IFC-Bank of Italy Workshop on "Data Science in Central Banking: Applications and tools"
14-17 February 2022

Keynote speech

Artificial intelligence in finance - quo vadis[1]

Joerg R. Osterrieder,
Professor of Sustainable Finance, Bern Business School, Switzerland
Associate Professor of Finance and Artificial Intelligence, University of Twente, Netherlands
Chair of the European COST Action CA19130 on Fintech and Artificial Intelligence
Coordinator of the European MSCA Doctoral Network on Digital Finance

[1] This contribution was prepared for the workshop. The views expressed are those of the author and do not necessarily reflect the views of the Bank of Italy, the BIS, the IFC or the other central banks and institutions represented at the event.

Artifcial Intelligence in Finance
Quo Vadis?

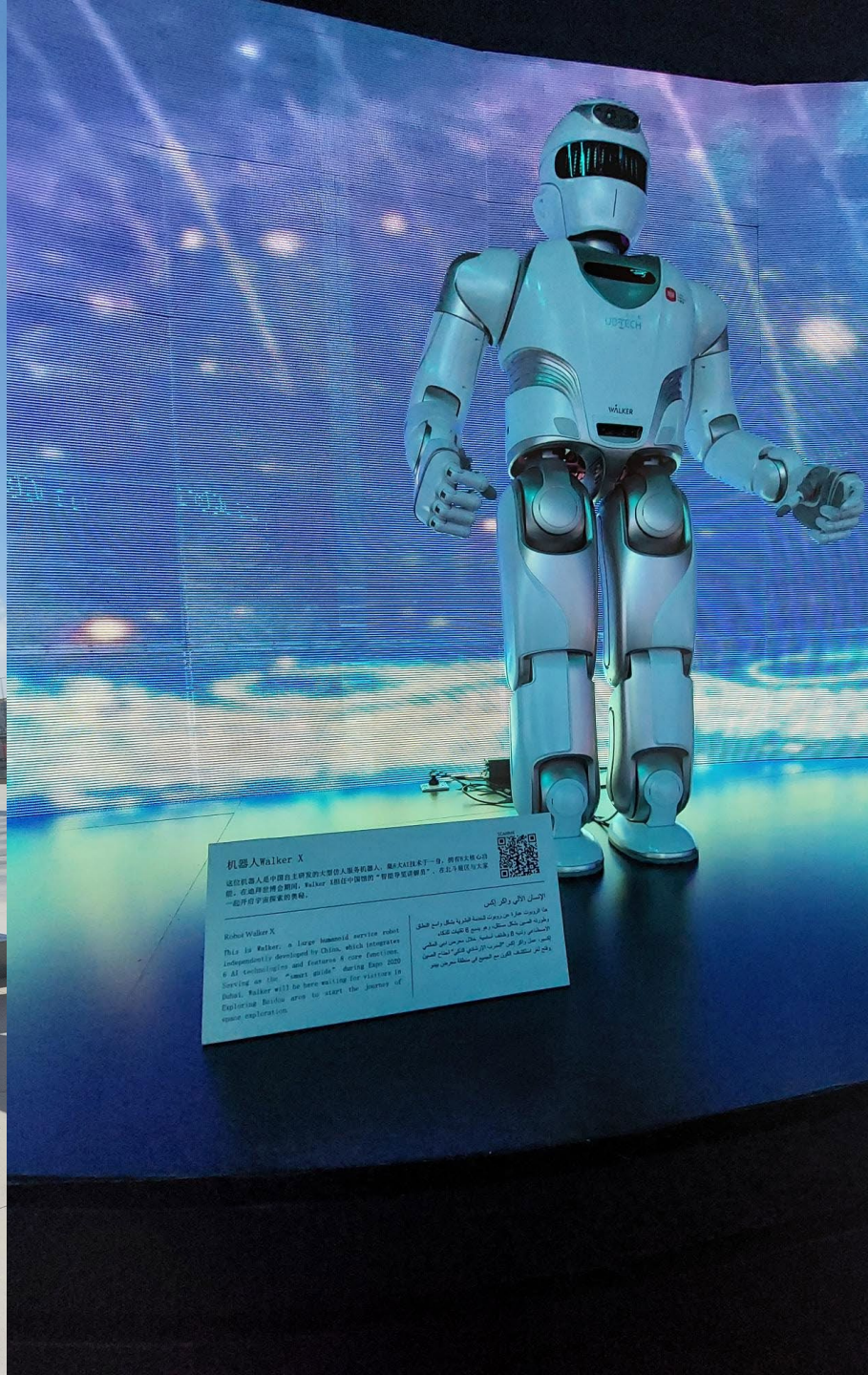
IFC workshop on Data science in central banking:
Applications and Tools
14 – 17 February, 2022

Irving Fisher Committee on Central Bank Statistics

BIS

Prof. Dr. Jörg Osterrieder


EXPO
2020


机器人Walker X
Robot Walker X

Prof. Dr. Jörg Osterrieder

- Professor of Finance and Risk Modelling, Zurich University of Applied Sciences, Switzerland
- Associate Professor of Finance and Artificial Intelligence, University of Twente, Netherlands
- Action Chair EU COST Action Fintech and Artificial Intelligence
- Senior Advisor to ING Group, Netherlands

Fintech and Artificial Intelligence in Finance

FIN AI

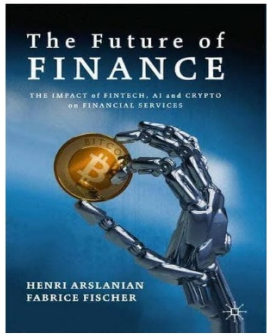
Our Team

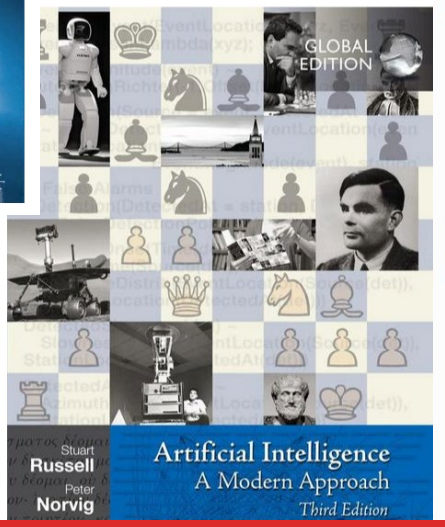
Jörg Osterrieder

Branka Hadji Misheva

Piotr Kotlarz

AI has started a financial revolution - here's how





Preparing Your Business For The Artificial Intelligence Revolution

Forbes

Dmitry Matskevich Forbes Councils Member
Forbes Technology Council COUNCIL POST | Paid Program
Innovation

POST WRITTEN BY
Dmitry Matskevich

CEO and Co-founder of Dbrain, a blockchain platform to collectively build AI apps.

FUTURE DEVELOPMENT

Whoever leads in artificial intelligence in 2030 will rule the world until 2100

Financial Revolution: How IT Startups Change The Rules On Wall Street

Forbes

3,529 views | Jun 4, 2020, 03:16pm EDT

Is AI Overhyped?

Kathleen Walch Contributor
COGNITIVE WORLD Contributor Group
AI

Feb 22, 2019, 10:24am EST

The Fintech Revolution Is Here. Can It Help Build A Better Economy?

Jennifer Pryce Contributor
Hedge Funds & Private Equity
I connect communities and capital markets

Forbes

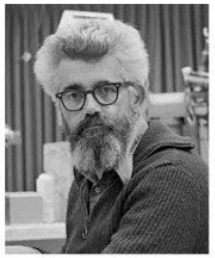
What Is The Artificial Intelligence Revolution And Why Does It Matter To Your Business?

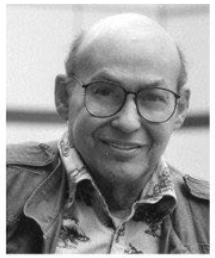
What is Artificial Intelligence?

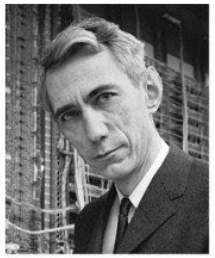
Dartmouth Summer Research Project on Artificial Intelligence - Summer 1956

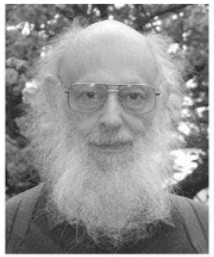
The study is to proceed on the basis of the conjecture that every aspect of learning or ***any other feature of intelligence*** can in principle be so precisely described that *a* ***machine can be made to simulate it***.

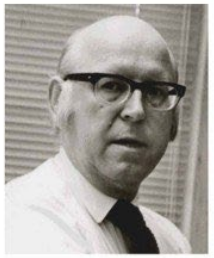
1956 Dartmouth Conference: The Founding Fathers of AI


John MacCarthy


Marvin Minsky

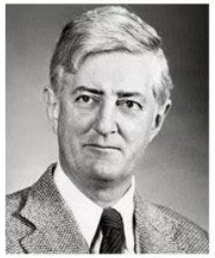

Claude Shannon


Ray Solomonoff


Alan Newell


Herbert Simon


Arthur Samuel


Oliver Selfridge

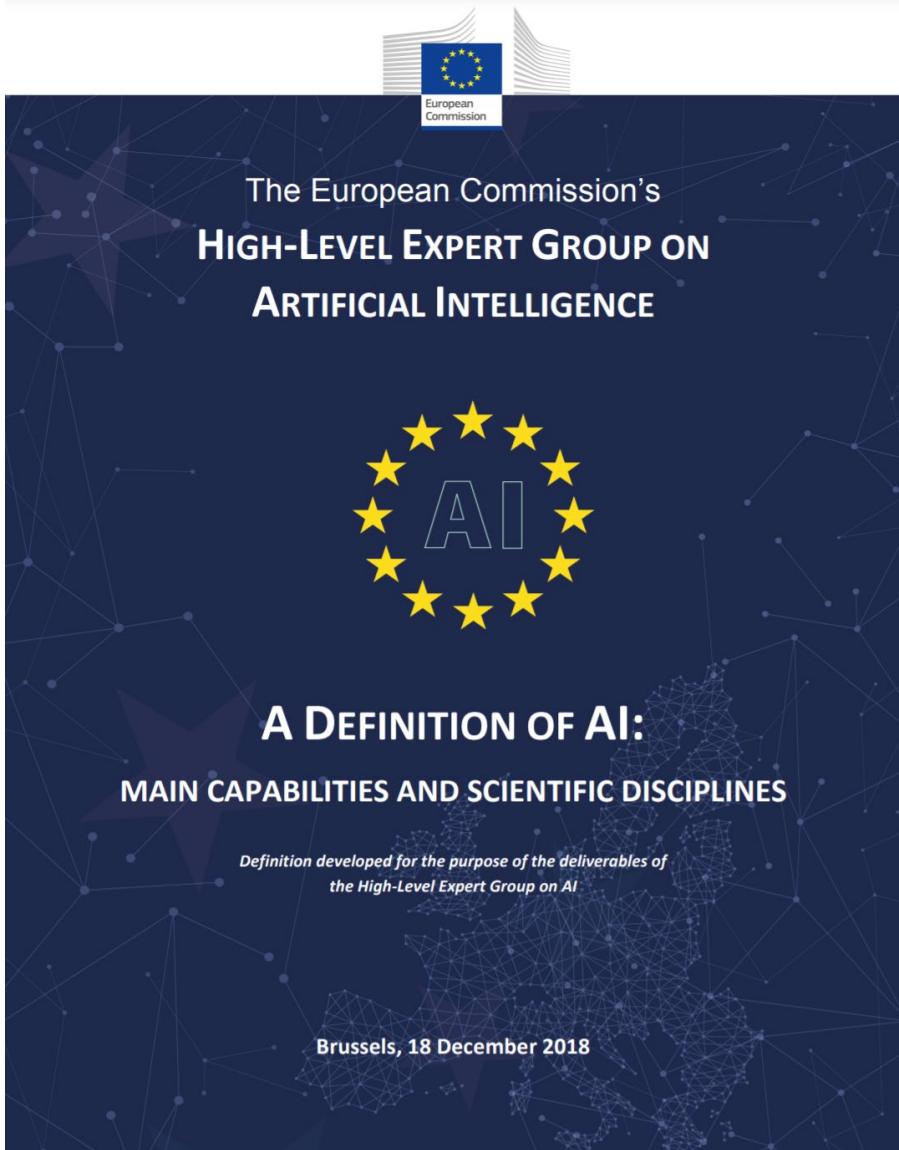

Nathaniel Rochester


Trenchard More

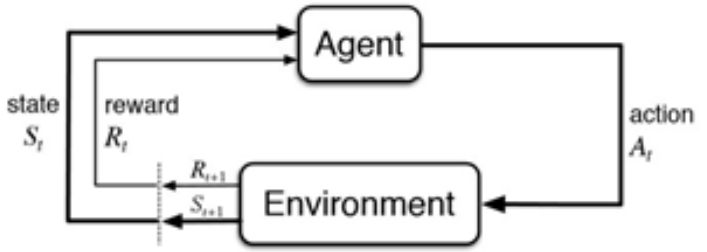
Artificial Intelligence Definition - European Commission

