AI Science and Engineering:
A new scientific discipline?
Societal and environmental impact

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Version 2.0

VML

Artificial Intelligence & Information Analysis Lab

AI Science and Engineering

- **What is AI?**
- AI and Human Mind
- AI and Society
- AI and the Environment
- AI Science and Engineering?
- AI studies

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What is AI?

- **AI Science and Engineering** (AISE) is the interdisciplinary, scientific study and engineering of **Artificial Systems** that mimic and/or surpass **human intelligence** in information analysis and **human interaction** with the world.

- Core AISE disciplines are:
  - **Machine Learning** (ML),
  - Classical (Symbolic) **Artificial Intelligence** (AI)

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What is AI?

- Closely related AISE disciplines:
  - **Robotics,**
  - Autonomous Systems,
  - Digital Signal/Image Processing and Analysis,
  - Data Science and Data Analytics
  - **Network Theory**.

- Very useful in defining:
  - Data, analysis modes, applications.
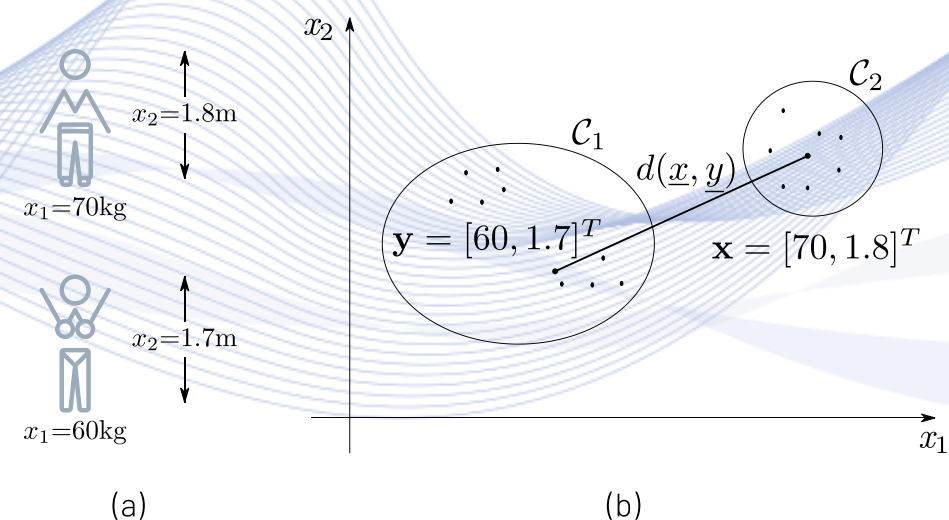
What is AI?

- Complementary AISE-related disciplines:
  - Cognitive Science,
  - Neuroscience,
  - Psychology,
  - ***Philosophy, Ethics***
  - Linguistics
  - Sociology.

What is AI?

Data/information/knowledge definitions

Data: measured quantities related to nature and/or human activities.

- ***Data are primarily numbers*** representing object characteristics (features).
- Passive/active data acquisition.
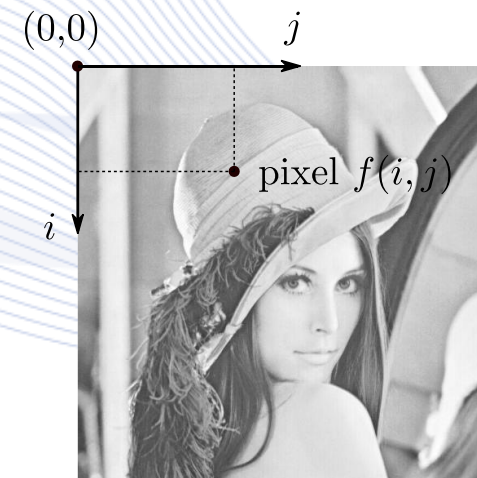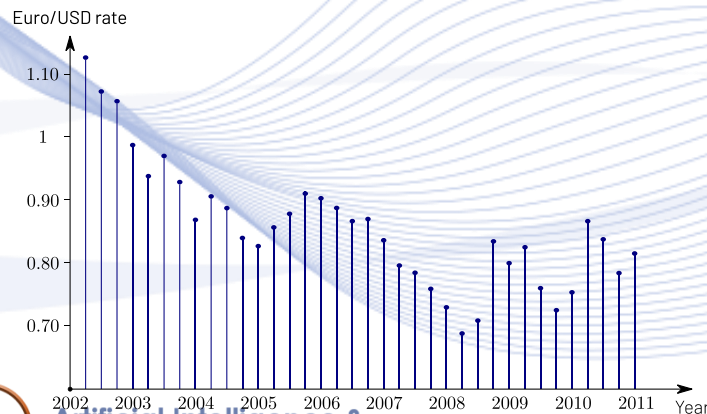- Data sampling.

- ***Measured in bits.***

(a)   (b)

What is AI?

Data can have ***spatiotemporal structure***:

- 1D temporal signals, e.g., music

- 2D spatial signals: images

- Signals and object features can be represented by ***vectors***:

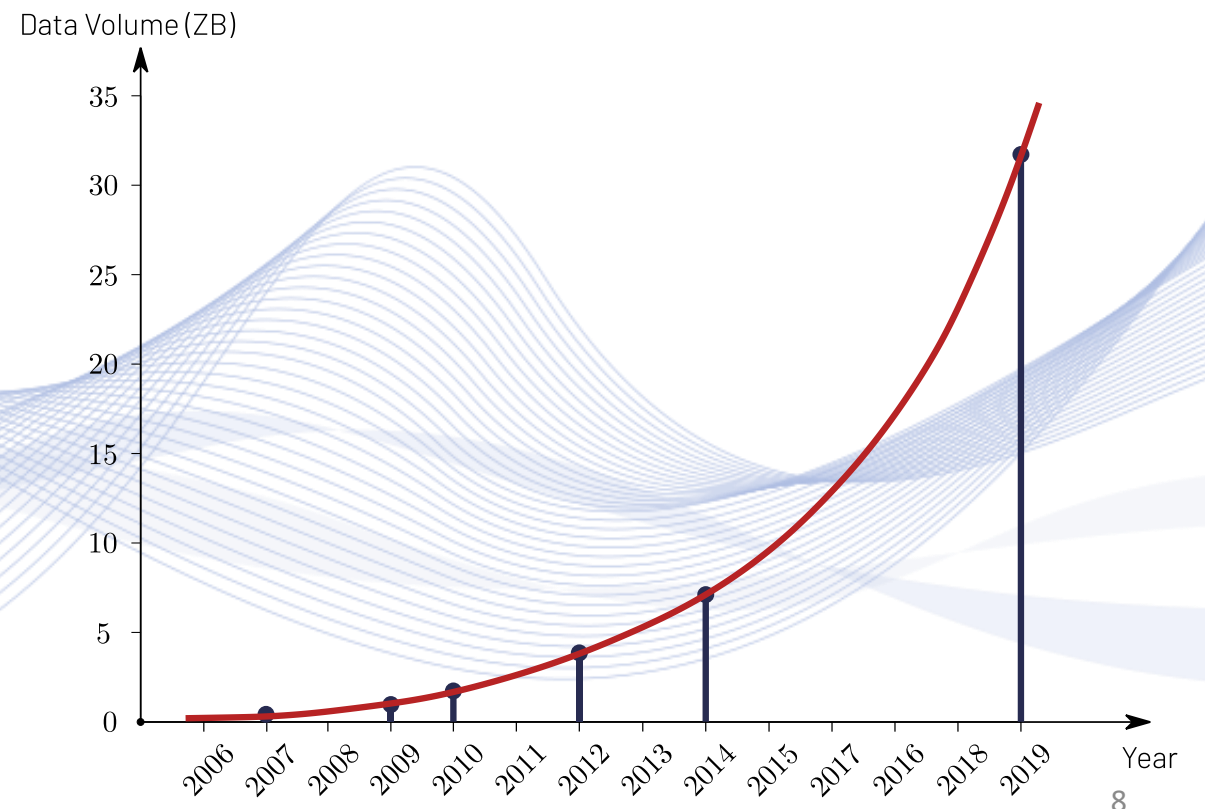$$\mathbf{x}^T = [x_1, x_2, \ldots, x_n].$$

pixel $f(i,j)$

What is AI?

