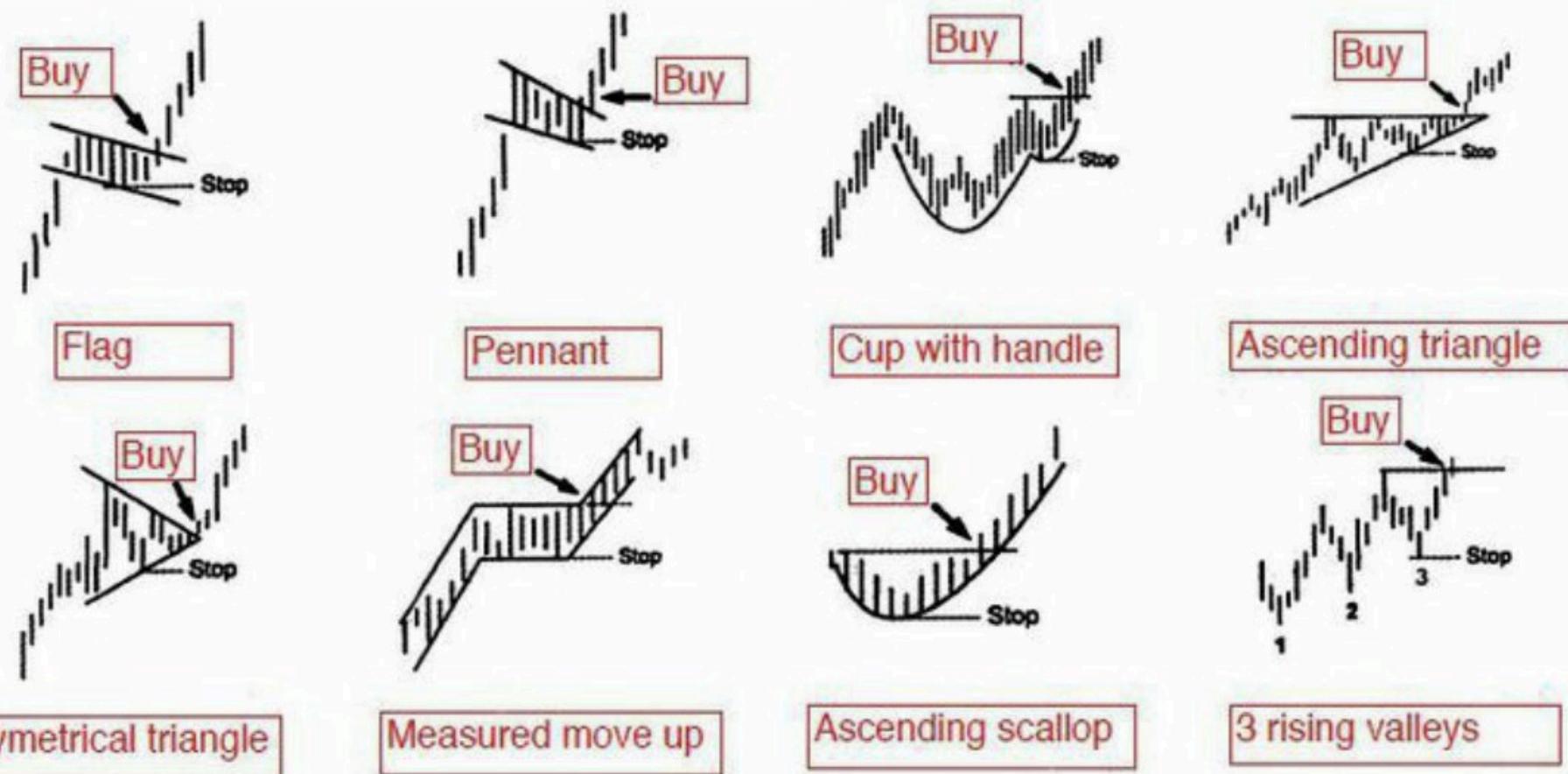
a method of procedure that has characterized natural science since the 17th century, consisting in systematic observation, measurement, and experiment, and the formulation, testing, and modification of hypotheses.

