What is AI?
All you need to understand AI
Fundamentals

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Version 1.1

Artificial Intelligence & Information Analysis Lab

Introduction to AI Science

- Symbolic AI
- Data
- Machine Learning
  - Clustering
  - Classification
  - Neural Networks
- Computer Vision
- Natural Language Processing
- Generative AI
- Knowledge
- AI and Society
- AI, Life and the Environment

Why this lecture?

Learn Artificial Intelligence (AI) basics in 1 hour.

- No special knowledge neither mathematics are needed.

Questions that YOU should answer:

- How can I use AI to improve my business?
- Will AI steal my job?
- Can machines become more intelligent than humans?
- Should we be afraid of machines?
- ***Is AI a blessing or a curse?***

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:
  - Classical (Symbolic) ***Artificial Intelligence*** (AI),
  - ***Machine Learning*** (ML).

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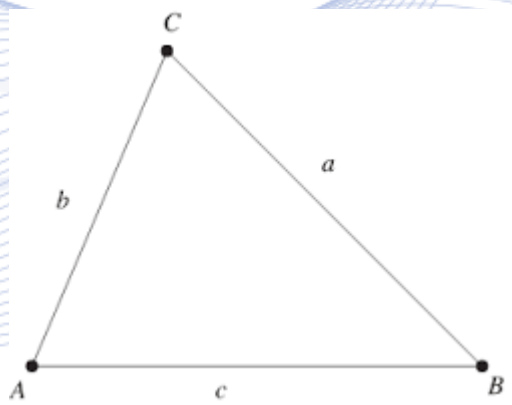
Symbolic AI

Concepts and ideas (ιδέες).

- Concepts are specific mental constructs residing in our mind (brain?) that refine and abstract ideas.
- Examples: ‘Triangle’, ‘Freedom’, ‘Love’.
- ***Concept definition***: Triangle consists of three points connected by 3 straight line segments.