Exponential data increase:

- Proliferation of sensors
- Detailed recording of nature and humans
- Sensing automation.

Data volume increase in past decade.

Data Volume (ZB) vs Year

What is AI?

Why we need ever more data?

- To navigate in an ever more complex world.
  - *Why do we need a more complex world?*

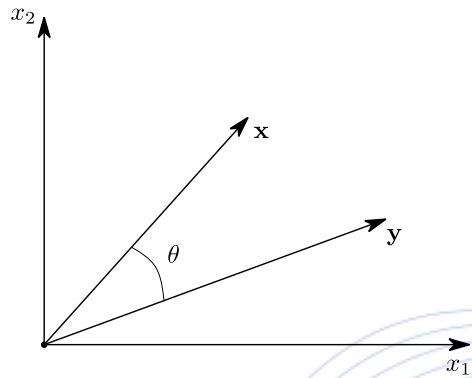Data sustainability:

- HW enabled
- *Moore's law*
- Data storage constraints
- Data communication constraints.

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What is AI?

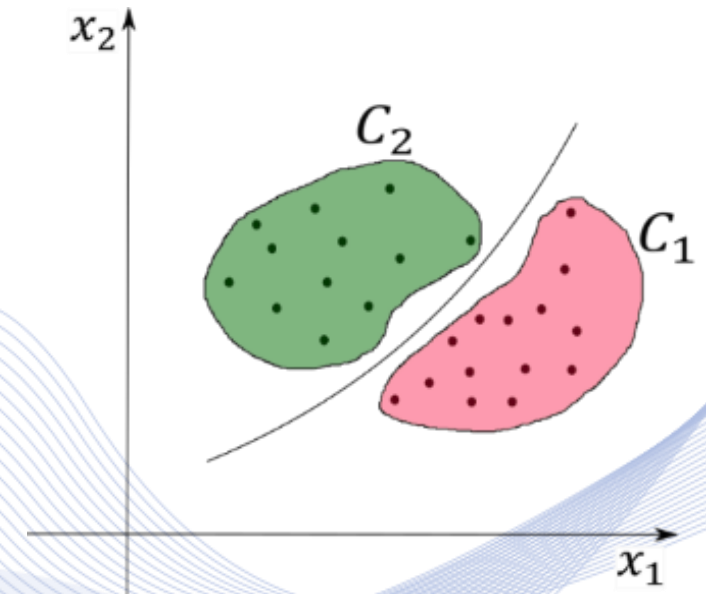## *Unsupervised Machine Learning*

- Data clustering:

- Data geometry
- *Abstraction*
- *Data compression.*

What is AI?

Supervised Machine Learning

- Learning functions $\mathbf{y} = f(\mathbf{x}; \boldsymbol{\theta})$ from labeled training data $\{(\mathbf{x}_i, \mathbf{y}_i), i = 1, \ldots, N\}$.

- **Classification**

- **Regression.**

- Learning data probability distributions $p(\mathbf{x})$.

  - **Generative neural networks.**

    - **Fake data creation.**

What is AI?

Information

- Notoriously vague definitions

- My definition: **Information is the result of the manual or automatic Data Analysis**.

  Taxonomy: Data → Information → Knowledge.

Machine Learning/inference produces **information** (including metadata).

- **Information theory/entropy: bits (once more)!**

What is AI?

Concepts and ideas (ιδέες).

- Concepts are specific mental constructs residing in our mind (brain?) that refine and abstract ideas.

- **Concept instances**

Instances of a triangle.
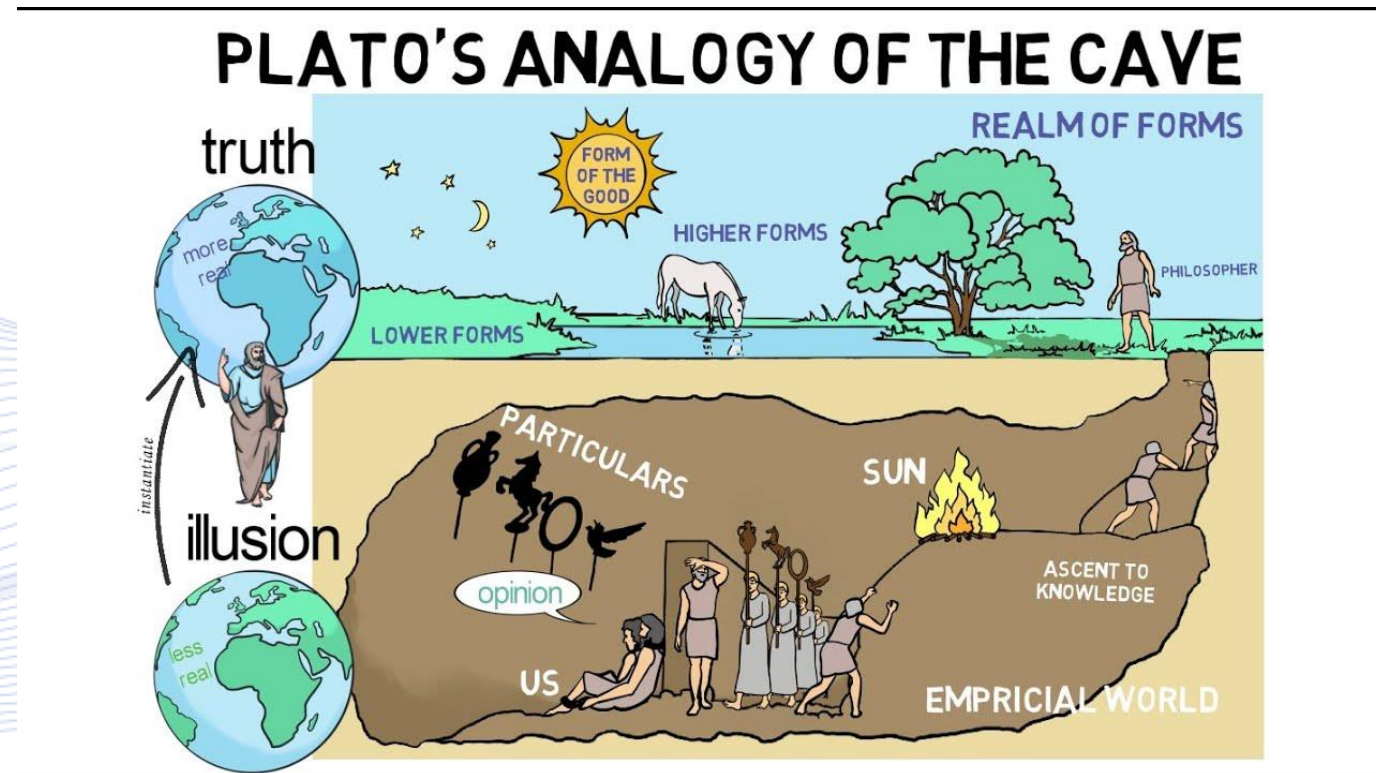
- **Abstraction and generalization**:
  - Simplification and data compression.

What is AI?

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Ideas in Philosophy.

- Idealism, materialism, dualism.
- Plato's cave.

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What is AI?

Symbolic AI

- A ***symbol*** ('Σύμβολο') is a ***comprehensible representation*** of an object, idea, concept, action, status, or relationship.
- Symbolic AI mimics and simulates high-level human intelligence and ***reasoning***.
- It represents and operates on concepts and their relations though ***logic*** and ***search***.

- ***Reasoning*** is one of the most complex brain activities.

What is AI?

Knowledge

- It is a familiarity, awareness, or *understanding of someone or something*:
  - Facts (propositional knowledge),
  - Skills (procedural knowledge),
  - Objects relations (relational knowledge).