"criticism is the backbone of the scientific method"

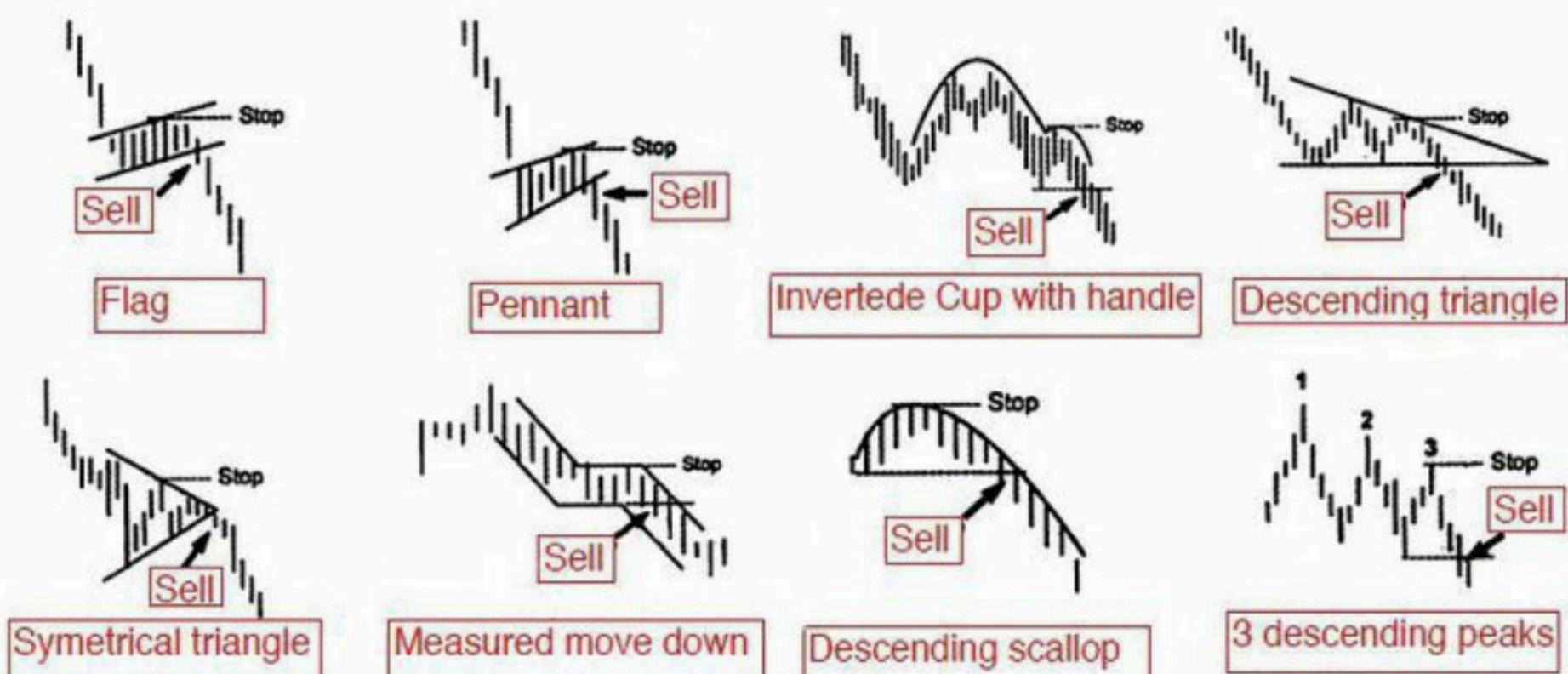


“Machine learning is the scientific method on steroids. It follows the same process of generating, testing, and discarding or refining hypotheses. But while a scientist may spend his or her whole life coming up with and testing a few hundred hypotheses, a machine-learning system can do the same in a second. Machine learning automates discovery. It’s no surprise, then that it’s revolutionizing science as much as it’s revolutionizing business.”

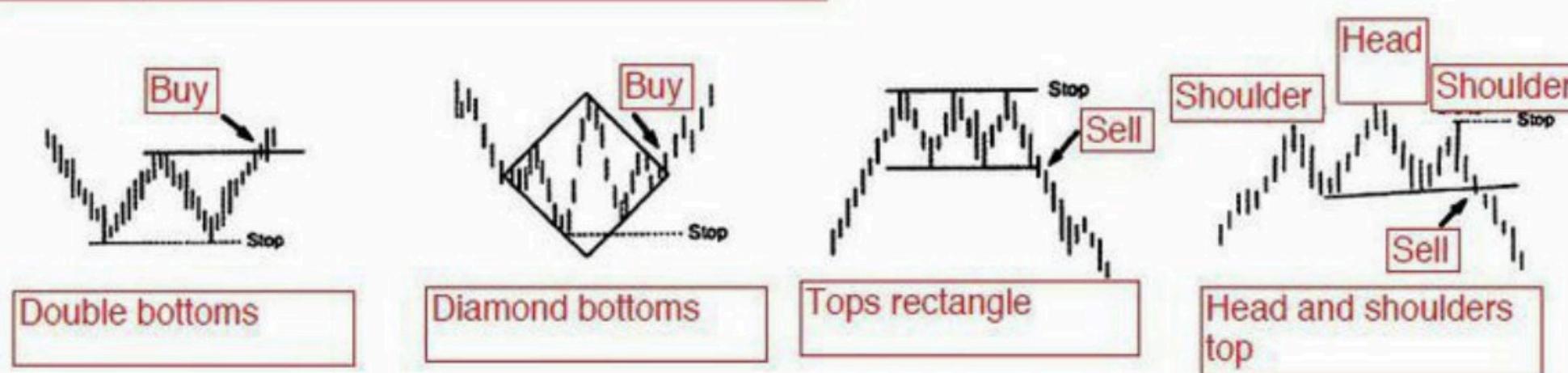
Bullish patterns (going up)