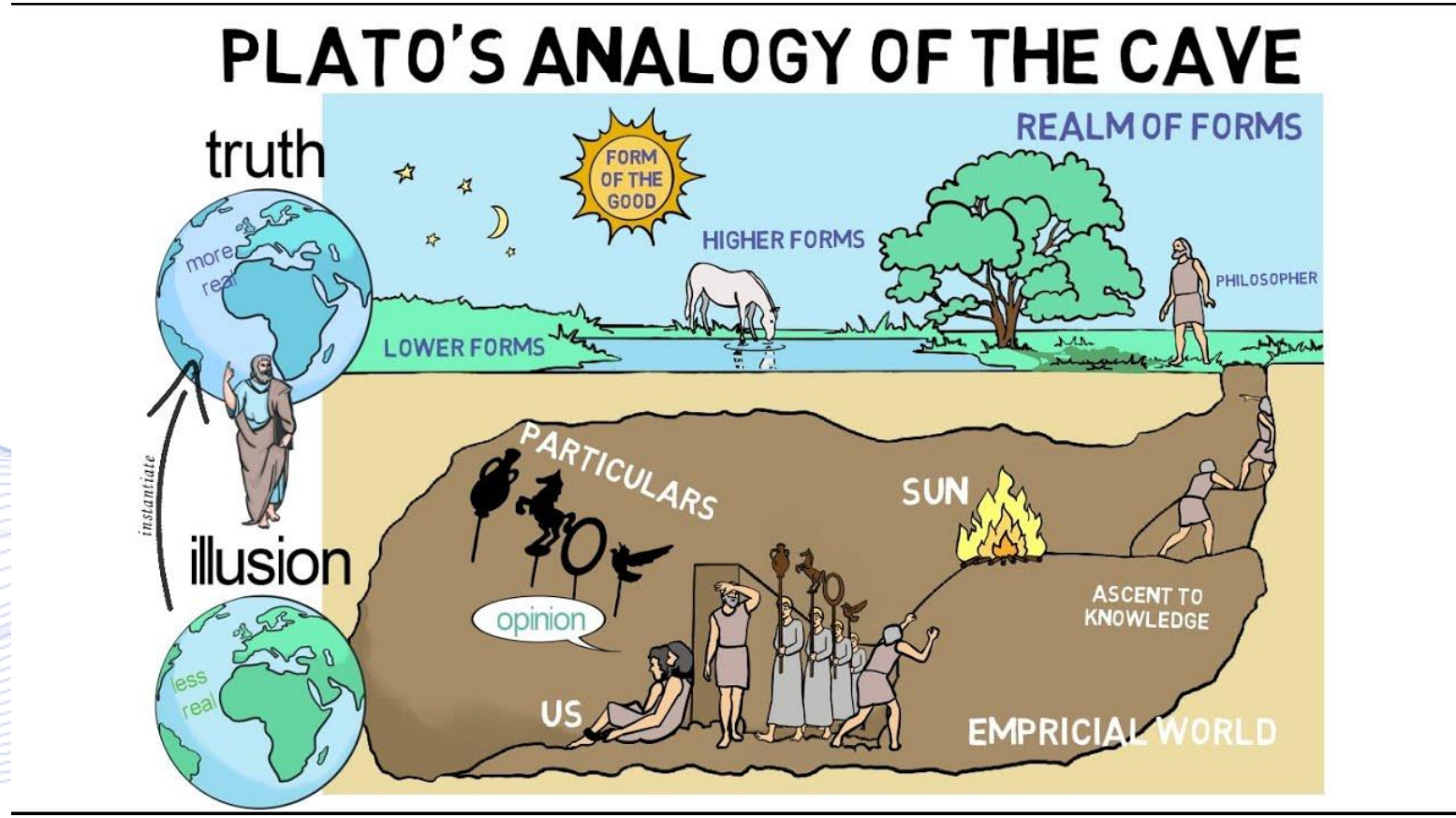


Triangle.

Symbolic AI

Ideas in Philosophy.

- Plato's cave.
- ***Idealism***: reality is a reflection of ideas.
- ***Materialism***: ideas are shadows of matter on itself (brain).



Symbolic AI

- ***Symbolic AI*** operates on concepts and their relations though ***logic*** and ***search***.
- It mimics and simulates high-level human intelligence and ***reasoning***.

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

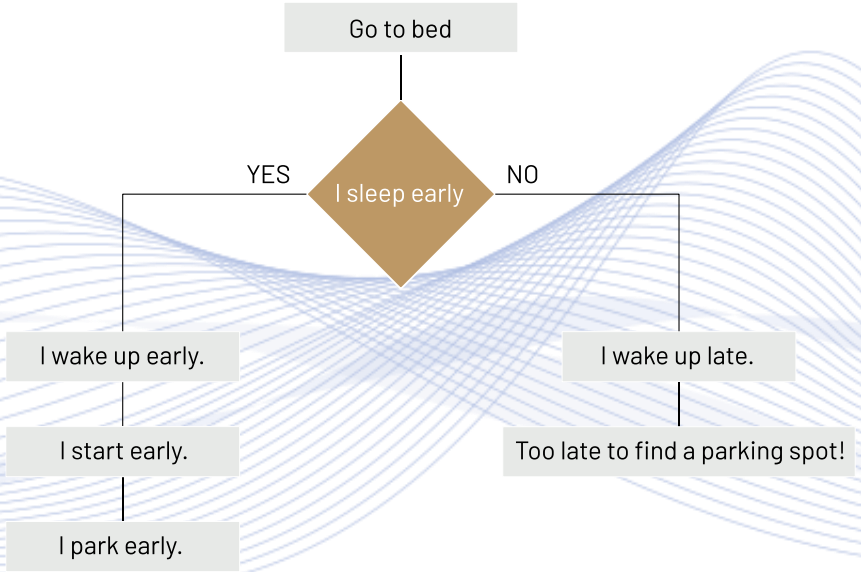
- ***Symbolic AI*** employs Mathematical Logic.

Symbolic AI

- Examples:

  ‘If somebody has high fever and coughs, she/he has flu.’