- Various knowledge descriptions.
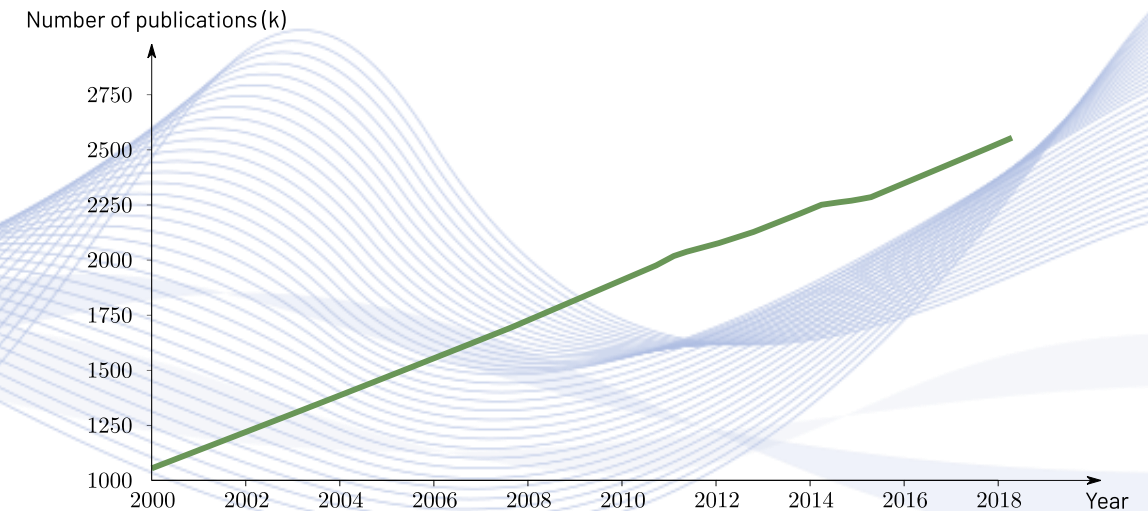
Artificial Intelligence & Information Analysis Lab
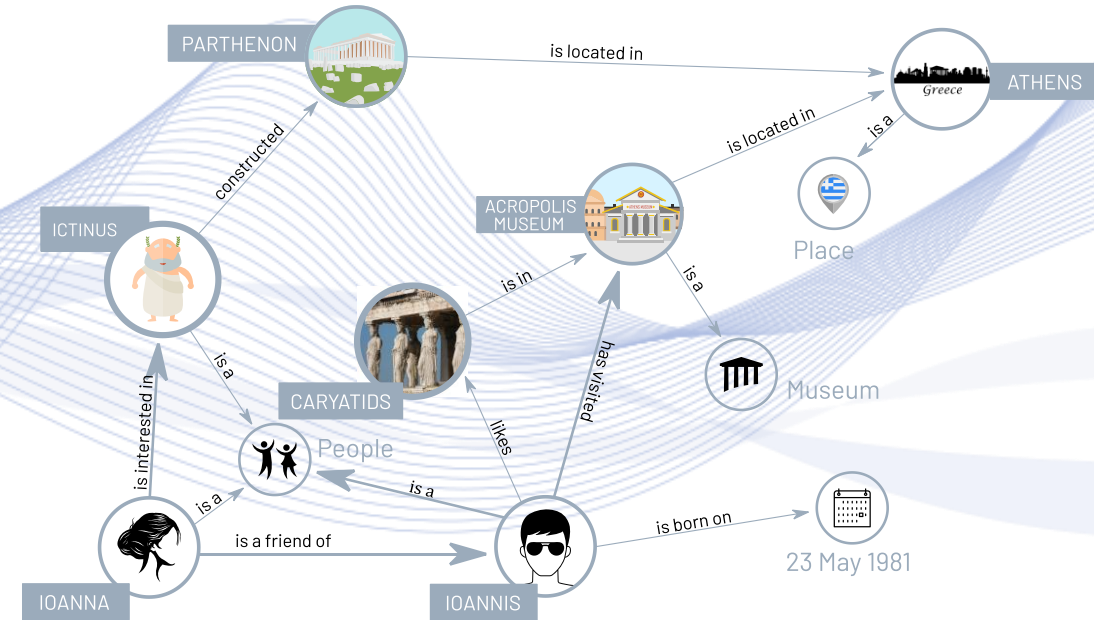
What is AI?

Knowledge is primarily a product of reasoning.

- Is knowledge finite?
- ***Can we measure knowledge?***
- Knowledge increase is linear.

- ***Encyclopedias***
- ***Research publications.***

Global research output (publication) growth.

What is AI?

Current AI revolution:

- ***AI means ML, which means Deep Neural Networks***
- Stagnation of symbolic AI
- Resurrection of a dead term: AI

Major breakthrough needed:

- Advancement of symbolic AI
- ***Fusion of Machine Learning and symbolic AI.***

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What is AI?

Data/Information society:

- Exponential data growth.

- Data acquisition automation.

- **_Information extraction automation through ML._**

Sustainability?

- More sensors, more processors, Moore's law.

- **_Energy-intensive data and information extraction._**

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What is AI?

Knowledge society:

- Exponential knowledge growth.
- Not there yet: ***knowledge production and communication is still manual***.

- Past devastating setbacks in knowledge uptaking:
- Dark ages (beginning of the medieval times).

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What is AI?

Knowledge Sustainability:

- Limitations in brain capacity.

- Solution: *social swarm intelligence*

- Example: collective memory.

- Knowledge communication through *education* is way suboptimal:

  - New education mode needed, stressing **critical thinking** and **abstraction**.
  - **Morphosis**: formation of knowledgeable citizens.
  - **Global education**: diminishing social and regional barriers to education.

- ***Unified machine and human learning theories?***

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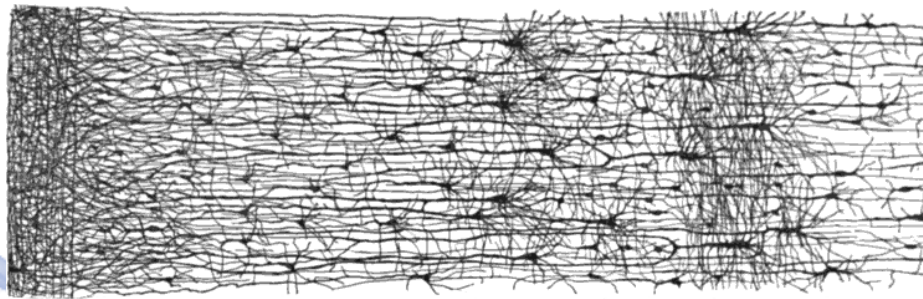Information Analysis Lab

AI Science and Engineering

- What is AI?
- **AI and Human Mind**
- AI and Society
- AI and the Environment
- AI Science and Engineering?
- AI studies
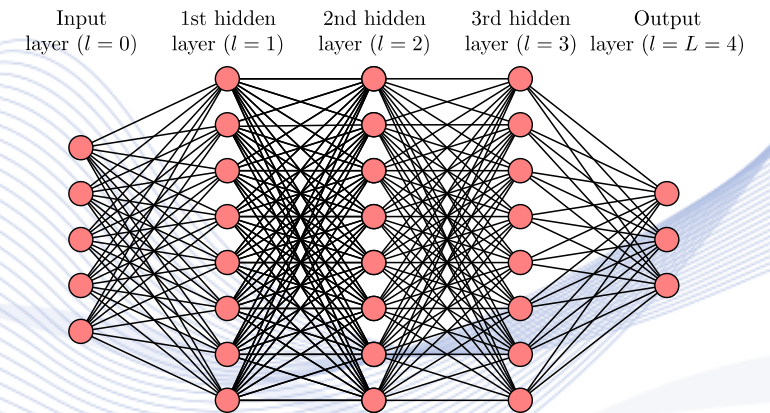
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AI and Human Mind

Artificial and Biological neural networks

- Is **network complexity** the basis of both the biological and artificial intelligence?