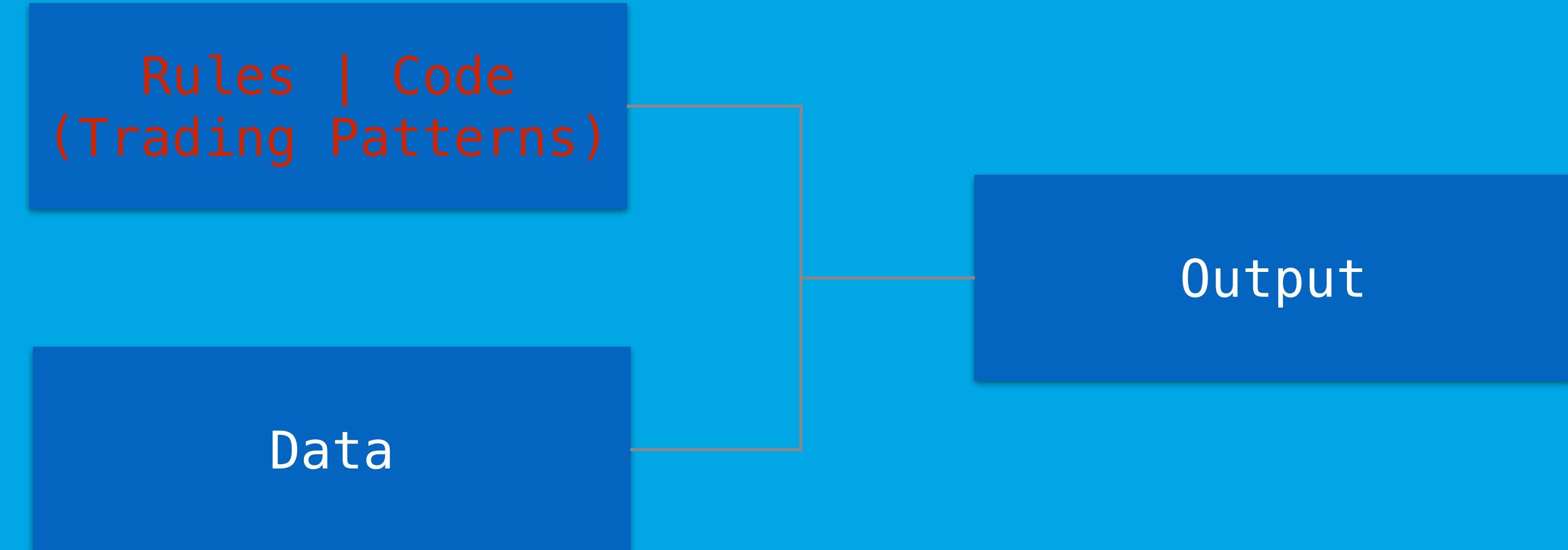
Bearish patterns (going down)