  ‘If I turn left, I may enter the opposite lane.’



- ***Symbolic AI failed to deliver!***

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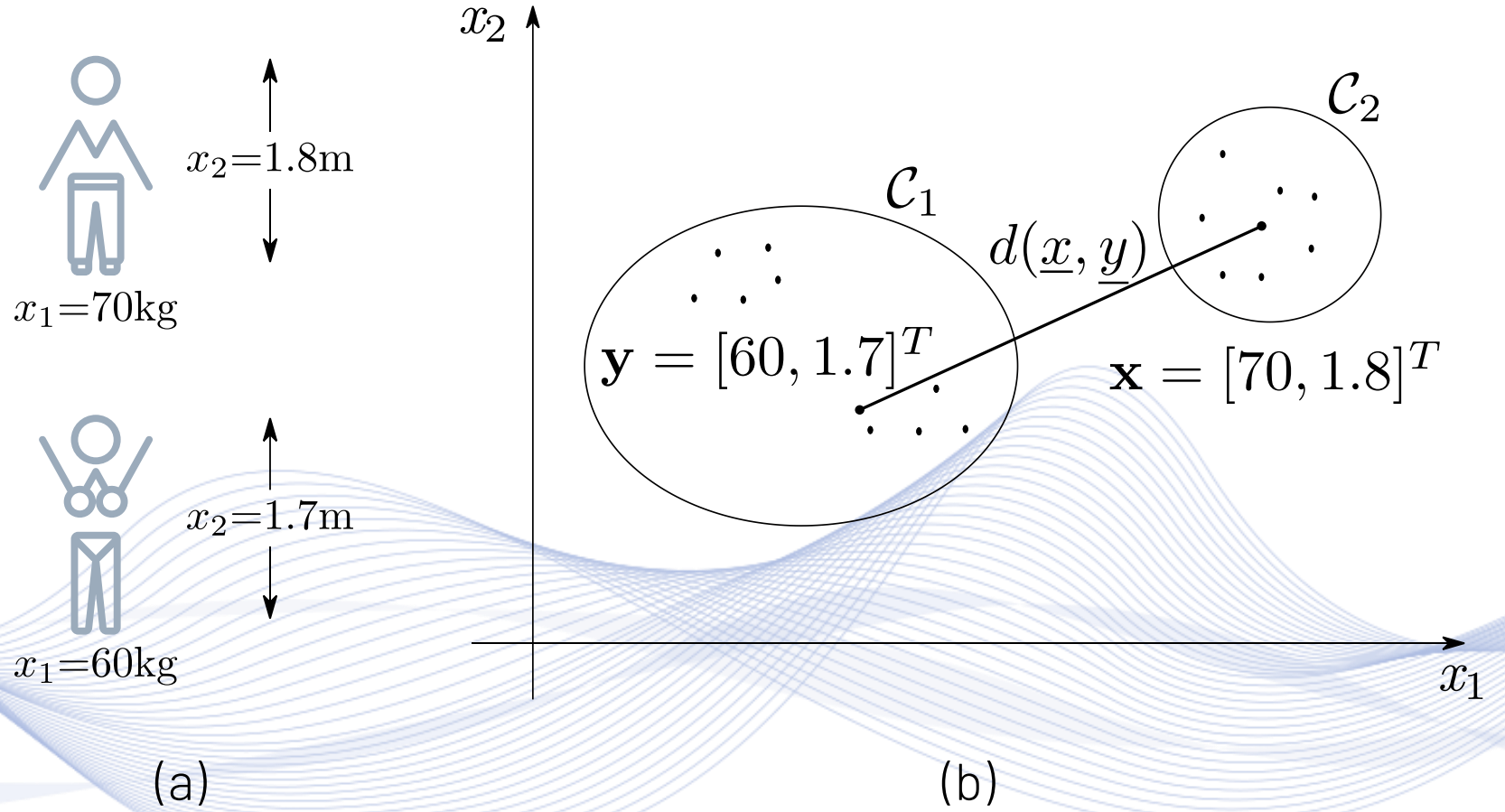
Data

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

- ***Data are primarily numbers*** representing object characteristics (***features***).
- ***Measured in bits.***

- ***Data can be organized in vectors.***

Data



Measuring humans and producing their weight and height vectors.