Biological NN (https://en.wikipedia.org/wiki/Cerebral_cortex)

Multilayer perceptron

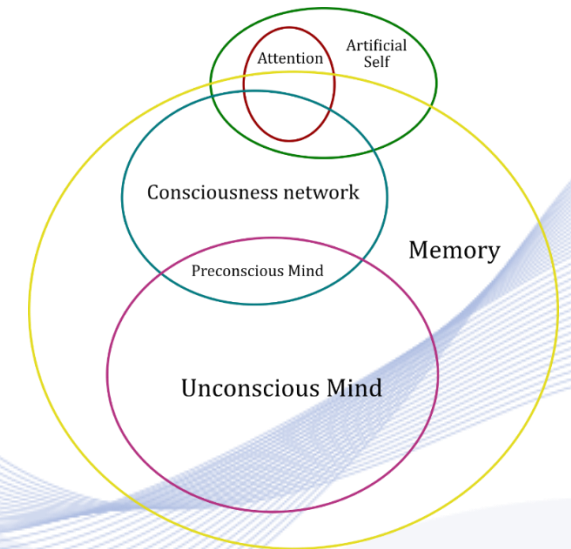# AI and Human Mind

Interoception and Physical Intelligence

- **Interoception** is the perception of stimuli from inside our body.
- It supports **homeostasis** (maintenance of functional body equilibrium).
- **It is essential for human (self)consciousness.**
- Current robots do not have interoception.
- Closest approximation: **Physical Intelligence** uses distributed sensors to allow robots to live in unstructured environments.
  - Multimodal machine perception: tactile, smell, taste sensors.

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AI and Human Mind

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Brain-Inspired Computing

- ***Computational Neuroscience*** creates mathematical models of the brain and nervous systems.

- Despite advances, no breakthroughs compared to AI revolution.

- Modeling memory, consciousness, affect etc.

- Major advances expected by Neuroscience and AI/ML fusion.

Attention

Artificial Self

Consciousness network

Preconscious Mind

Memory

Unconscious Mind

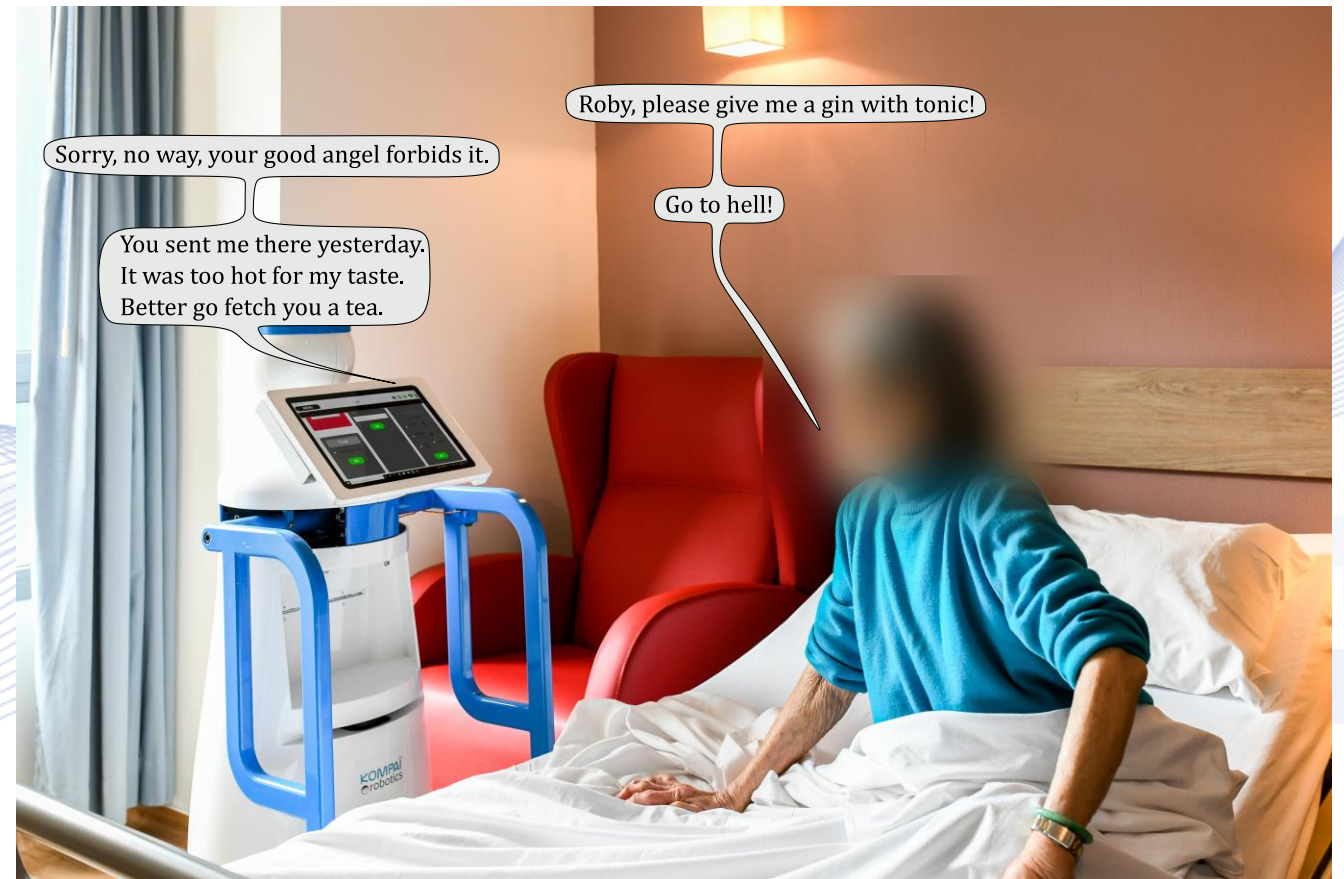**Artificial Intelligence & Information Analysis Lab**

AI and Human Mind

Intelligent Self-aware systems

- Memory   (easy)
- Affect   (easy?)
- Consciousness(doable?)
- Real intelligence (difficult?)

- Swarm/social intelligence (doable).

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AI and Human Mind

- Intelligent systems can be very useful.
- *Should we be technophobic?*

AI Science and Engineering

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AI and Society

AI and IT enable **Social Engineering**:

- Understanding and analyzing social processes

- Influencing individual humans, social strata and structure.

- Marx's famous eleventh thesis on Feuerbach: "***Philosophers have hitherto only interpreted the world in various ways; the point is to change it.***"

AI and Society

AI-powered Social Engineering examples

On-line marketing and recommendation systems

- New gold-rush: personal data

- Massive personal data collection (Surveillance Capitalism).

- *User profiling* and recommendations (turn data into profit):
  - On-line marketing.

- Using *Cognitive Psychology* to hook users in the system.

- Solution: Protect and *valorize* personal data.
  - Blockchain technologies.

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AI and Society

AI-powered Social Engineering examples

Social match-making systems

- Essentially, recommendation and user profiling systems
- Great influence on personal relations and sexual life.
- **Can we allow agents decide our mates?**
  - Matchmaking is an age-old social tradition, e.g., in India.

- Coupling with mobile communications and VR:
  - Cybersex and beyond.