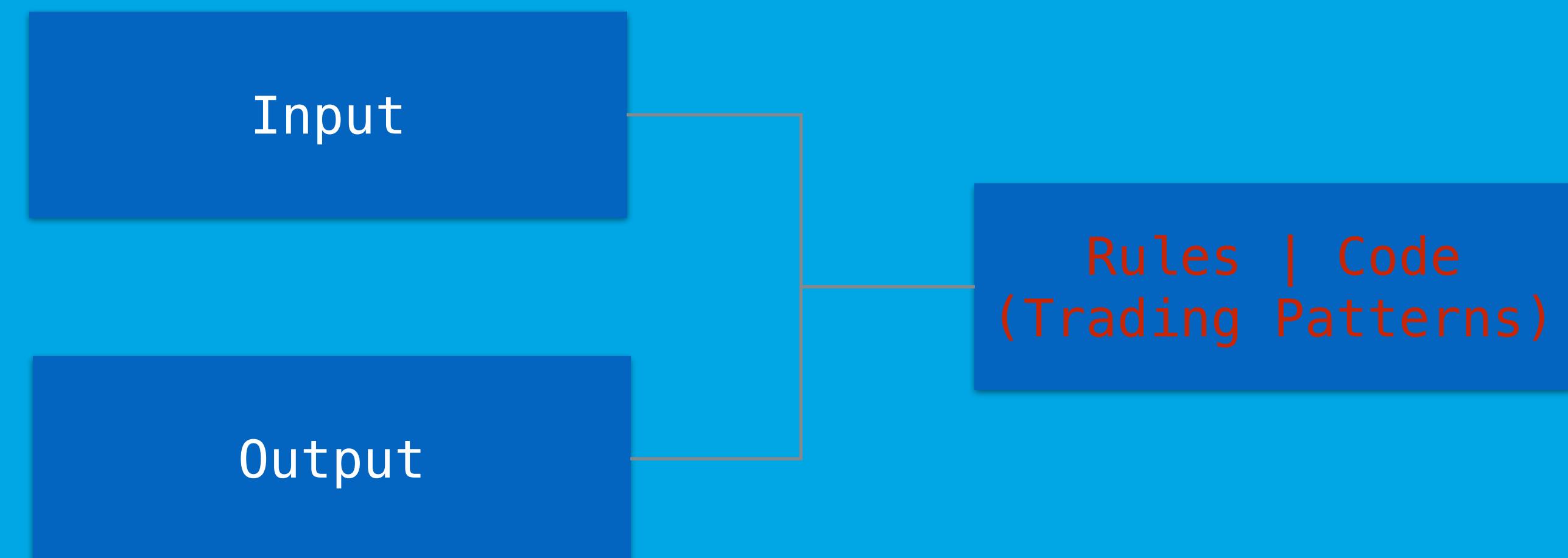
Reversal patterns



Programming.



Machine Learning.



Financial Markets

“normative economics = assumptions, axioms, etc.”

x



y

“non-linear, complex, changing”

Finance History

“positive economics = data, relationships, etc.”



$f(\bullet)$

(too) “simple and elegant theories”

“hardly any supporting empirical evidence”

$f(x) \neq y$

“brain-driven & beauty myth”

AI in Finance

x

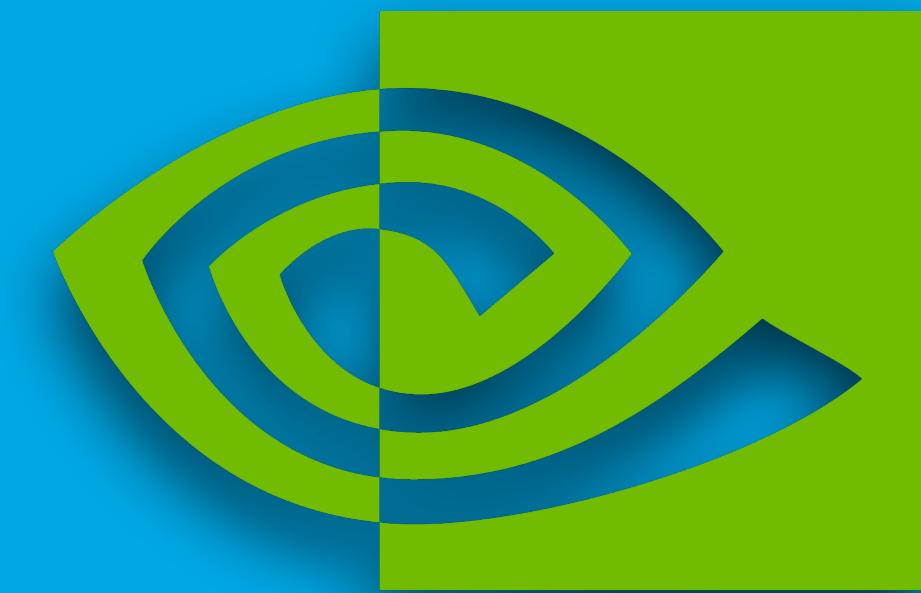
“general, parametrizable, trainable algorithms”