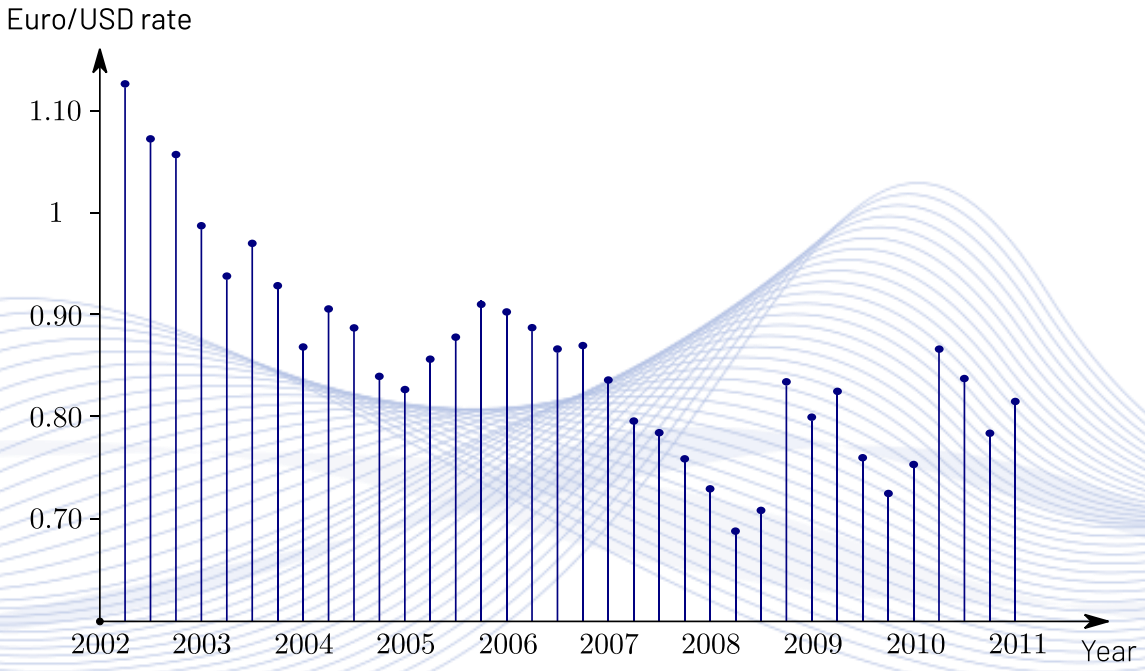
Data

Calculating ***object features***: person weight and height.

Data

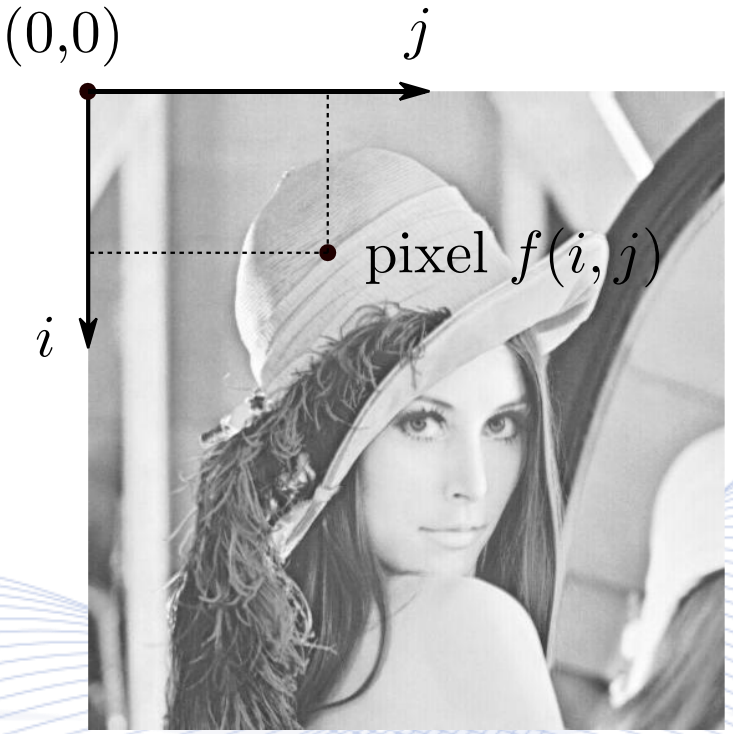
Signals $y = f(t)$: voice, financial ***time series*** etc.