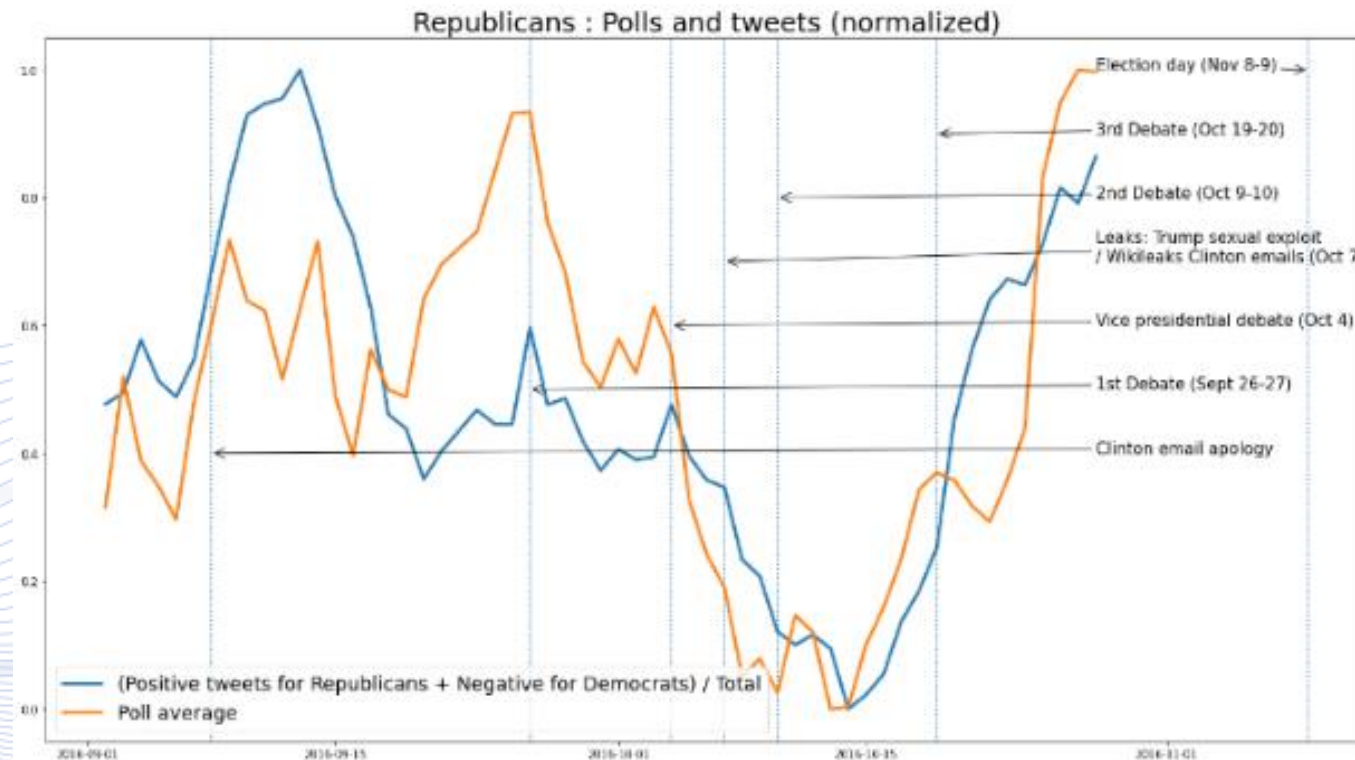# AI and Society

AI-powered Social Engineering paradigm gone bad:

- *Social media changed the way we interact with humans*
- The world became too small: 5 hops to reach anybody.
- Constant 24/7 connectivity and information flooding.
- *Great communication facilitators.*
- Downside:
  - *Generalized OnLine Affect and Cognition* (GOLAC) *disorder*.
    - *Anti-intellectualism and Disinformation.*

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AI and Society

AI and Politics: observing the society.
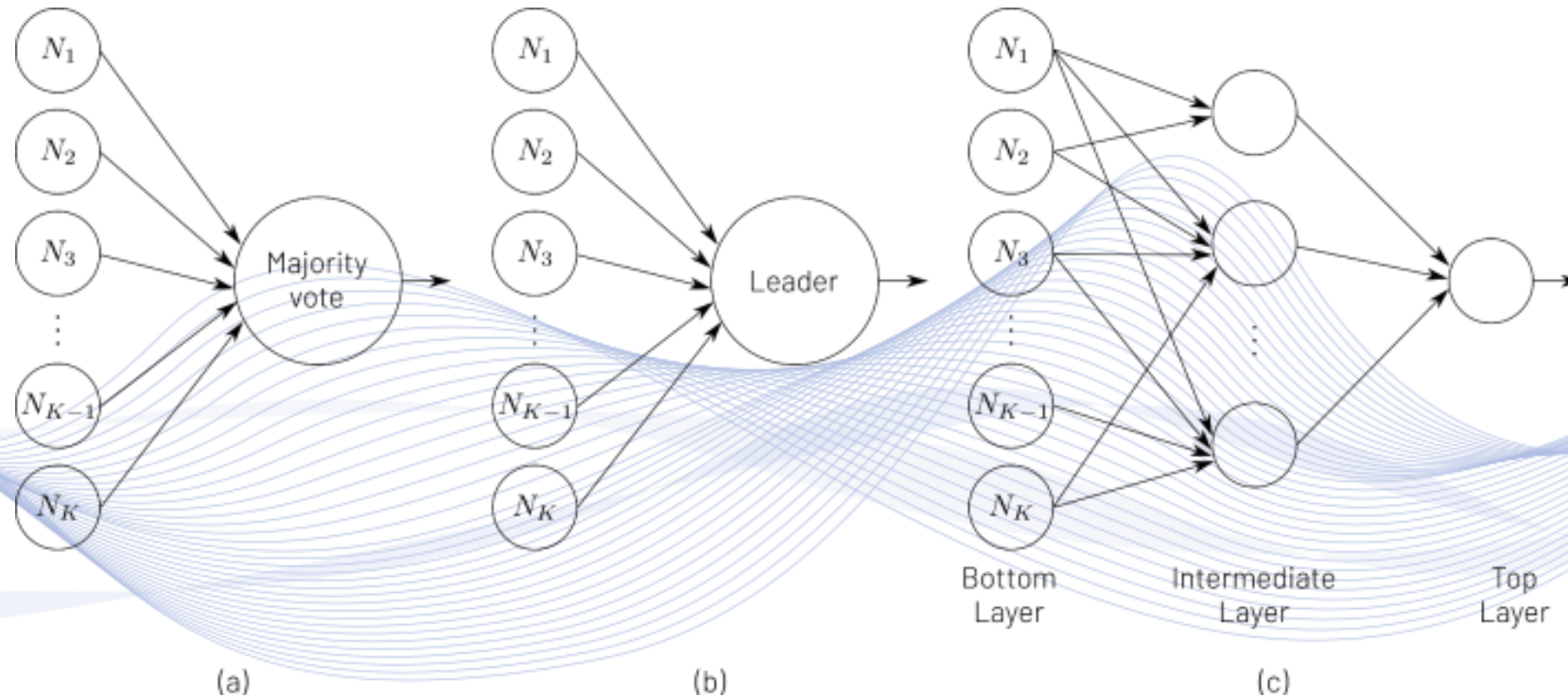
- Are political polls redundant?

Poll and tweet sentiment trends for Republicans in the 2016 presidential election in USA.

AI and Society

AI and Politics: changing the society.

- *Revising Democracy?*

AI Science and Engineering

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AI and the Environment

Law of Complexity

- Is **matter complexity** the basis of life and intelligence?

$$Atoms > nucleotides > DNA - RNA - proteins >$$
$$subcellular\ structures > cells\ (neurons) > organisms$$
$$> multicelular\ organism >\ colonies, swarms, networks.$$

- **Can we envisage other complex matter forms?**

AI and the Environment

- Does living **matter complexity** ever increases?
- Do we see the same in man-made constructions?
  - Smart buildings, complex societal processes, intelligent machines?

The evolution of architecture

shutterstock.com · 280451036
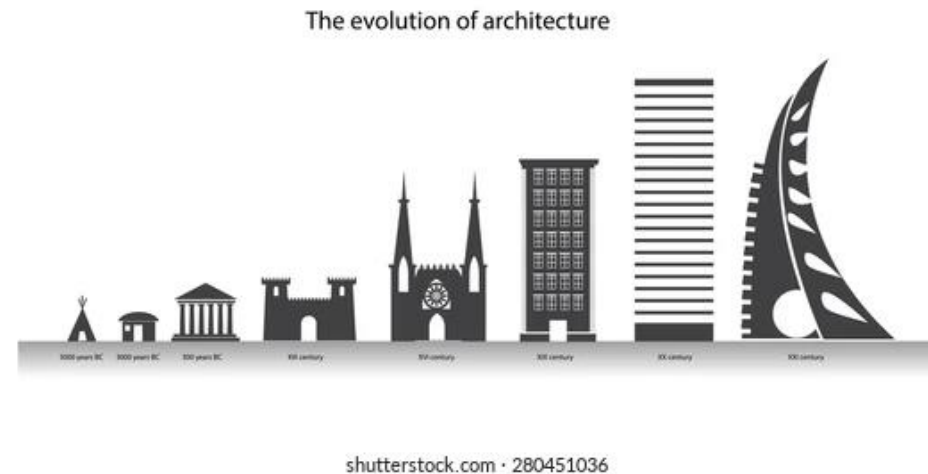
- Contrast to the 2nd thermodynamic law (**thermal death**).
- Do we move from **life-through-evolution** to **life-by- design**?