Artificial intelligence refers to systems that display intelligent behaviour by analysing their environment and taking actions – ***with some degree of autonomy*** *– to achieve specific goals.*

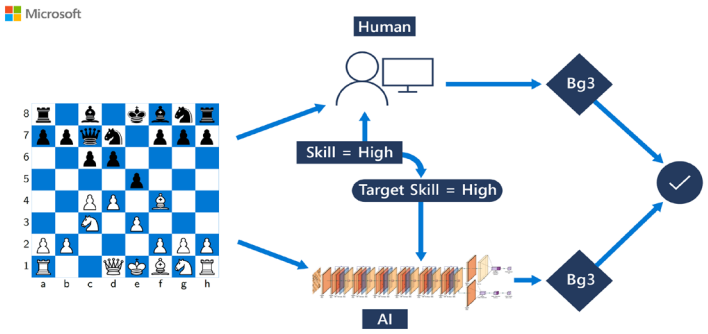
AI-based systems can be purely software-based, acting in the virtual world (e.g. voice assistants, image analysis software, search engines, speech and face recognition systems) or AI can be embedded in hardware devices (e.g. advanced robots, autonomous cars, drones or Internet of Things applications).

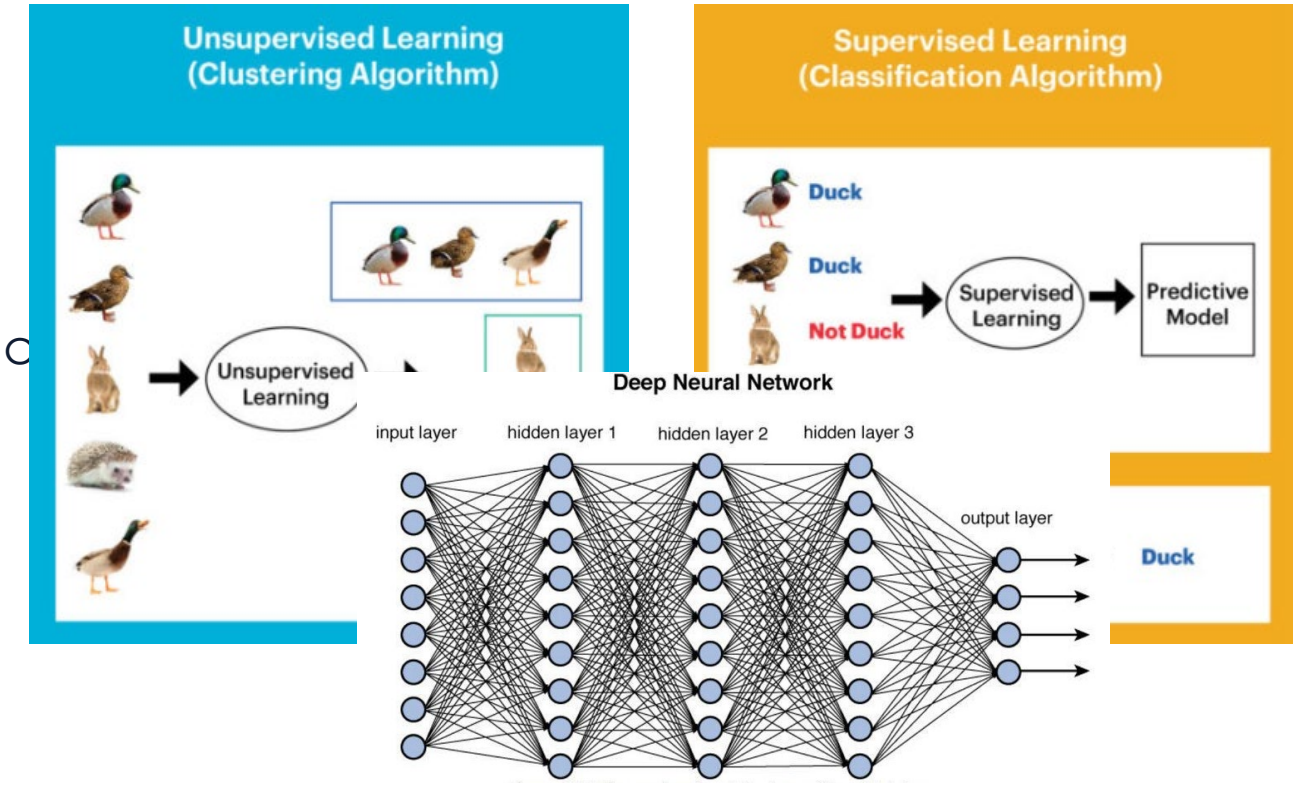


Machine Learning



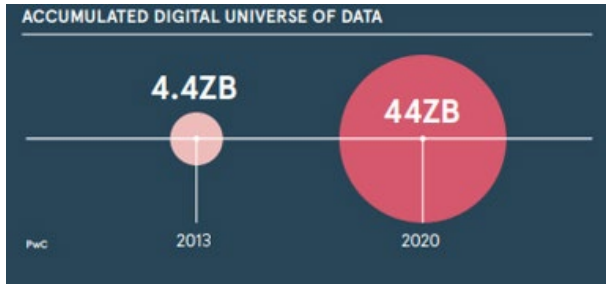
- Machine learning → "*a method of designing a sequence of actions* ***to solve a problem*** *that optimises automatically through experience and with limited or* ***no human intervention***" (FSB, 2017)
- Categories of machine learning:
  - **Supervised machine learning**
  - **Unsupervised machine learning**
  - **Reinforcement learning**
  - **Deep Learning**
- Few decades ago chess playing was c





What is Artificial Intelligence?

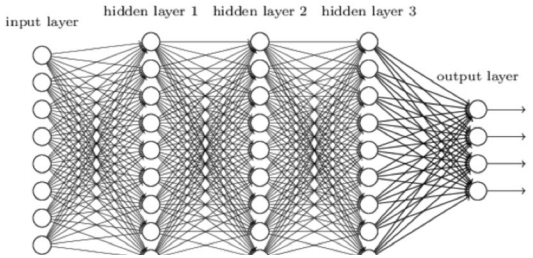
Data



A day in data

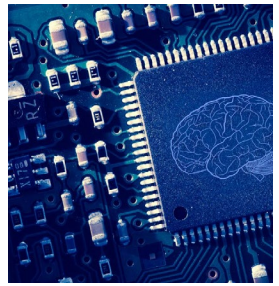
- 65 billion Whatsapp messages
- 10^{15} bytes generated by Facebook
- 500m tweets

The Mathematics



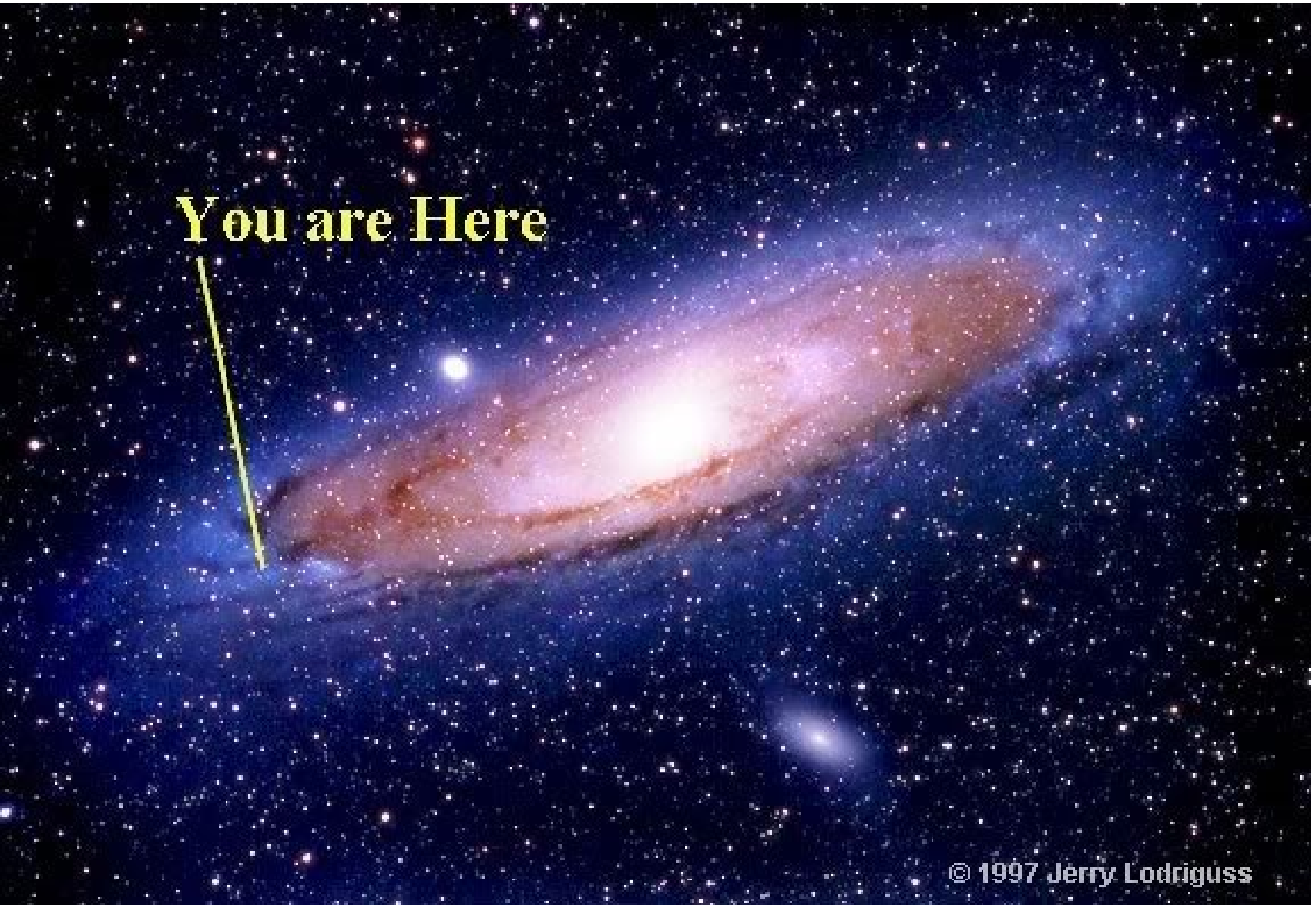
- Machine Learning
- Neural networks
- Numerical optimizations

Computing power

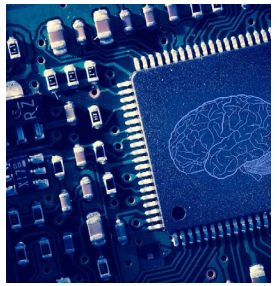


- 10^{21} FLOPS (floating point operations per second) globally available
- 10^{12}, one trillion, is 80 tiimes the global GDP
- Cost of 1 GFLOP
  - 1945: 1800 trillion USD
  - 2000: 1500 USD
  - 2020: 0.04 USD

What is Artificial Intelligence?