$m(\bullet, a, b)$

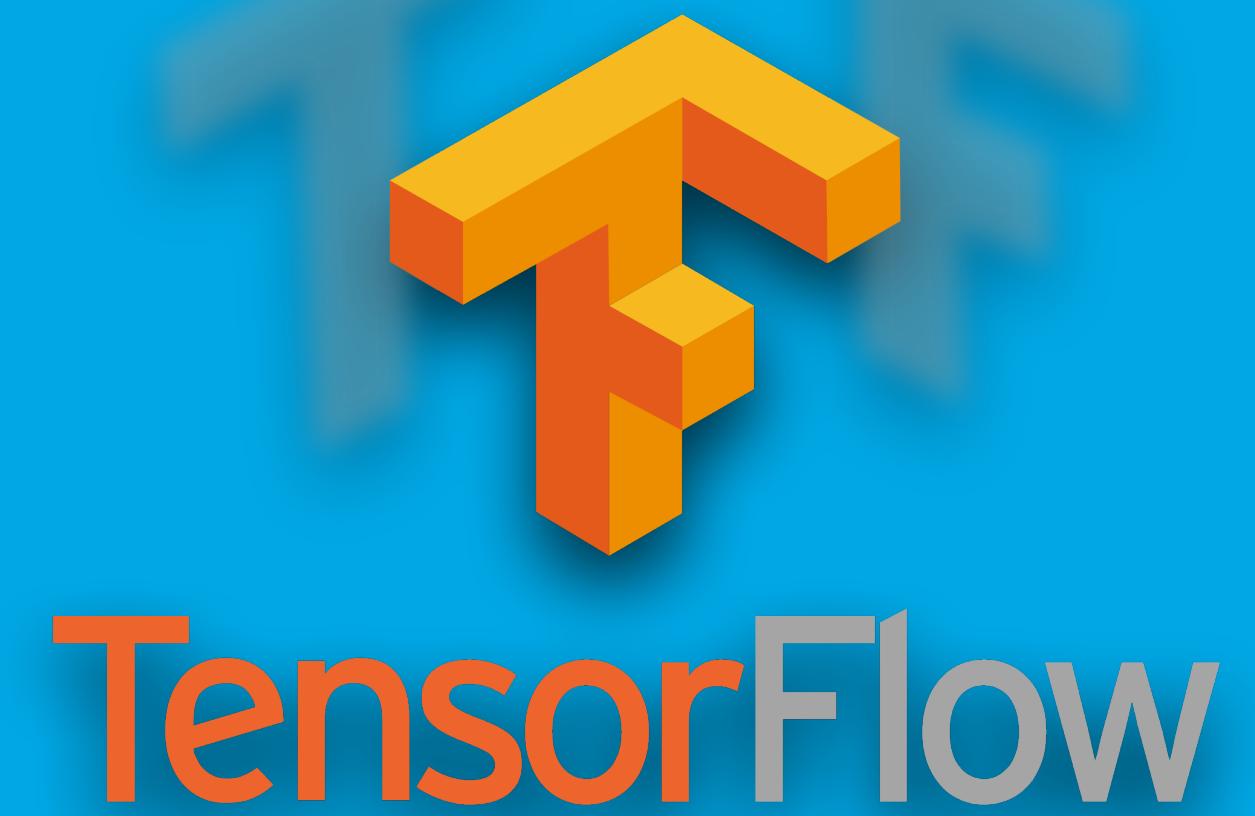
“might show good performance, but black box”

$m(x, a^*, b^*) \approx y$

“data-driven & AI-first”