AI Science and Engineering

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AI Science and Engineering: A new scientific discipline?

- ***Computer Science*** is the study of computation and information.

- ***Computer Engineering*** is a branch of Engineering that integrates several CSE fields that are required to develop computer hardware and software.

- Traditionally, AI and ML were CSE disciplines.

- Do AI and ML have own scientific methodology?

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AI Science and Engineering: A new scientific discipline?

- ***AISE Interdisciplinarity*?**
  - AI and Brain/mind studies
  - AI and social studies/engineering.

- Mature AISE Interdisciplinarity?
  - Not there yet!

- Risks: ***depth vs shallowness***.

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AI Science and Engineering: A new scientific discipline?

CSE spawning new disciplines **_through specialization_**:

- Web science
- Data science
- AI Science and Engineering.

- New scientific methodologies are not **_necessarily_** essential.
- Poor terminology?

- Past experience: **_Physics spawning Engineering disciplines_**
  - Electrical Engineering, Mechanical Engineering.

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AI Science and Engineering: A new scientific discipline?

AISE background

Lots of mathematics:

- **Analysis/calculus, Optimization**
- Geometry
- Linear Algebra
- Graph Theory
- **Probability theory and statistics**
- Mathematical Logic.

AI Science and Engineering:
A new scientific discipline?

AISE background

Classical studies at University and high school level

- Philosophy, ethics, logic

- Linguistic competences.

- Physics?, Biology?

- *Do we prescribe universal AI scientists?*

- What about commoners?

AI Science and Engineering: A new scientific discipline?

Changes will be drastic and will come very soon.

Schools of 'Information Science and Engineering' with departments of:

- Computer Science/Informatics,
- Mathematics
- Computer Engineering
- Artificial Intelligence Science and Engineering
- Internet/Web Science.

AI Science and Engineering

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University Education on AI

- Very many AI MSc and PhD study programs
- AI Schools & Departments (12)
- AI Undergraduate Studies (59)

- *Developments are mostly demand-driven.*
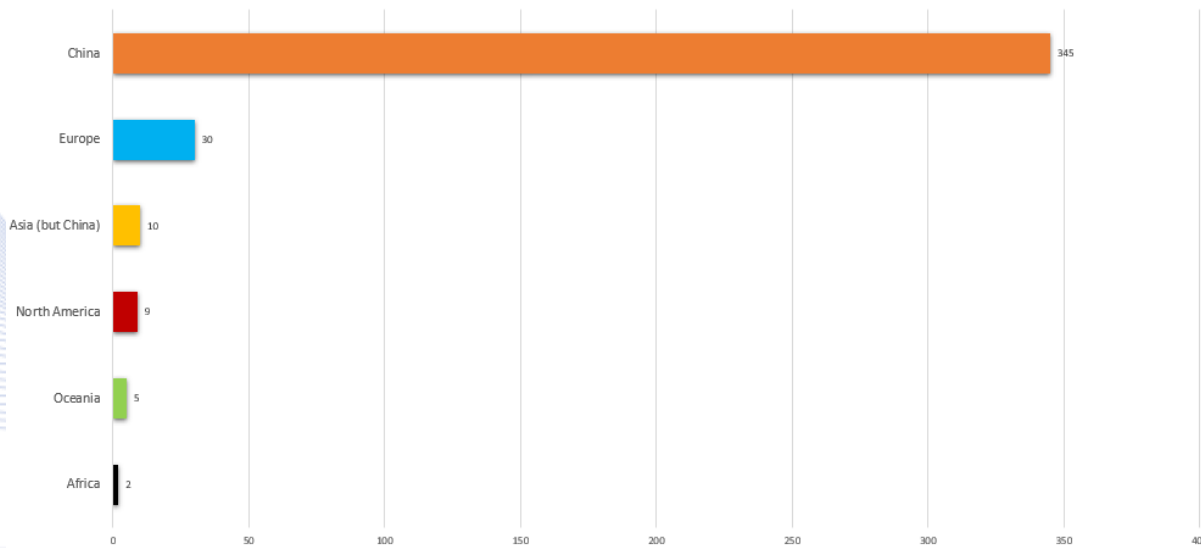- Smaller players can be more adventurous in AI studies.