Computing power



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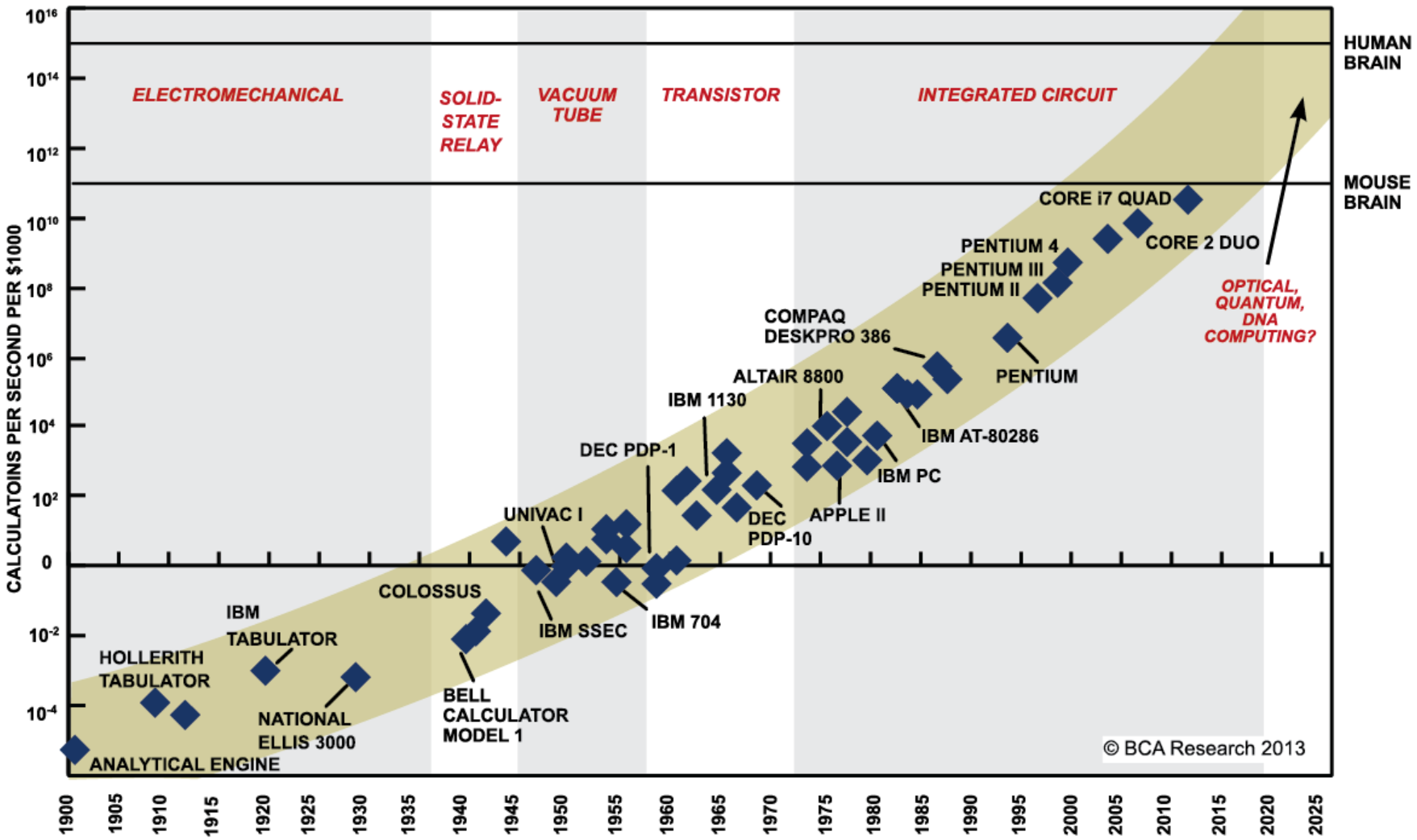
Computing power



SOURCE: RAY KURZWEIL, "THE SINGULARITY IS NEAR: WHEN HUMANS TRANSCEND BIOLOGY", P.67, *THE VIKING PRESS*, 2006. DATAPOINTS BETWEEN 2000 AND 2012 REPRESENT BCA ESTIMATES.

A DAY IN DATA

The exponential growth of data is undisputed, but the numbers behind this explosion – fuelled by internet of things and the use of connected devcies – are hard to comprehend, particularly when looked at in the context of one day

DEMYSTIFIYING DATA UNITS

From the more familiar 'bit' or 'megabyte', larger units of measurement are more frequently being used to explain the masses of data

Unit		Value	Size
b	bit	0 or 1	1/8 of a byte
B	byte	8 bits	1 byte
KB	kilobyte	1,000 bytes	1,000 bytes
MB	megabyte	$1,000^2$ bytes	1,000,000 bytes
GB	gigabyte	$1,000^3$ bytes	1,000,000,000 bytes
TB	terabyte	$1,000^4$ bytes	1,000,000,000,000 bytes
PB	petabyte	$1,000^5$ bytes	1,000,000,000,000,000 bytes
EB	exabyte	$1,000^6$ bytes	1,000,000,000,000,000,000 bytes
ZB	zettabyte	$1,000^7$ bytes	1,000,000,000,000,000,000,000 bytes
YB	yottabyte	$1,000^8$ bytes	1,000,000,000,000,000,000,000,000 bytes

*A lowercase "b" is used as an abbreviation for bits, while an uppercase "B" represents bytes.

463EB

of data will be created every day by 2025

IDC

500m

tweets are sent every day

Twitter

4PB

of data created by Facebook, including

350m photos

100m hours of video watch time

Facebook Research

65bn

messages sent over WhatsApp and two billion minutes of voice and video calls made