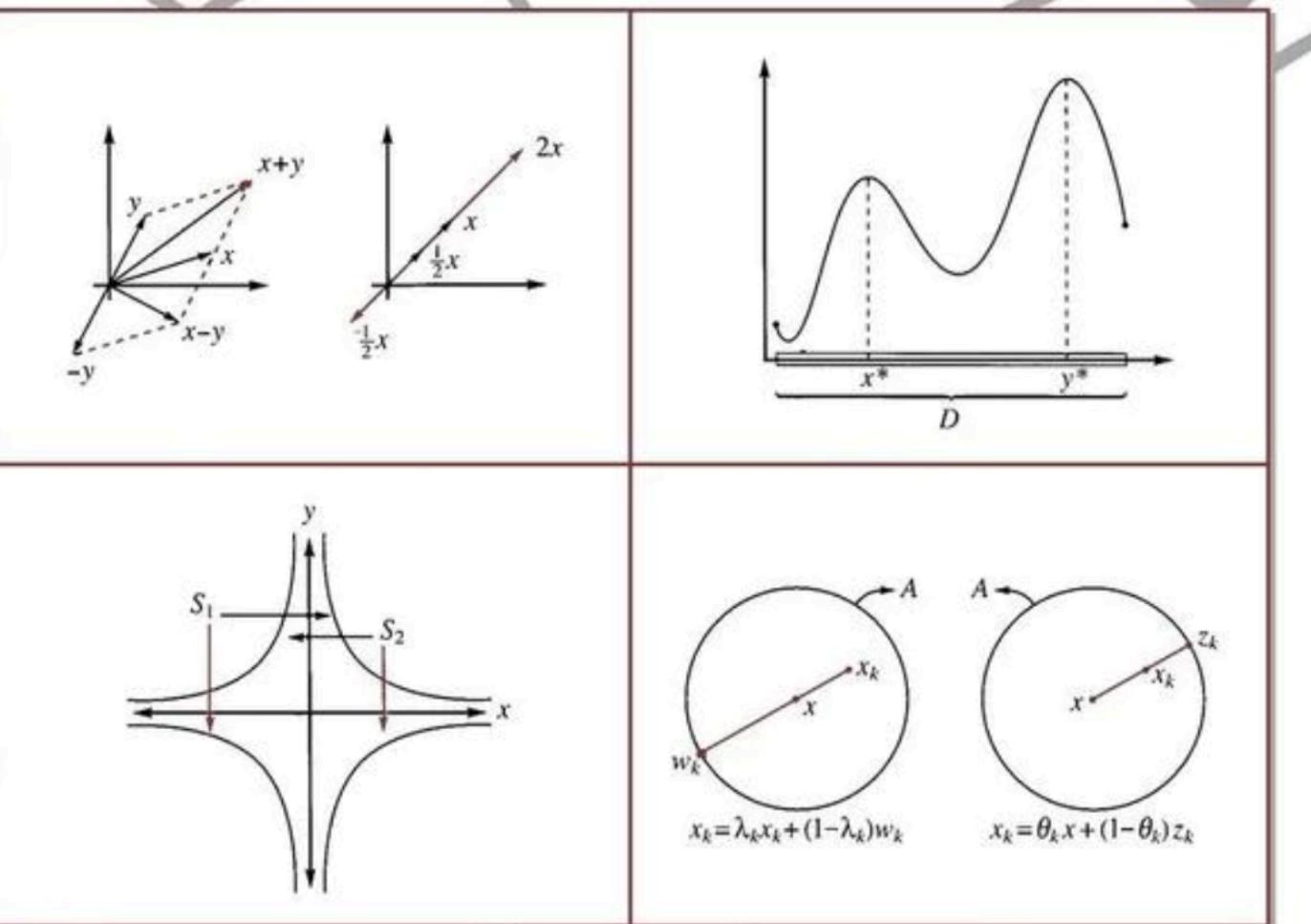


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Dynamic Programming –Excursion

A First Course in Optimization Theory



Rangarajan K. Sundaram

Economic Dynamics
THEORY AND COMPUTATION

John Stachurski

A ***Finite Horizon (Markovian) Dynamic Programming Problem*** (FHD P) is defined by a tuple

$$\{S, A, T, (r_t, f_t, \Phi_t)_{t=0}^T\}$$

where

1. S is the *state space* of the problem, with generic element s .
2. A is the *action space* of the problem, with generic element a .
3. T , a positive integer, is the *horizon* of the problem.
4. For each $t \in \{0, 1, \dots, T\}$
 - A. $r_t : S \times A \rightarrow \mathbb{R}$ is the period- t *reward function*
 - B. $f_t : S \times A \rightarrow S$ is the period- t *transition function*
 - C. $\Phi_t : S \rightarrow P(A)$ is the period- t *feasible action correspondence*

The objective is to choose a plan for taking actions at each point in time in order to maximize the sum of the per-period rewards over the horizon of the model, i.e. to solve