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University Education on AI
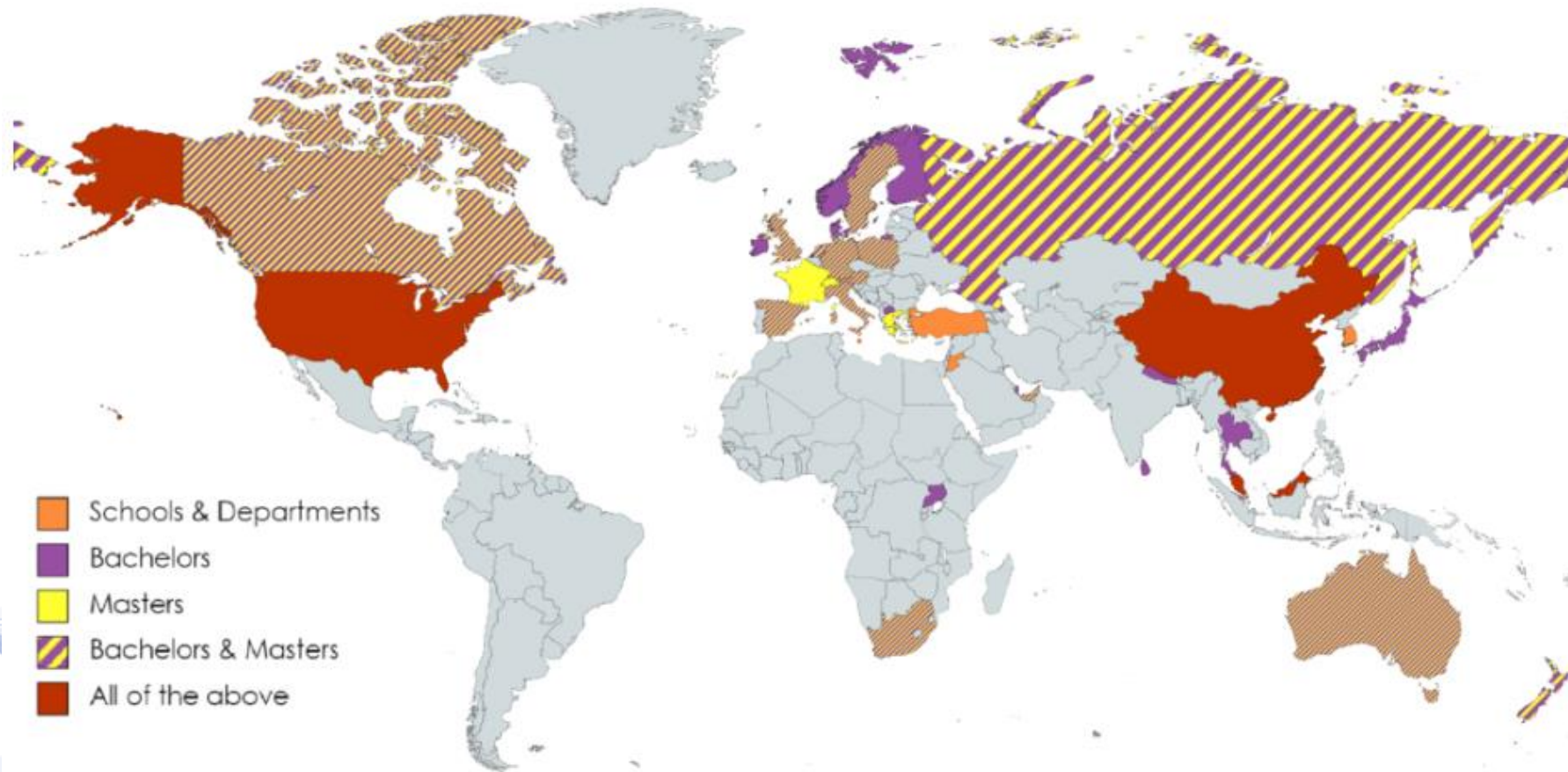
Countries that offer AI studies.
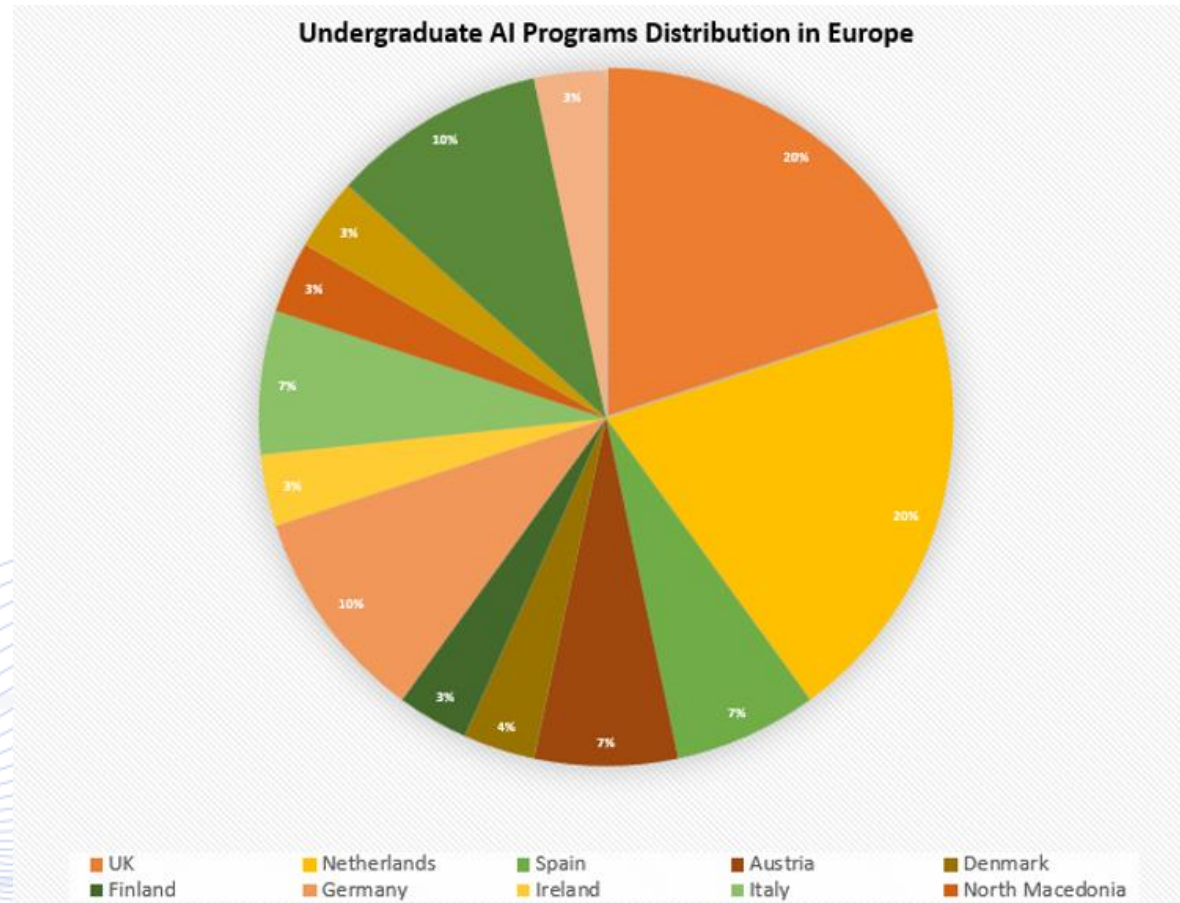
University Education on AI

Number of undergraduate AI programs worldwide.
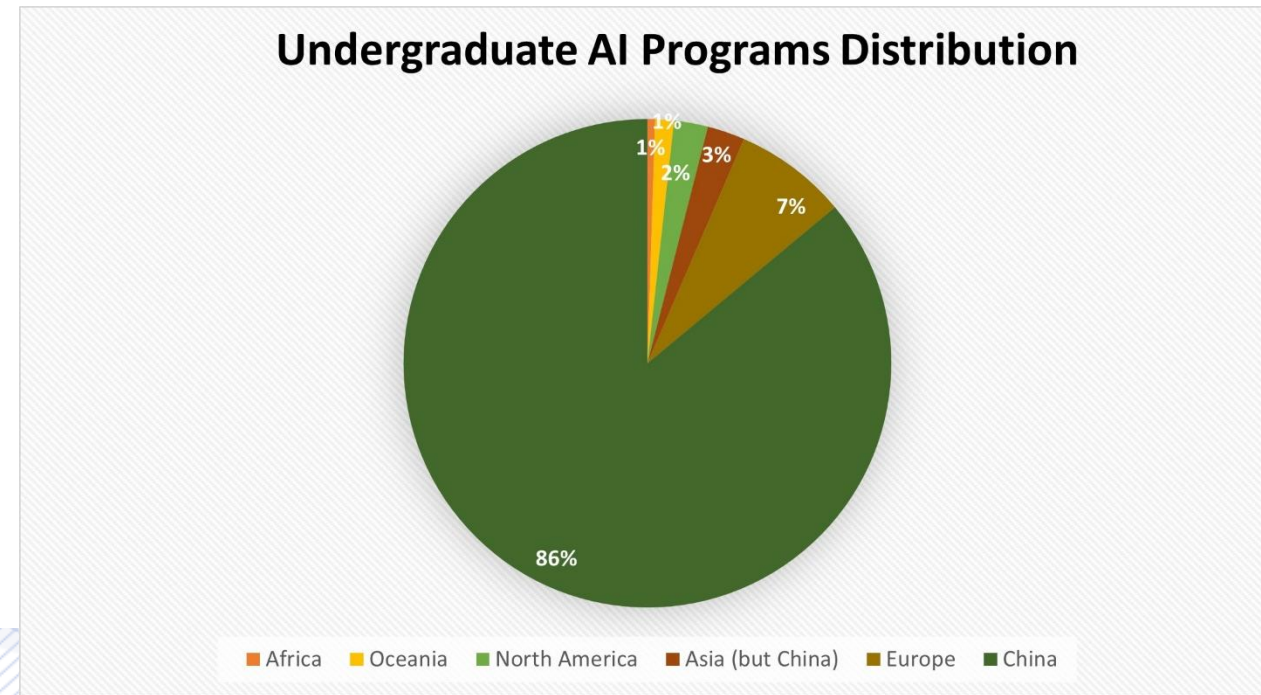
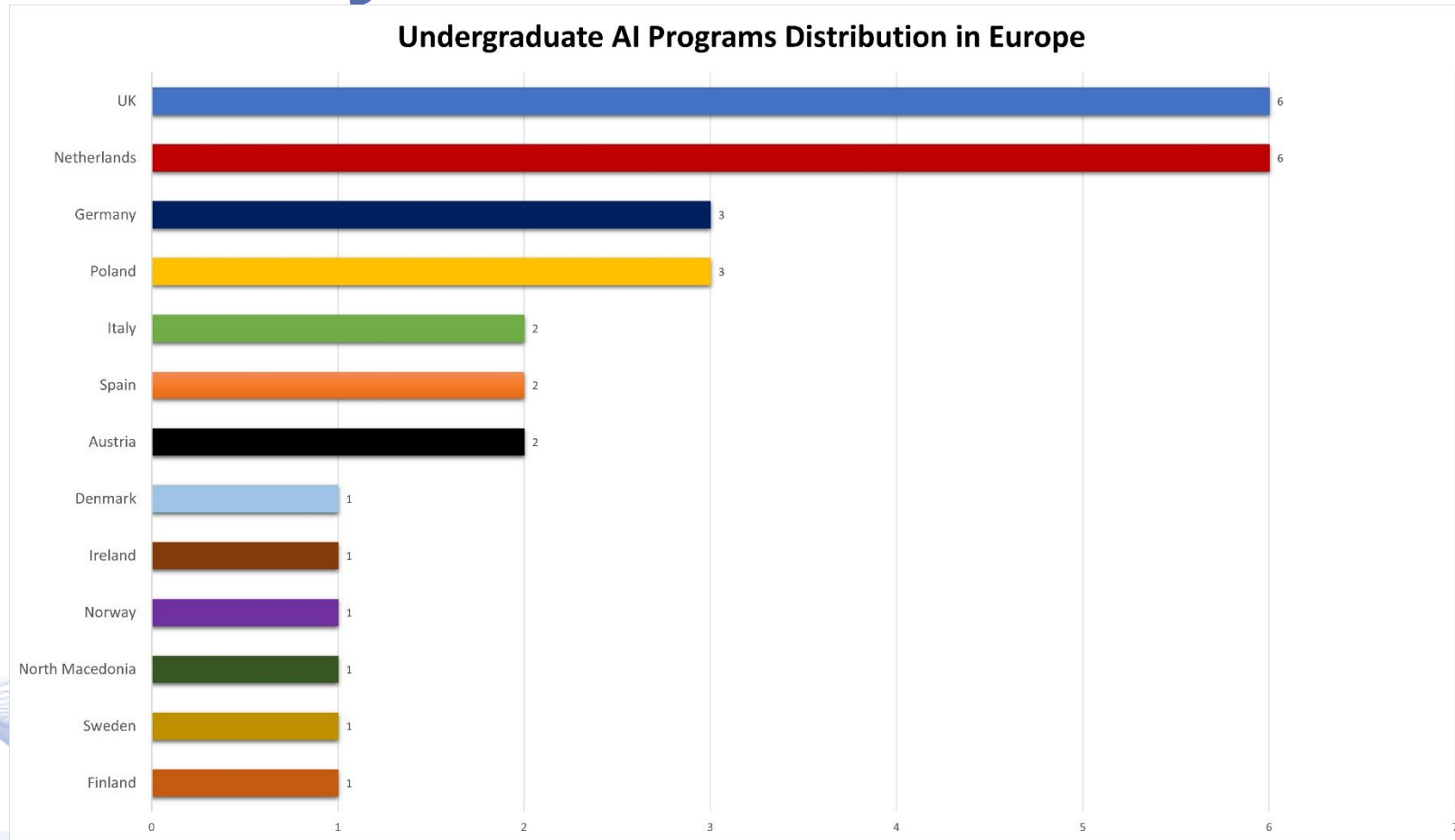Global distribution of undergraduate AI studies.