Facebook

95m

photos and videos are shared on Instagram

Instagram Business

320bn

emails to be sent each day by 2021

306bn

emails to be sent each day by 2020

294bn

billion emails are sent

Radicati Group

3.9bn

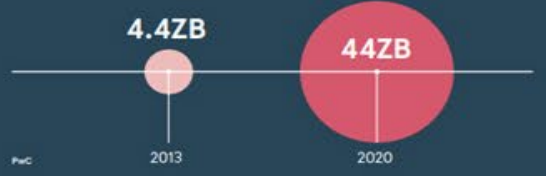
people use emails

4TB

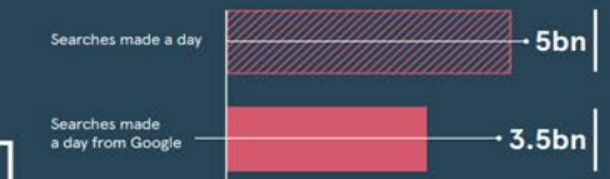
of data produced by a connected car

Intel

ACCUMULATED DIGITAL UNIVERSE OF DATA



PwC



Smart Insights

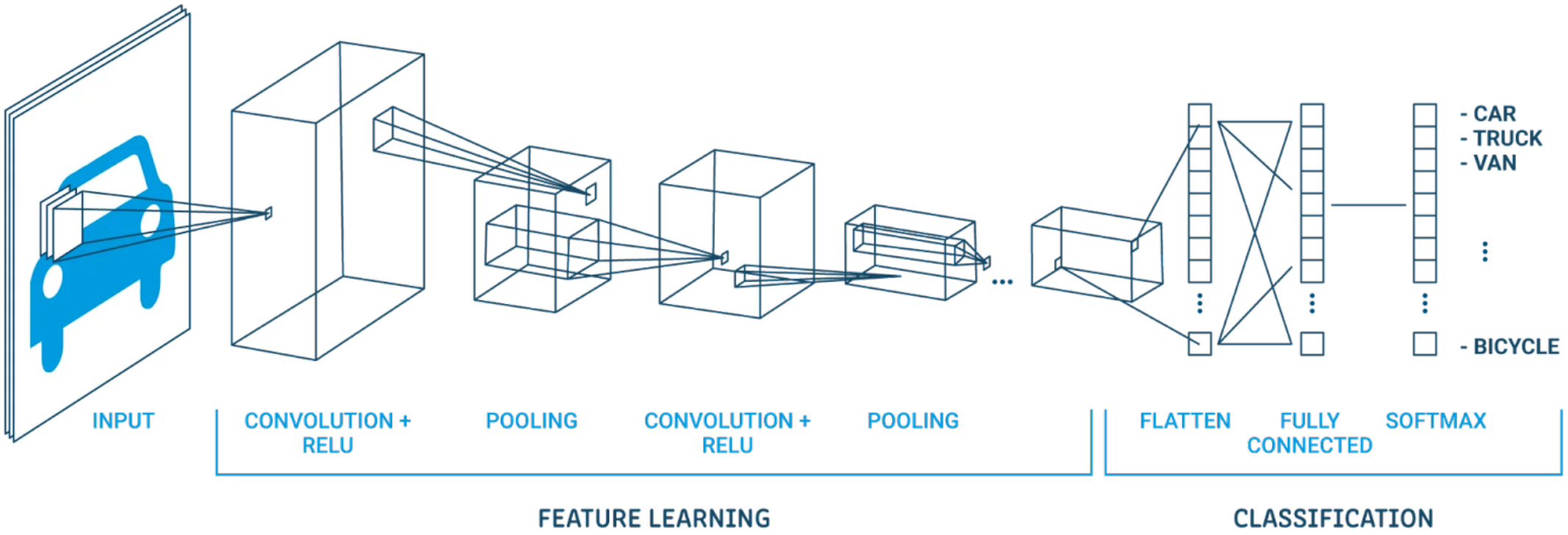
28PB

to be generated from wearable devices by 2020

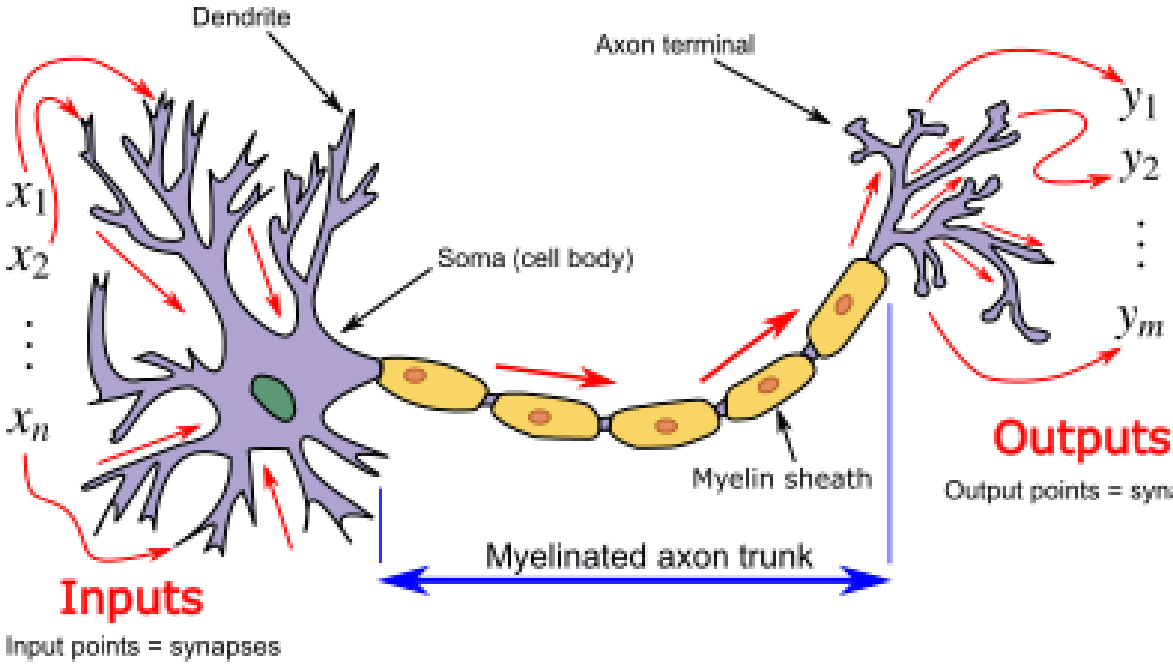
Statista

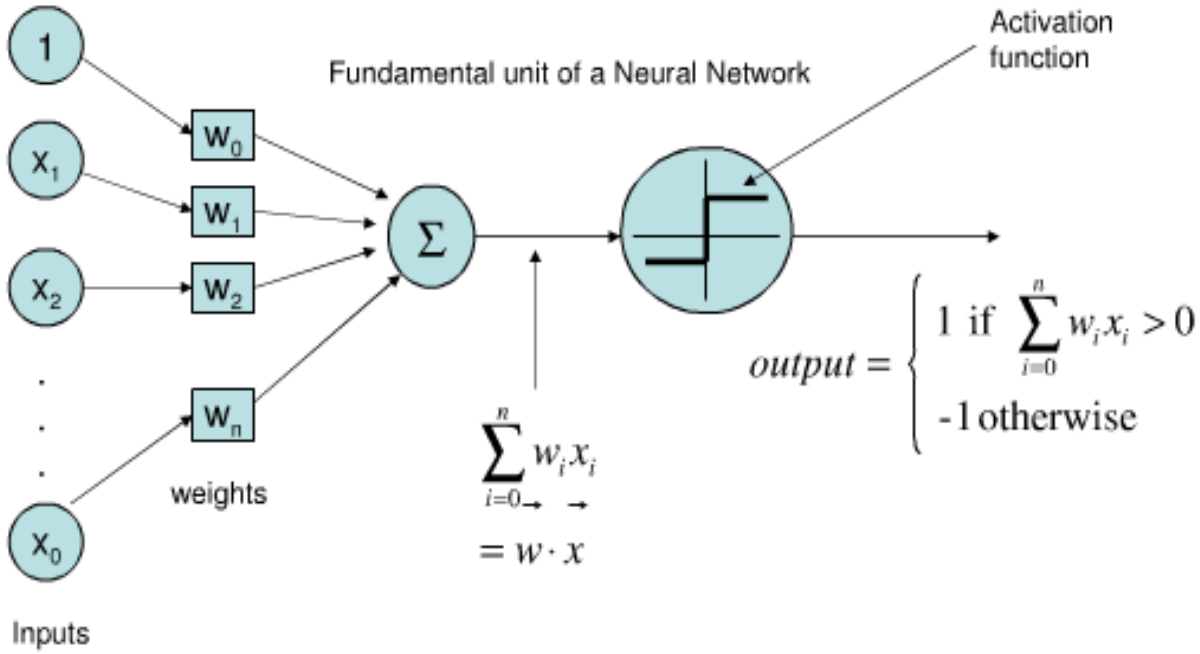
RACONTEUR

Artificial Intelligence techniques – The Mathematics



The Mathematics





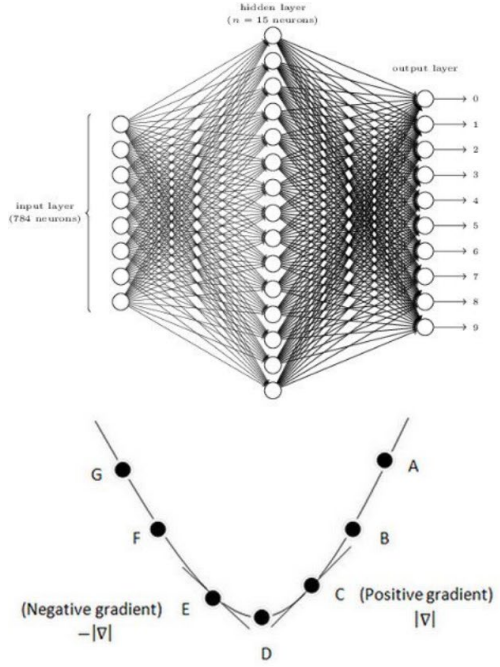
$$f : \mathbb{R}^n \to \mathbb{R}^m$$

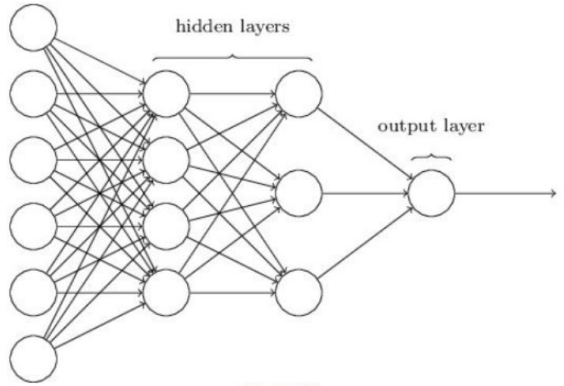
Neural networks (Artificial Intelligence) are functions

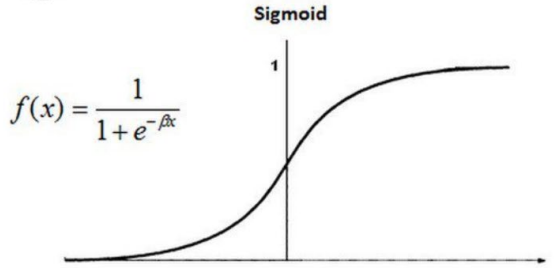
Neural networks and the universal approximation theorem

Neural networks can approximate (almost) arbitrary mathematical functions

Cybenko (1989) states that any continuous mathematical function on a compact domain can be **approximated with any precision** by an appropriate neural network with sufficient width and depth

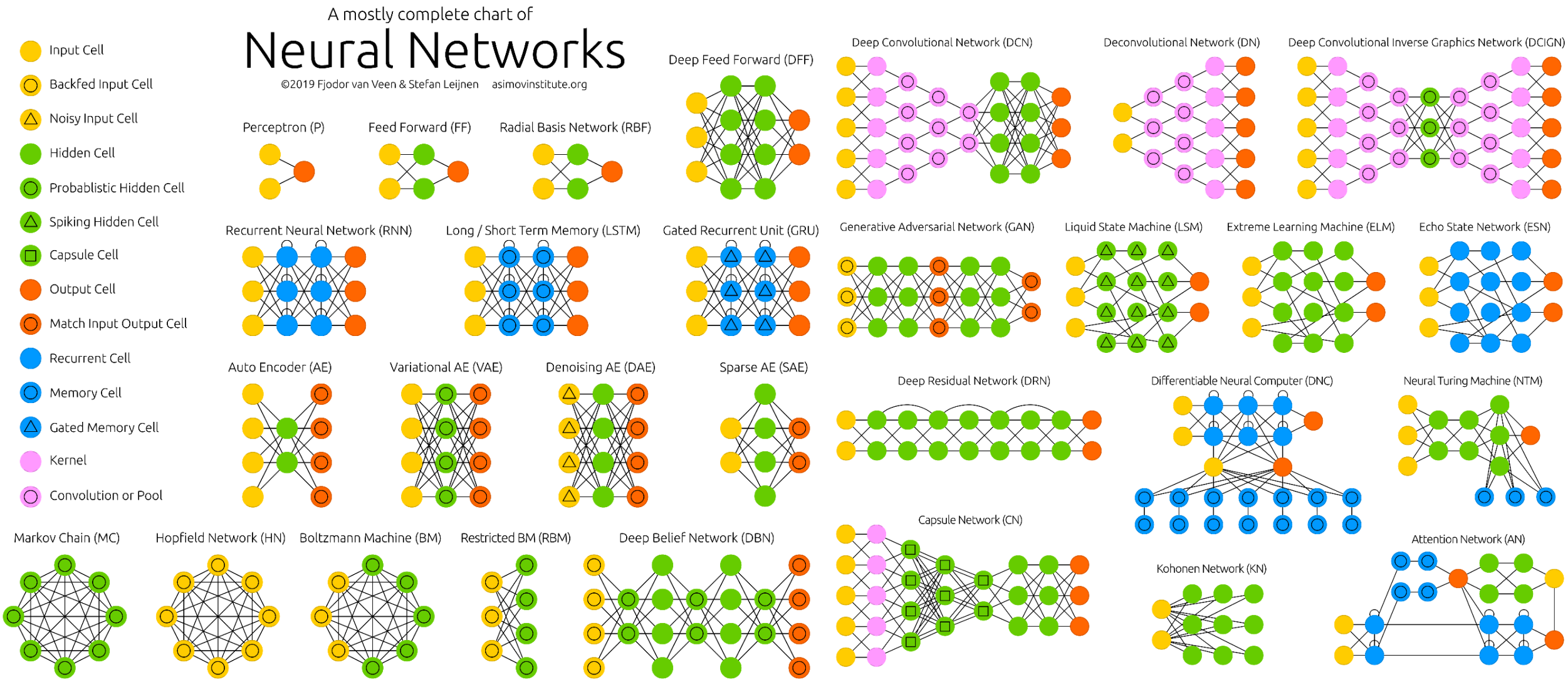






Neural networks are the most powerful functions we have ever had

Neural networks



History of Artificial Intelligence

Antiquity

Greek myths Sacred mechanical statues built in Egypt and Greece were believed to be capable of wisdom and emotion.

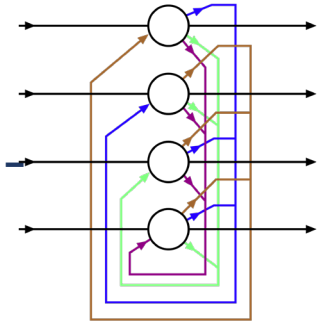
Symbolic AI 1956 – 1974

"Machines will be capable, within twenty years, of doing any work a man can do."

Boom 1980 – 1987

The rise of expert systems

The money returns: the Fifth Generation project



AI 1993 – 2011

Milestones and Moore's law

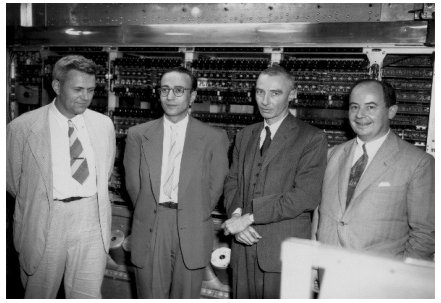
Intelligent agents

AI behind the scenes - AI had solved a lot of very difficult problems

The birth of AI 1952 – 1956

Turing's test

Dartmouth Workshop 1956



The first AI winter 1974 – 1980

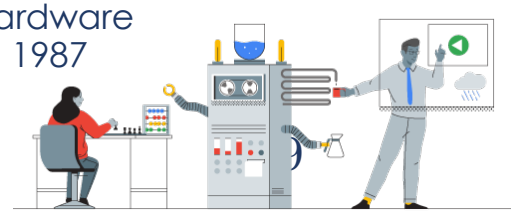
Limited computer power

Intractability and the combinatorial explosion

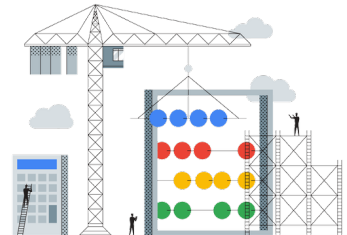
The end of funding

Bust: the second AI winter 1987 – 1993

Sudden collapse of the market for specialized AI hardware in 1987



Deep learning, big data and artificial intelligence: 2011 – present



AI Coins

A GLOBAL LOOK AT R&D SPENDING

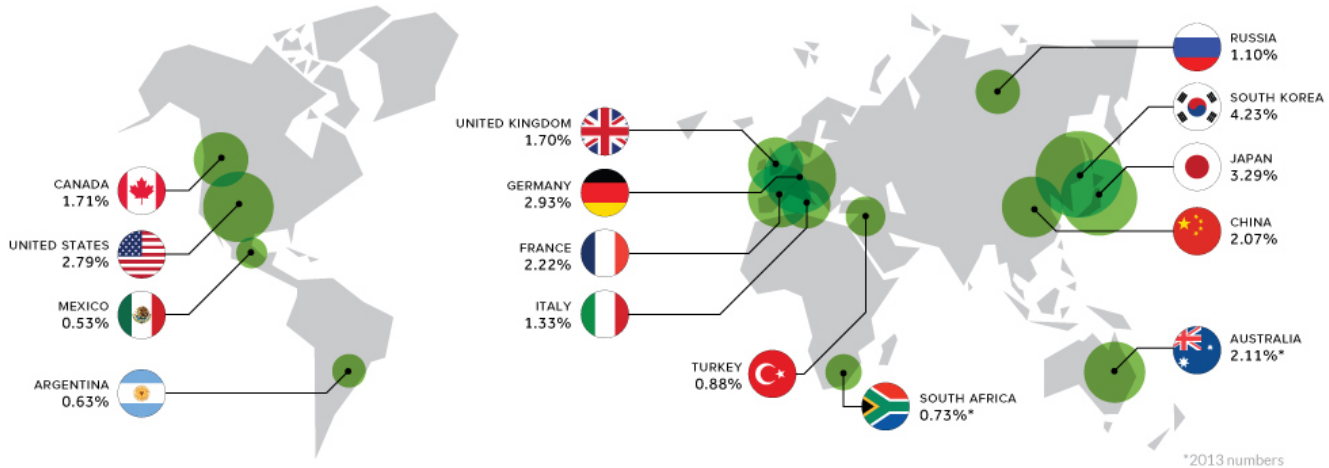
The companies and nations that are leading the way in innovation and research