$$\text{Maximize} \quad \sum_{t=1}^T r_t(s_t, a_t)$$

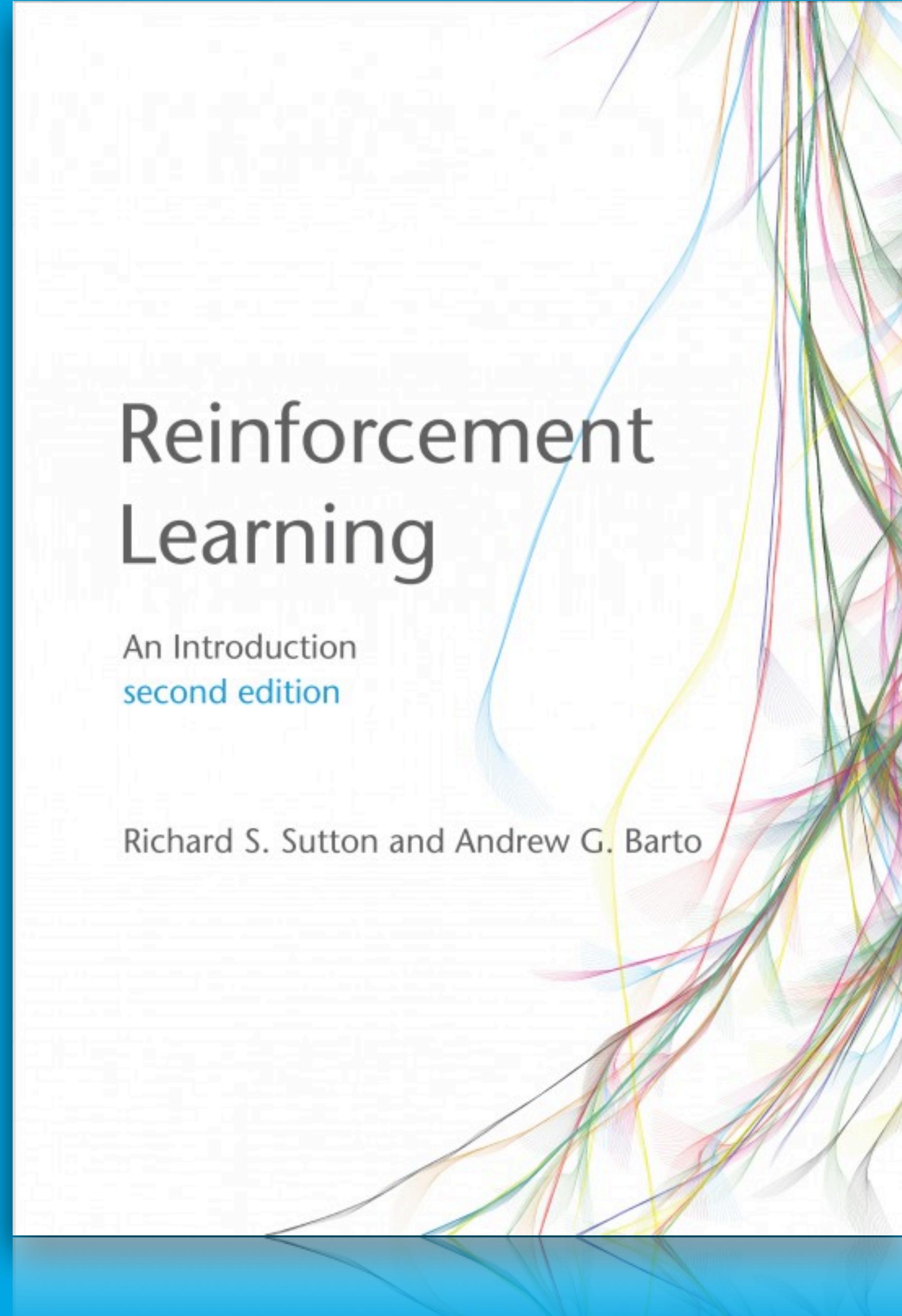
subject to $s_0 = s \in S$

$$s_t = f_{t-1}(s_{t-1}, a_{t-1}), t = 1, \dots, T$$

$$a_t \in \Phi_t(s_t), t = 1, \dots, T$$

Reinforcement Learning

–Basic Notions



Reinforcement Learning

An Introduction
second edition

Richard S. Sutton and Andrew G. Barto

“Of all the forms of machine learning, reinforcement learning is the closest to the kind of learning that humans and other animals do, and many of the core algorithms of reinforcement learning were originally inspired by biological learning systems.”

“The most important feature distinguishing reinforcement learning from other types of learning is that it uses training information that evaluates the actions taken rather than instructs by giving correct actions.”

“Reinforcement learning is about learning from interaction how to behave in order to achieve a goal. The reinforcement learning agent and its environment interact over a sequence of discrete time steps.”

The Science of
Consequences



HOW THEY
AFFECT GENES, CHANGE THE BRAIN,
AND IMPACT OUR WORLD

SUSAN M. SCHNEIDER

2020 IN SCHNEIDER

JUDEA PEARL
WINNER OF THE TURING AWARD
AND DANA MACKENZIE

THE
BOOK OF
WHY



THE NEW SCIENCE
OF CAUSE AND EFFECT

Environment

The ***environment*** defines the problem at hand. This can be a computer game to be played or a financial market to be traded in.

State

A ***state*** subsumes all relevant parameters that describe the current status of the environment. In a computer game this might be the whole screen with all its pixels. In a financial market, this might include current and historical price levels, financial indicators such as moving averages, macroeconomic variables, and so on.

Agent

The term *agent* subsumes all elements of the RL algorithm that interacts with the environment and that learns from these interactions. In a gaming context, the agent might represent a player playing the game. In a financial context, the agent could represent a trader placing bets on rising or falling markets.

Action

An agent can choose one *action* from a (limited) set of allowed actions. In a computer game, movements to the left or right might be allowed actions, while in a financial market going long or short could be admissible.

Step

Given an action of an agent, the state of the environment is updated. One such update is generally called a *step*. The concept of a step is general enough to encompass both heterogeneous and homogeneous time intervals between two steps. While in computer games, real-time interaction with the game environment is simulated by rather short, homogeneous time intervals (“game clock”), a trading bot interacting with a financial market environment could take actions at longer, heterogeneous time intervals, for instance.

Reward

Depending on the action an agent chooses, a *reward* (or *penalty*) is awarded. For a computer game, points are a typical reward. In a financial context, profit (or loss) is a standard reward.

Target

The *target* specifies what the agent tries to maximize. In a computer game, this in general is the score reached by the agent. For a financial trading bot, this might be the trading profit.

Policy

The ***policy*** defines which action an agent takes given a certain state of the environment. Given a certain state of a computer game, represented by all the pixels that make up the current scene, the policy might specify that the agent chooses “move right” as the action. A trading bot that observes three price increases in a row might decide, according to its policy, to short the market.