University Education on AI

Distribution of undergraduate AI programs in Europe.

University Education on AI

Geographical distribution of AI undergraduate programs in Europe.

University Education on AI

AI-centered Schools & Departments (examples):

- Machine Learning Department, Carnegie Mellon University, USA.
    - https://www.ml.cmu.edu/

- Institute for AI, Tsinghua University, China.
    - https://ml.cs.tsinghua.edu.cn/thuai/#/

- School of Intelligence Science and Technology, Peking University, China.
    - https://www.cis.pku.edu.cn/English/Home.htm

- Department of AI, College of Informatics, Korea University, S. Korea
    - http://xai.korea.ac.kr/eng/company/greeting?language=eng

University Education on AI

Undergraduate AI Studies (examples):

- BSc in Data Science and AI, Nanyang Technological University, Singapore.
  - https://www.ntu.edu.sg/education/undergraduate-programme/bachelor-of-science-in-data-science-artificial-intelligence

- BSc in AI , University of Technology Sydney, Australia.
  - https://www.uts.edu.au/study/find-a-course/bachelor-artificial-intelligence

- BSc in AI and Decision Making, Massachusetts Institute of Technology , USA.
  - http://catalog.mit.edu/degree-charts/artifical-intelligence-decision-making-course-6-4/

- BSc in AI, The University of Edinburgh , UK.
  - https://www.ed.ac.uk/studying/undergraduate/degrees/index.php?action=view&code=G700

- BSc in AI, Vrije Universiteit Amsterdam, Netherlands.
  - https://vu.nl/en/education/bachelor/artificial-intelligence

- BSc in AI, Polytechnic University of Catalonia, Spain.
  - https://www.upc.edu/en/bachelors/artificial-intelligence-barcelona-fib

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University Education on AI

Curriculum of BSc on AI, CMU, USA (example)

https://www.cs.cmu.edu/bs-in-artificial-intelligence/

- Principles of Imperative Computation
- Integration and Approximation
- Mathematical Foundations for Computer Science
- Great Theoretical Ideas in Computer Science
- Matrices and Linear Transformations
- Calculus in Three Dimensions
- Concepts in AI
- AI: Representation and Problem Solving
- Parallel and Sequential Data Structures and Algorithms
- Probability Theory for Computer Science
- Introduction to Machine Learning

- Introduction to Computer Systems
- Computer Vision
- Natural Language Processing
- Modern Regression
- Neural Computation
- Autonomous Agents
- Cognitive Robotics: The Future of Robot Toys
- Planning Techniques for Robotics
- Mobile Robot Algorithms Laboratory
- Robot Kinematics and Dynamics
- Deep Reinforcement Learning & Control

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University Education on AI

Curriculum of BSc on AI, CMU, USA

- Mobile Robot Algorithms Laboratory
- Robot Kinematics and Dynamics
- Deep Reinforcement Learning & Control
- Deep Learning Systems: Algorithms and Implementation
- Intermediate Deep Learning
- Machine Learning for Structured Data
- Machine Learning for Text and Graph-based Mining
- Introduction to Deep Learning
- Advanced Methods for Data Analysis

- Search Engines
- Speech Processing
- Computational Perception
- Computational Photography
- Design of Artificial Intelligence Products
- Human AI Interaction
- Designing Human Centered Software
- Human Robot Interaction

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University Education on AI

Curriculum of MSc in Machine Learning, UCL, UK (example)

https://www.ucl.ac.uk/prospective-students/graduate/taught-degrees/machine-learning-msc

- Applied Machine Learning
- Advanced Topics in Machine Learning
- Approximate Inference and Learning in Probabilistic Models
- Probabilistic and Unsupervised Learning
- Statistical Natural Language Processing
- Reinforcement Learning
- Machine Vision

- Supervised Learning
- MSc Machine Learning Project
- Machine Learning Seminar
- Bayesian Deep Learning
- Statistical Learning Theory
- Applied Deep Learning
- Graphical Models

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Bibliography

[1] I. Pitas, "Artificial Intelligence Science and Society Part A: Introduction to AI Science and Information Technology", Amazon/Kindle Direct Publishing, 2022,

https://www.amazon.com/dp/9609156460?ref_=pe_3052080_397514860

[2] I. Pitas, "Artificial Intelligence Science and Society Part B: AI Science, Mind and Humans", Amazon/Kindle Direct Publishing, 2022,
https://www.amazon.com/dp/9609156479?ref_=pe_3052080_397514860

[3] I. Pitas, "Artificial Intelligence Science and Society Part C: AI Science and Society", Amazon/Kindle Direct Publishing, 2022,
https://www.amazon.com/dp/9609156487?ref_=pe_3052080_397514860

[4] I. Pitas, "Artificial Intelligence Science and Society Part D: AI Science and the Environment", Amazon/Kindle Direct Publishing, 2022,

https://www.amazon.com/dp/9609156495?ref_=pe_3052080_397514860

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Q & A

Thank you very much for your attention!

**More material in
http://icarus.csd.auth.gr/cvml-web-lecture-series/**

**Contact: Prof. I. Pitas
pitas@csd.auth.gr**

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