The G20 accounts for **92%** of global spending on research

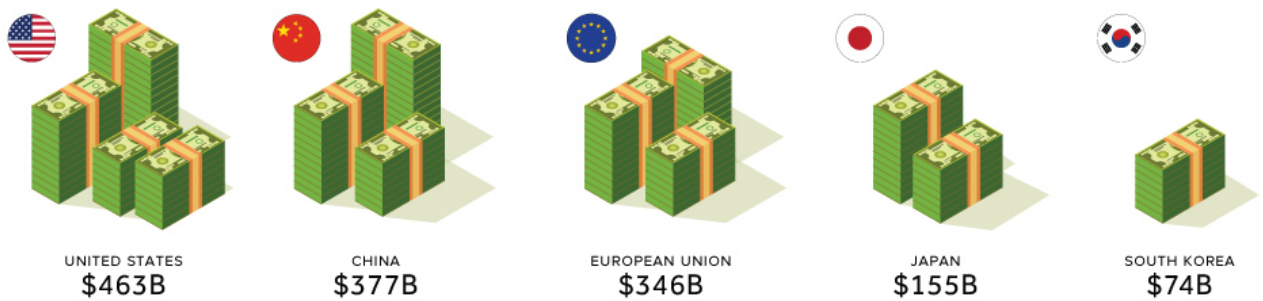
94% of patents granted by the US Patent and Trademark Office stem from G20 countries

R&D Expenditure as a percentage of GDP

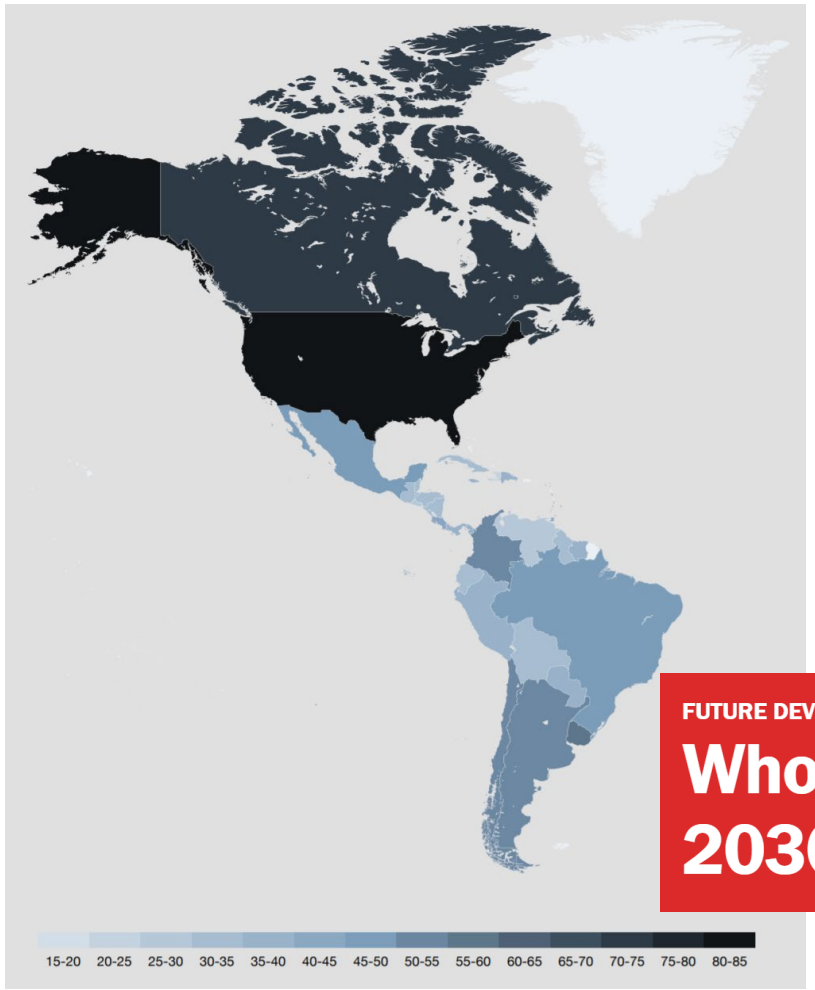
Select G20 countries; 2015

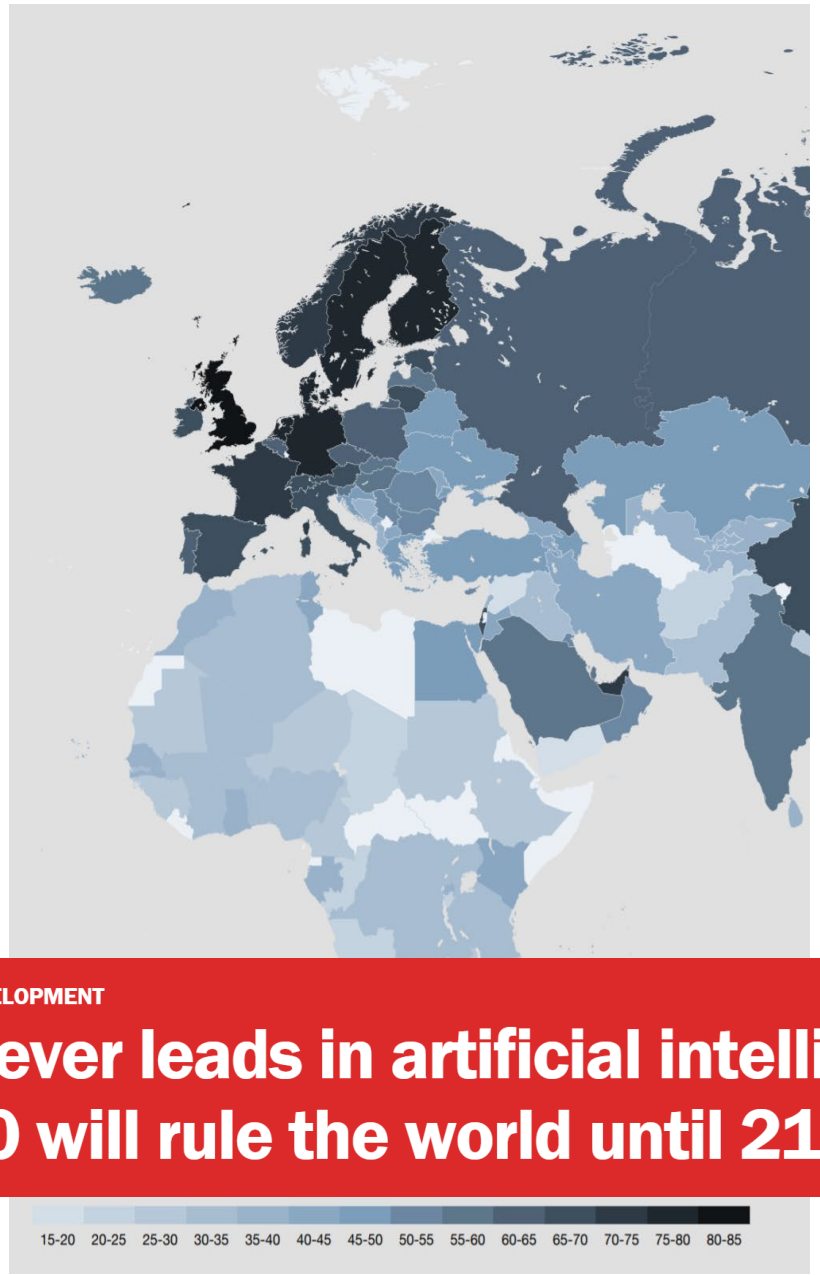


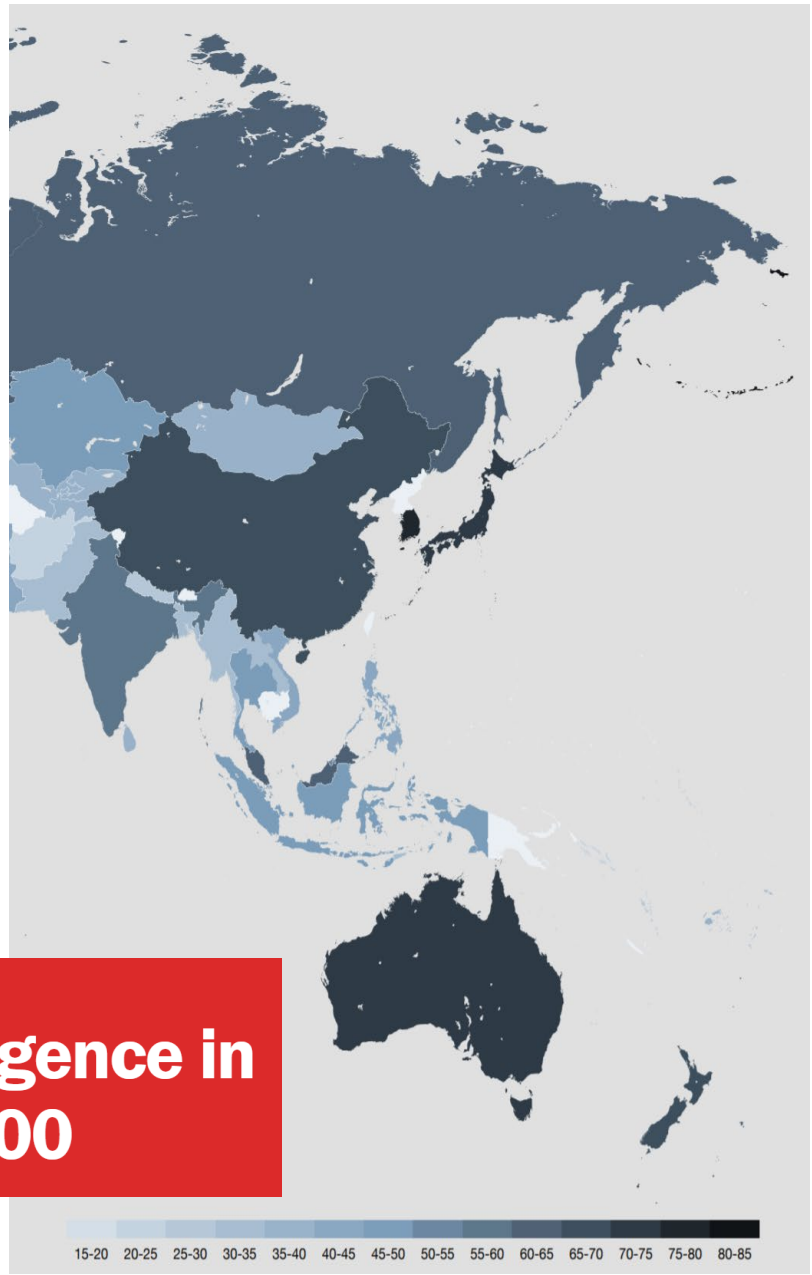
Top 5 Jurisdictions by R&D Expenditure (2015)



AI Readiness







FUTURE DEVELOPMENT

Whoever leads in artificial intelligence in 2030 will rule the world until 2100

A biased tour through AI in Finance Research: Data Science, Fintech and Blockchain Technology

Artificial Intelligence is impacting all business areas

	BACK OFFICE	MIDDLE OFFICE	FRONT OFFICE
Asset management	Reporting and record management	Compliance	Asset allocation
Credit intermediation	Data analytics	Risk management	Robo-advisors, Chatbots, customer service
Algorithmic trading	Credit scoring / risk underwriting	AML/CFT KYC checks	Biometric authentication
Blockchain-based finance	Trading P&L, reconciliations	Control functions/ processes	Trading strategies, execution
	Post-trade processing	Anti-fraud	
	IT / infrastructure		Tailored, personalised products

Source: OECD staff illustration.