- Also called ***functions.***



Time series of Euro/USD conversion rate.

Data



Digital Images: Matrix of image dots (pixels).

Each image can have up to 48 Mpixels or more!

Data

Once we extract the object/image/signal features (data):

- Data analysis can be performed.
- Mathematics and Computer Science are needed.
- Machine Learning is applied Statistics, Calculus and Programming.

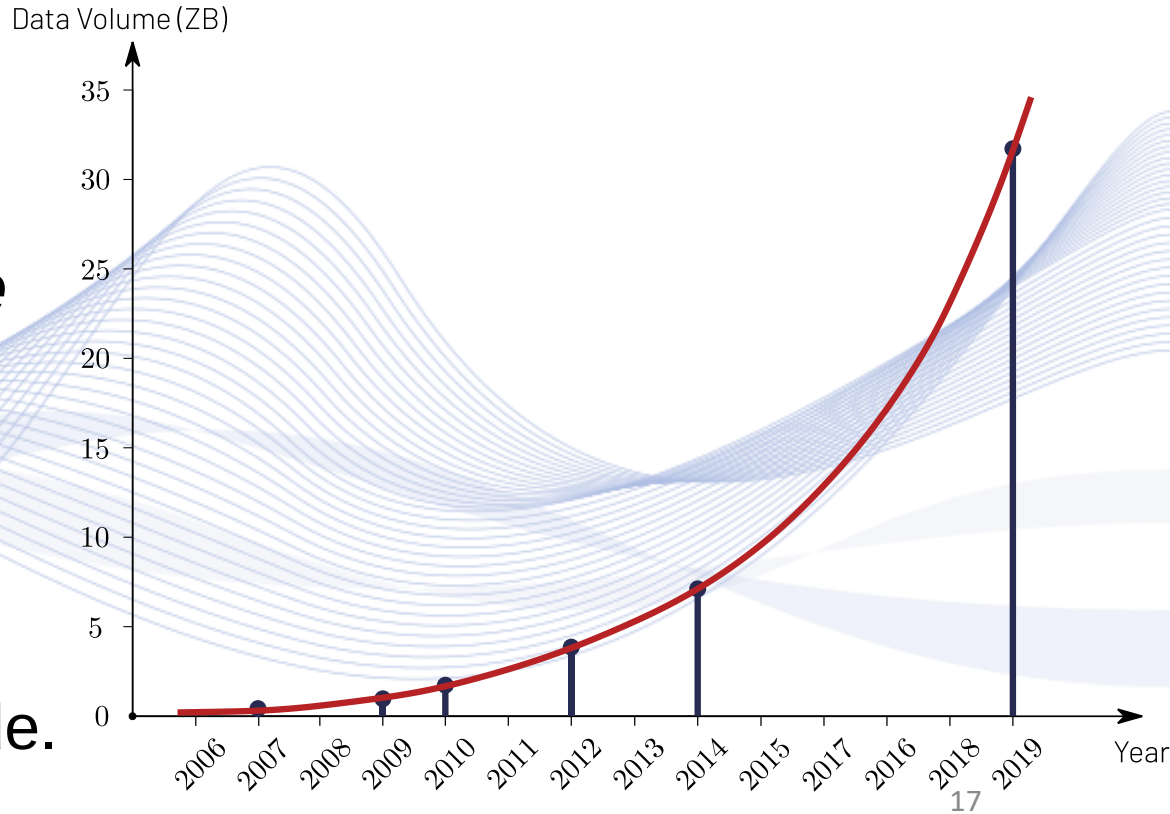
- We can concentrate on data and forget the real world.
- ***All sciences are increasingly mathematized.***
- High impact on Liberal sciences and Medicine.