Episode

An ***episode*** is a set of steps from the initial state of the environment until success is achieved or failure is observed. In a game, from the start of the game until a win or loss. In the financial world, for example, from the beginning of the year to the end of the year or to bankruptcy.

Reinforcement Learning

-Q-Learning

Reward Function

The reward function R assigns to each state-action (S, A) pair a numerical reward.

$$R : S \times A \rightarrow \mathbb{R}$$

Action Policy

An action policy Q assigns to each state S and allowed action A a numerical value. The numerical value is composed of the **immediate reward** of taking action A and the **discounted delayed reward** – given an optimal action taken in the subsequent state.

$$Q : S \times A \rightarrow \mathbb{R},$$

$$Q(S_t, A_t) = R(S_t, A_t) + \gamma \cdot \max_a Q(S_{t+1}, a)$$

Representation

In general, the optimal action policy Q can not be specified in closed form (e.g. in the form of a table). Therefore, Q-learning relies in general on approximate representations for the optimal policy Q .

Neural Network

Due to the approximation capabilities of neural networks (“Universal Approximation Theorems”), neural networks are typically used to represent optimal action policies Q . Features are the parameters that describe the state of the environment. Labels are values attached to each allowed action.

An Overview Of Artificial Neural Networks for Mathematicians

Leonardo Ferreira Guilhoto

Abstract

This expository paper first defines what an Artificial Neural Network is and describes some of the key ideas behind them such as weights, biases, activation functions (mainly sigmoids and the ReLU function), backpropagation, etc. We then focus on interesting properties of the expressive power of feedforward neural networks, presenting several theorems relating to the types of functions that can be approximated by specific types of networks. Finally, in order to help build intuition, a case study of effectiveness in the MNIST database of handwritten digits is carried out, examining how parameters such as learning rate, width, and depth of a network affects its accuracy. This work focuses mainly on theoretical aspects of feedforward neural networks rather than providing a step-by-step guide for programmers.

Contents

1	Introduction	2
2	An Overview of Feedforward Neural Networks	3
2.1	Structure	3
2.1.1	Nodes And Layers	3
2.1.2	Weights, Biases and Activation Functions	3
2.2	Learning Process	4
2.2.1	Cost Function	4
2.2.2	Gradient Descent	5
2.2.3	Backpropagation	5
3	The Expressive Power of Feedforward Neural Networks	8
3.1	Universal Approximation	8
3.1.1	Useful Definitions and Theorems from Functional Analysis	8
3.1.2	Statement and Proof of Universal Approximation Theorem for Sigmoid and ReLU Activation Functions	9
3.2	Effective Versions of the Universal Approximation Theorem	12
4	Implementation and Case Study of Efficiency	17
4.1	Procedure	17
4.2	Comparison Results	18
4.2.1	Learning Rate	18
4.2.2	Width	18
4.2.3	Depth	20
Acknowledgements		22
References		22
Appendix A Data		23

“In the mathematical theory of artificial neural networks, the universal approximation theorem states that a feed-forward network with a single hidden layer containing a finite number of neurons can approximate continuous functions on compact subsets of R^n , under mild assumptions on the activation function. The theorem thus states that simple neural networks can represent a wide variety of interesting functions when given appropriate parameters; however, it does not touch upon the algorithmic learnability of those parameters.”

–https://en.wikipedia.org/wiki/Universal_approximation_theorem

Exploration

This refers to actions taken by an agent that are random in nature. The purpose is to explore random actions and their associated values beyond what the current optimal policy would dictate.

Exploitation

This refers to actions taken in accordance with the current optimal policy.

Replay

This refers to the (regular) updating of the optimal action policy given past and memorized experiences (by re-training the neural network).

gamma

The parameter `gamma` represents the discount factor by which delayed rewards are taken into account.

epsilon

The parameter `epsilon` defines the ratio with which the algorithm relies on exploration as compared to exploitation.

epsilon_decay

The parameter `epsilon_decay` specifies the rate at which `epsilon` is reduced.

Reinforcement Learning –Applications

Conclusions

1. Finance has long been driven by the “**beauty myth**”
– elegant but too simplistic models, equations and approaches.
2. The availability of **big financial data** (historical –streaming, structured–unstructured) gave rise to ***data-driven finance***.
3. It might be assumed that the “**unreasonable effectiveness of big data**” holds true in the financial domain as well.
4. Due to the availability of big data (e.g. billions of hours of virtual car driving, billions of self-played games), **Artificial Intelligence (AI)** is changing almost every area of our lives.
5. It is to be assumed that in the same way the **combination of *data-driven and AI-first finance*** will influence and change finance and algorithmic trading for good.

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