A biased tour through AI research in Finance

Fintech and Risk Management

FINTECH RISK MANAGEMENT
www.fintech-ho2020.eu

100+ researchers from 15 European Universities

- Detecting Fraud in Blockchain payments
- Peer-to-peer lending
- Explainable AI
- Credit Risk Network models

Fintech and AI in Finance

European Commission

200+ researchers from 38 countries

Fintech and Artificial Intelligence in Finance
FIN AI

Reinforcement learning for Finance

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Confederation

Innosuisse – Swiss Innovation Agency

- Reinforcement learning for trading and forecasting financial markets

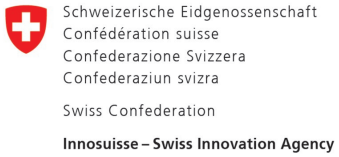
frontiers in Artificial Intelligence
REVIEW article
Front. Artif. Intell., 31 May 2021 | https://doi.org/10.3389/frai.2021.668465

The Applicability of Self-Play Algorithms to Trading and Forecasting Financial Markets

Jan-Alexander Posth[1*], Piotr Kotlarz[2,3], Branka Hadji Misheva[2], Joerg Osterrieder[2,4] and Peter Schwendner[1]

A biased tour through AI research in Finance II

Credit risk models



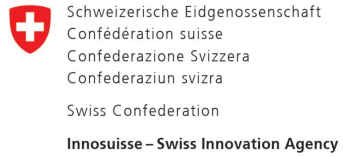
- Towards Explainable Artificial Intelligence and Machine Learning in Credit Risk Management

Peer-to-peer lending

Network-based credit risk models

- Network-based feature extraction techniques
- The use of multiple networks in feature extraction
- bagging and hyper-parameter tuning

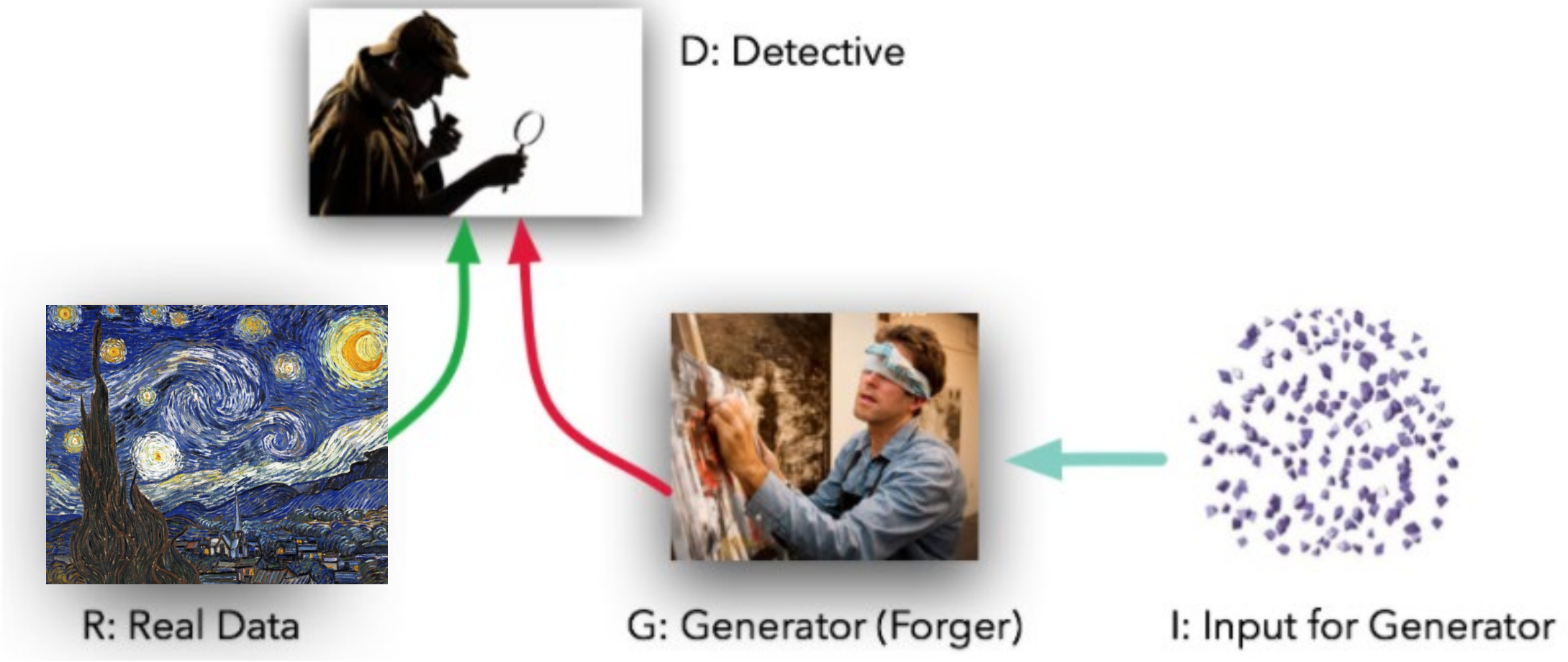
Reinforcement learning for Finance



- Limit order book case study
- Recommender systems
- Factor investing
- Multi-agent Reinforcement Learning

A biased tour through AI research in Finance III

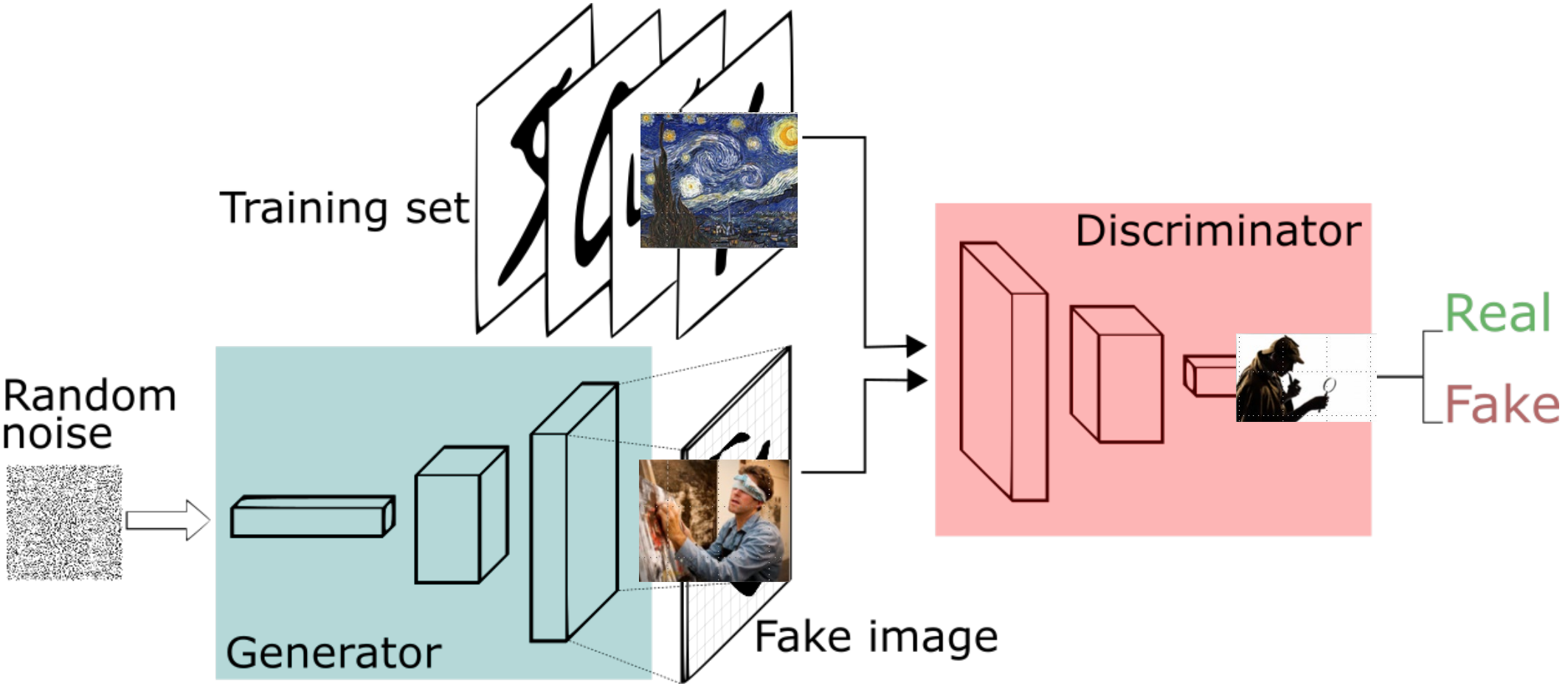
Generative Adversarial Networks



A biased tour through AI research in Finance IV

Generative Adversarial Networks

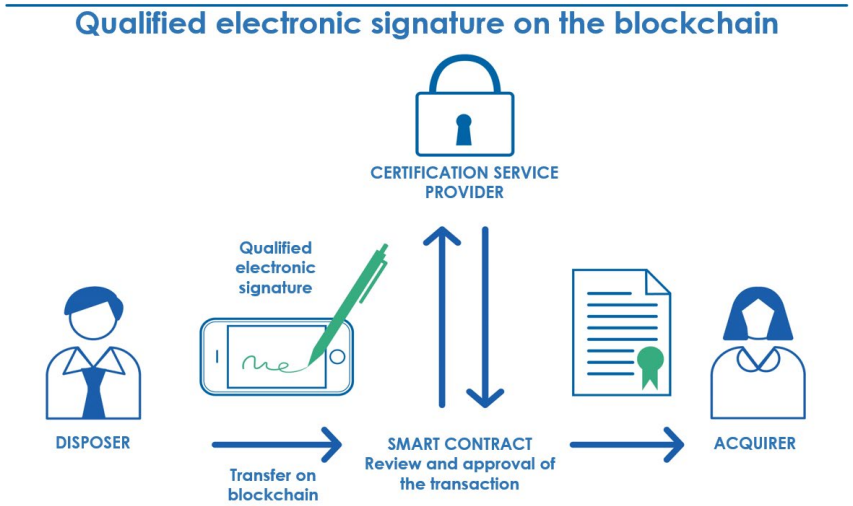
$$\min_{\mathcal{G}} \max_{\mathcal{D}} E_x \left[\log(\mathcal{D}(x))\right] + E_z \left[\log(1 - \mathcal{D}(\mathcal{G}(z)))\right]$$