Data

Exponential data increase:

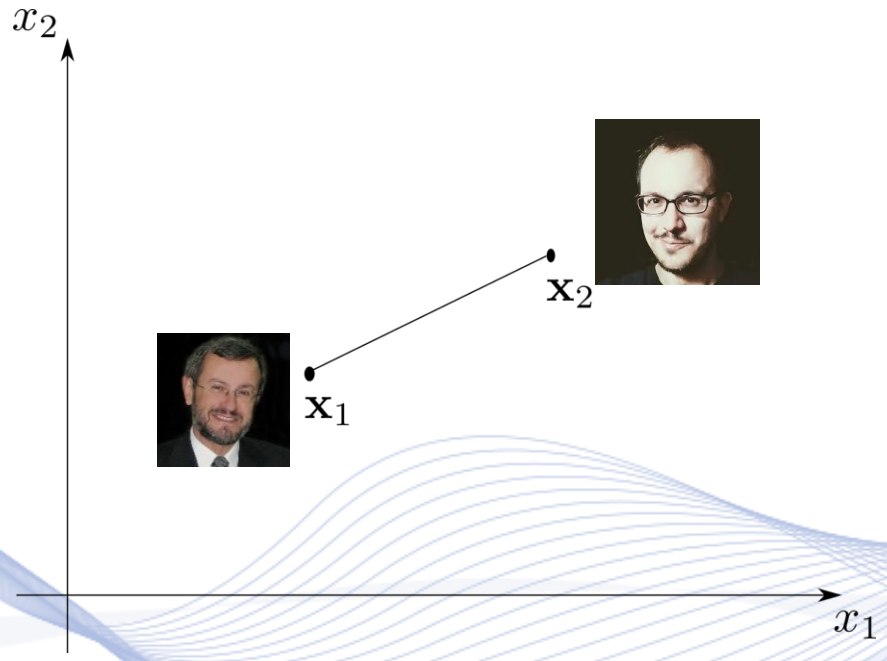
- Proliferation of sensors
- Detailed recording of nature and humans
- Sensing automation.

Big data analytics is only possible through Machine Learning.

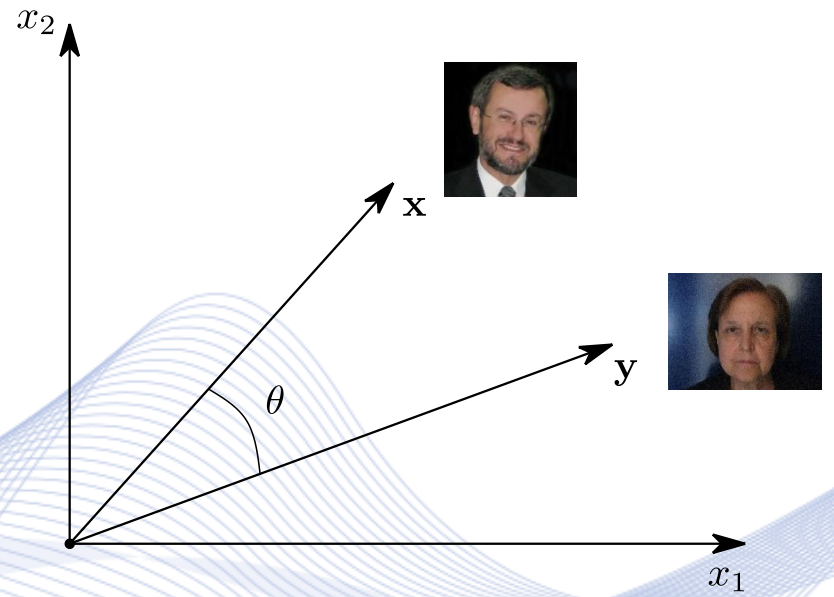


Data volume increase in past decade.