A biased tour through AI research in Finance V

Electronic Signature on the Blockchain

swisscom

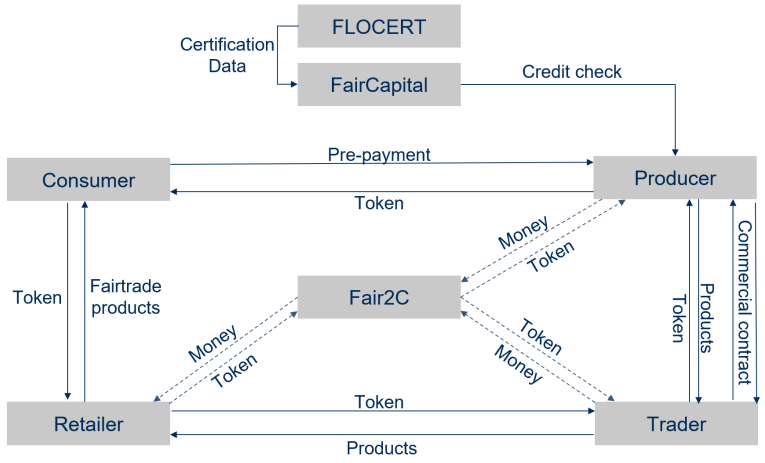


Blockchain-based Fair Trade

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

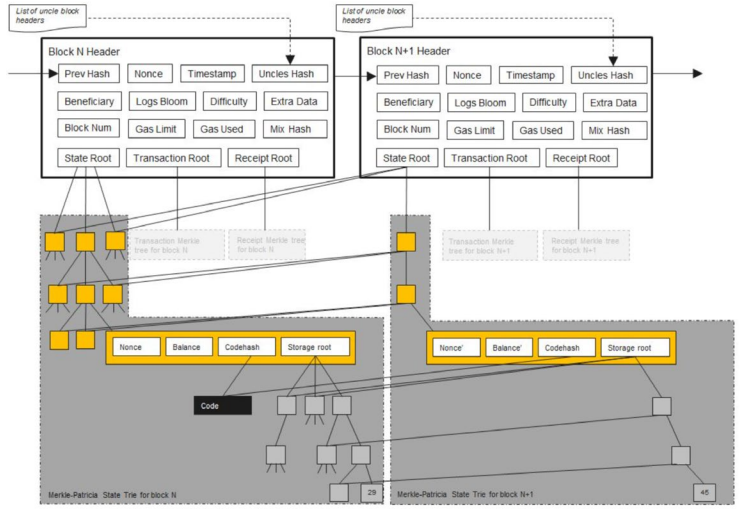
Swiss Confederation

Innosuisse – Swiss Innovation Agency

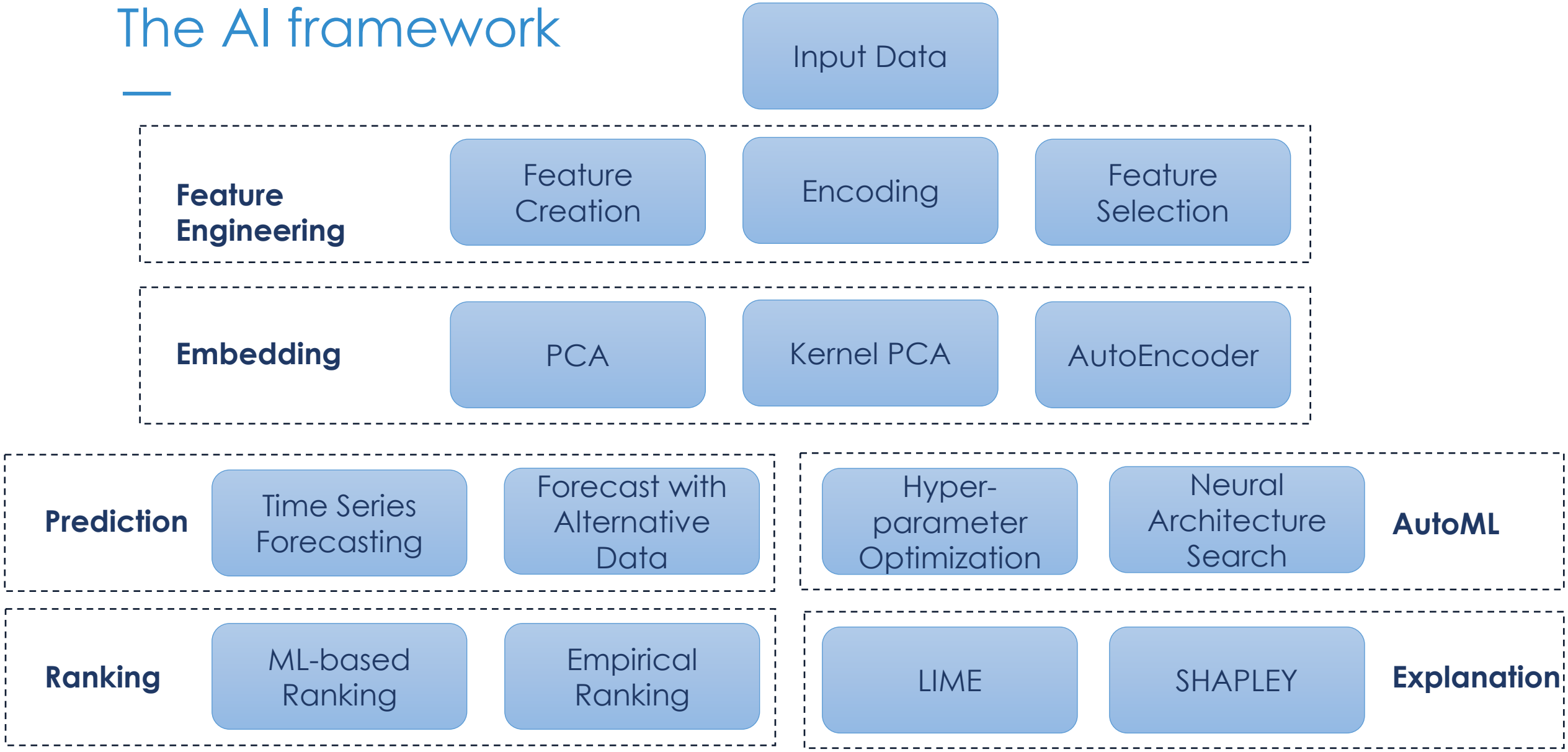


Virtual currencies

FNSNF
FONDS NATIONAL SUISSE
SCHWEIZERISCHER NATIONALFONDS
FONDO NAZIONALE SVIZZERO
SWISS NATIONAL SCIENCE FOUNDATION



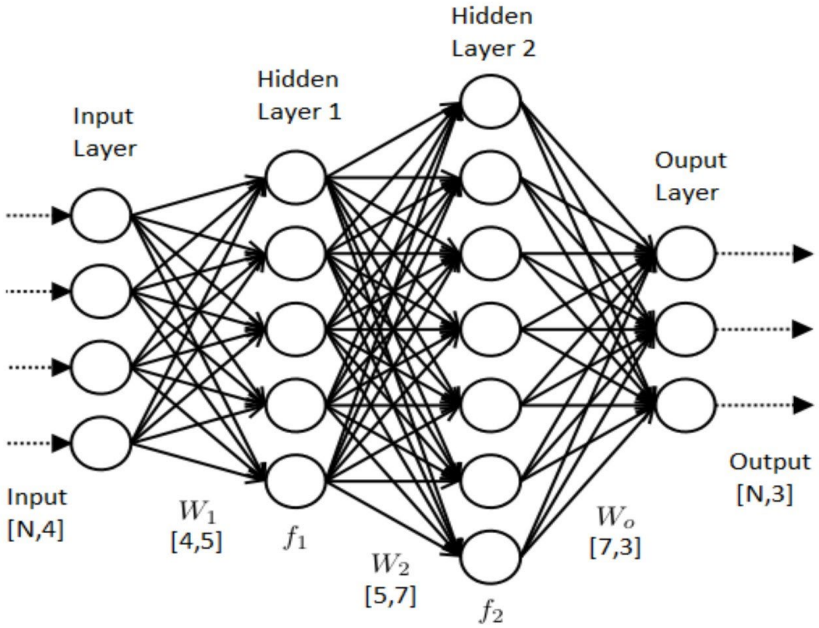
The AI framework

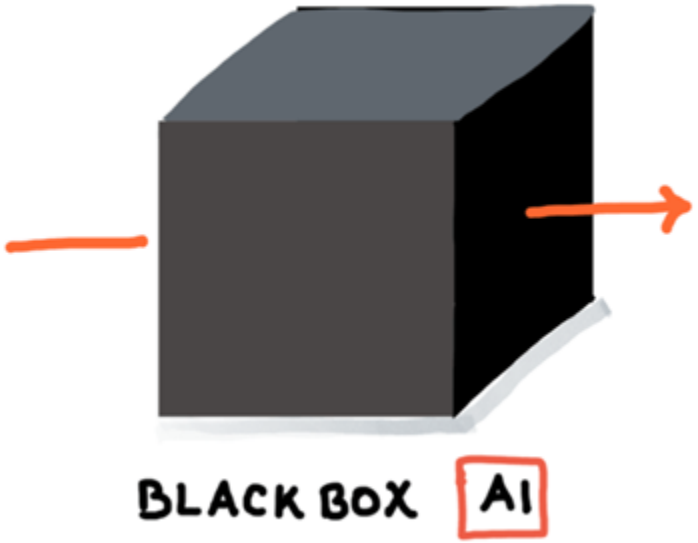


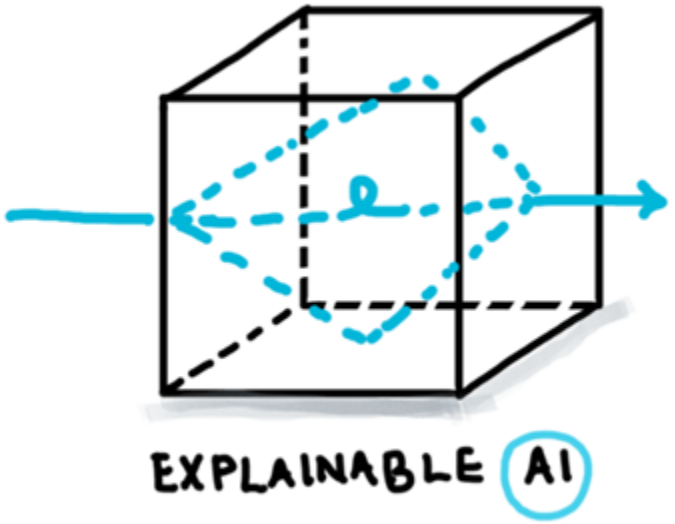
Regulatory aspects

The Need for eXplainable AI

It is not clear how variables are being combined to make predictions!







The Need for eXplainable AI

It is not clear how variables are being combined to make predictions!

INPUT → **BLACK BOX** → **OUTPUT**

It has found some snow!

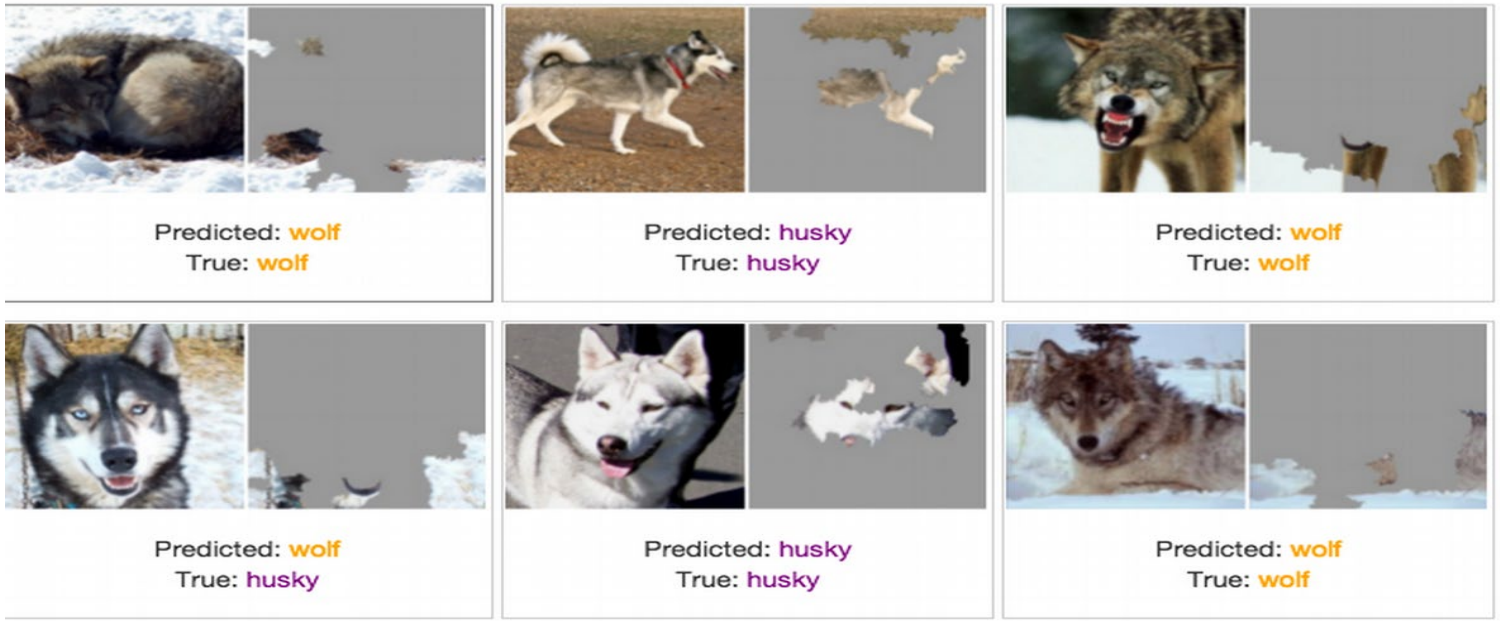


Image source: medium.com

Seven key requirements for AI systems

The European approach to trustworthy AI

European Commission

Unacceptable risk

- Clear threat to the safety, livelihoods and rights of people
- Systems or applications that manipulate human behaviour to circumvent users' free will
- 'social scoring' by governments

High-risk

- Critical infrastructures
- Educational or vocational training
- Safety components of products
- Employment, workers management and access to self-employment
- Essential private and public services
- Law enforcement
- Migration, asylum and border control management
- Administration of justice and democratic processes

Limited risk

- AI systems with specific transparency obligations
- Users should be aware that they are interacting with a machine so they can take an informed decision to continue or step back

Minimal risk

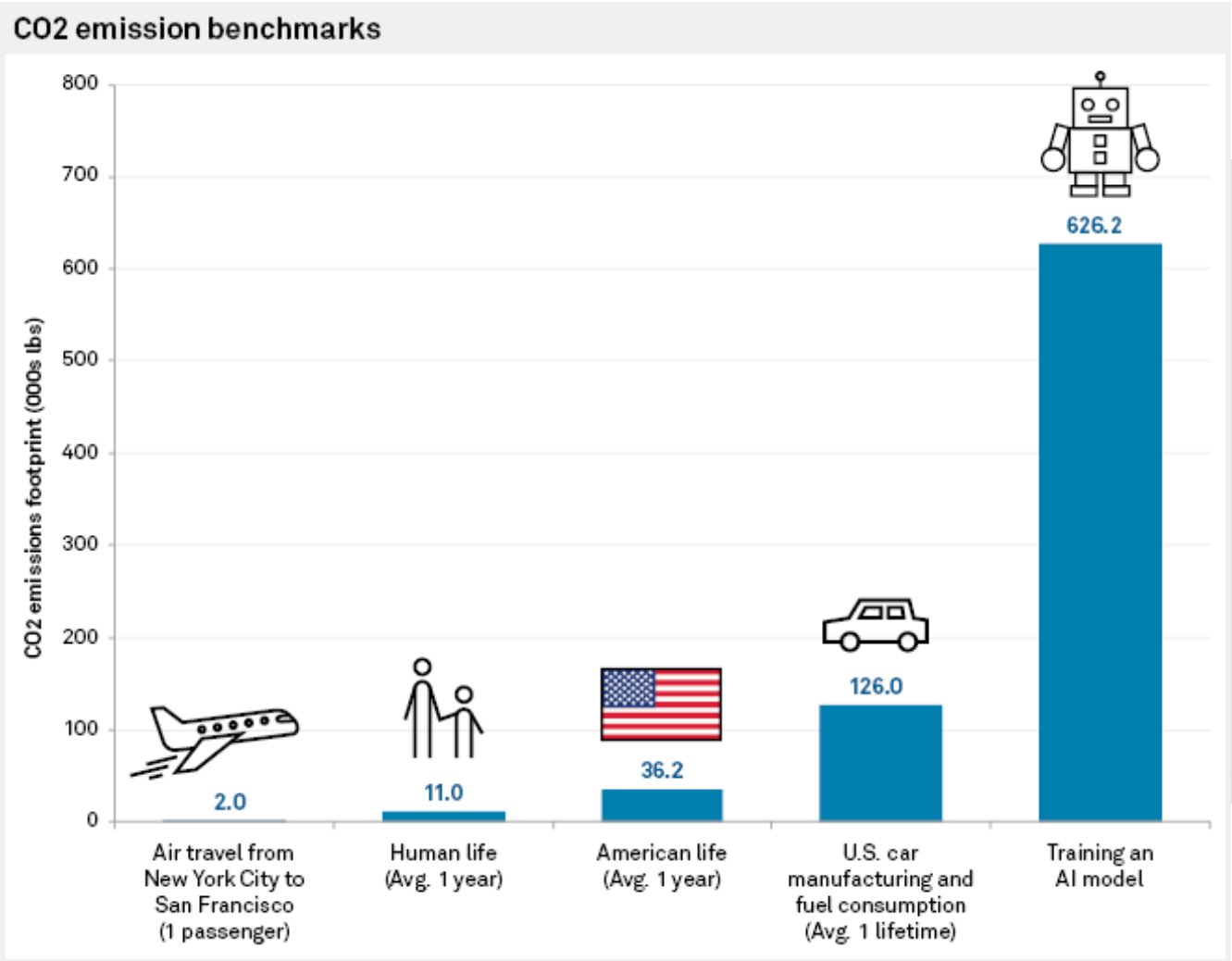
- Free use of applications such as AI-enabled video games or spam filters
- The draft Regulation does not intervene here, as these AI systems represent only minimal or no risk for citizens' rights or safety

Coordinated Plan on AI

- Funding allocated through the Digital Europe and Horizon Europe programmes, the Recovery and Resilience Facility and Cohesion Policy programmes
- Creation of enabling conditions for AI's development
- Foster AI excellence
- Ensure that AI works for people
- Build strategic leadership

Quantum Computing

AI and sustainability



Data compiled Oct. 9, 2019.
An "American life" has a larger carbon footprint than a "Human life" because the U.S. is widely regarded as one of the top carbon dioxide emitters in the world.
Source: College of Information and Computer Sciences at University of Massachusetts Amherst

In 2030, using AI for climate control could help reduce

2.6 to 5.3 gigatons

of GHG emissions, or 5% to 10% of the total

and could provide

$1 trillion to $3 trillion

in value added when applied to corporate sustainability generally

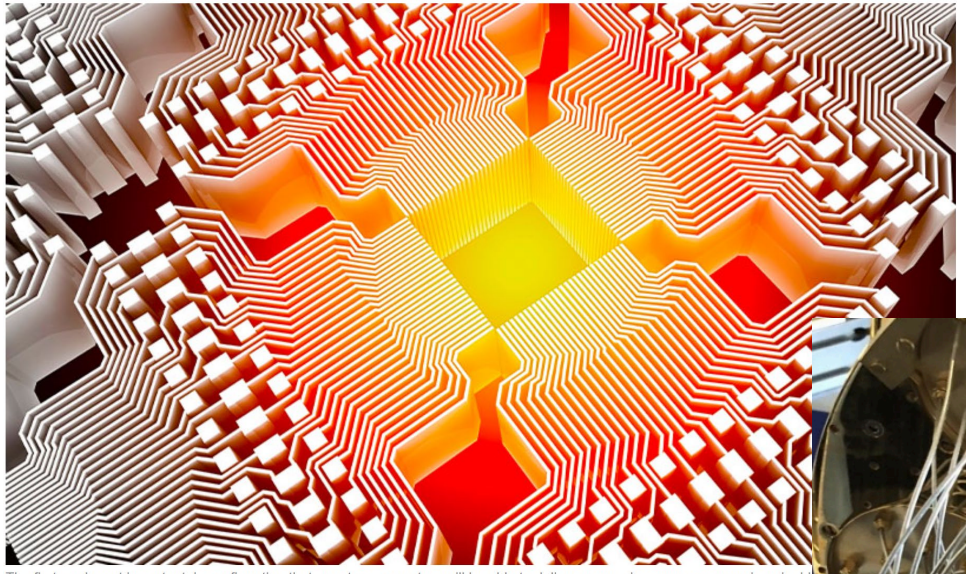
Source: BCG analysis.

How quantum computing could change financial services

In a Historic Milestone, Silicon Quantum Computing Just Exceeded 99% Accuracy

JP Morgan Chase Unleashes Honeywell's Quantum Computer on Tough Fintech Problems

The potential of quantum computing for finance



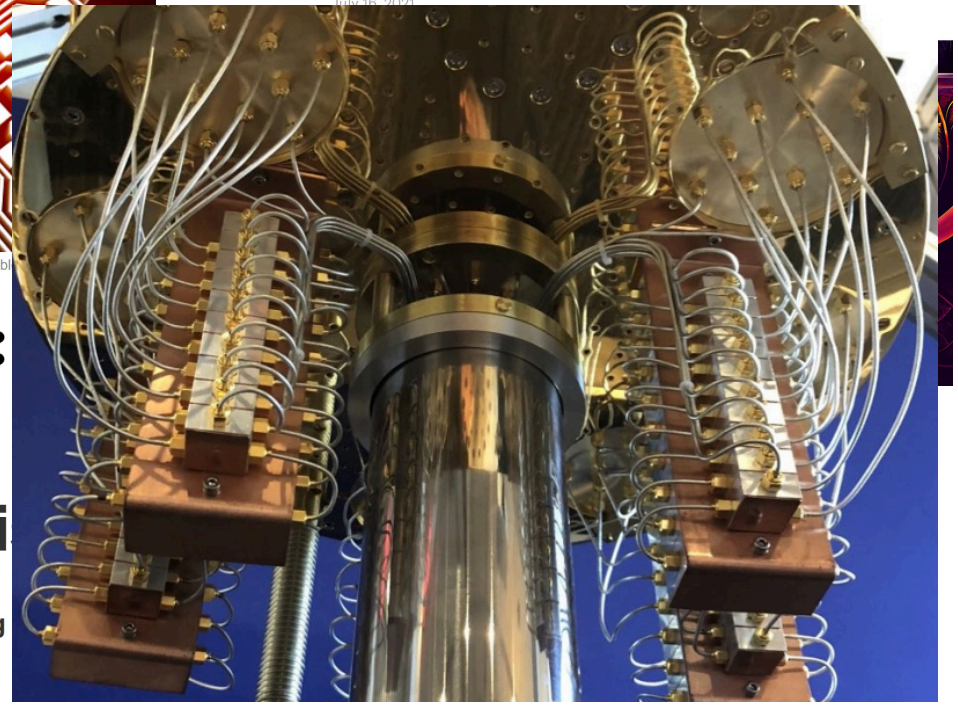
The first, and most important, is confirmation that quantum computers will be able to deliver processing power on an unimaginabl

Quantum Computing in Banking and Finance – Threat or Opportunity?

Quantum Computing Is Coming. What Can It Do?

by Francesco Bova, Avi Goldfarb, and Roger Melko

July 16, 2021



First fully programmable quantum computer based on neutral atoms

Bloomberg

Nuclear quantum computing:

Brought to you by the US Army

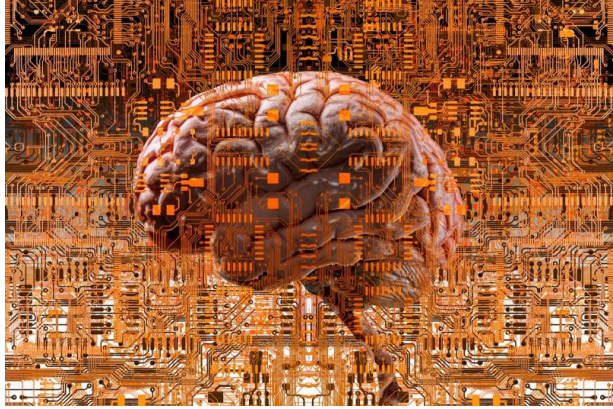
Finland moves to industriali

For the Finnish government, now is the time to start preparing quantum computers will have practical value

Markets | Markets Magazine

Quantum Computing Might Be Here Sooner Than You Think

The Future of Artificial Intelligence



- *"The development of full artificial intelligence could spell the end of the human race….It would take off on its own, and re-design itself at an ever-increasing rate. Humans, who are limited by slow biological evolution, couldn't compete, and would be superseded."*— Stephen Hawking

- *"Artificial intelligence would be the ultimate version of Google. The ultimate search engine that would understand everything on the web. It would understand exactly what you wanted, and it would give you the right thing. We're nowhere near doing that now. However, we can get incrementally closer to that, and that is basically what we work on."* —Larry Page

- *"Artificial intelligence will reach human levels by around 2029. Follow that out further to, say, 2045, we will have multiplied the intelligence, the human biological machine intelligence of our civilization a billion-fold."* —Ray Kurzweil

Artifcial Intelligence in Finance
Quo Vadis?

IFC workshop on Data science in central banking:
Applications and Tools
14 – 17 February, 2022

Irving Fisher Committee on Central Bank Statistics

BIS

Prof. Dr. Jörg Osterrieder