Data



Distance between two person images.



Similarity between two person characters.

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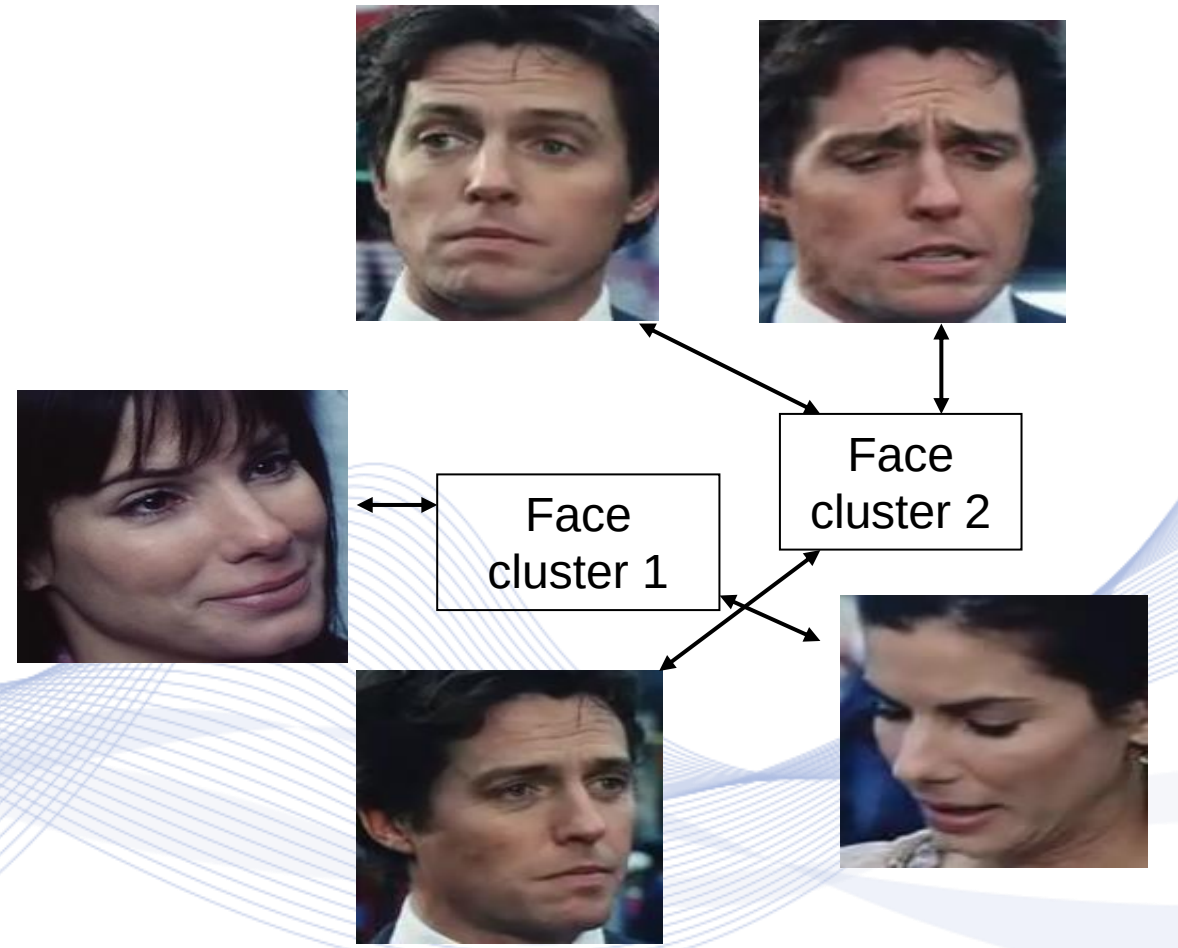
Data clustering

Face clustering:

- ***Input***: many facial ROIs
- ***Output***: facial image clusters.

- ***Unsupervised learning.***

- Applications:
  - Biometrics
  - Surveillance applications
  - Video analytics.

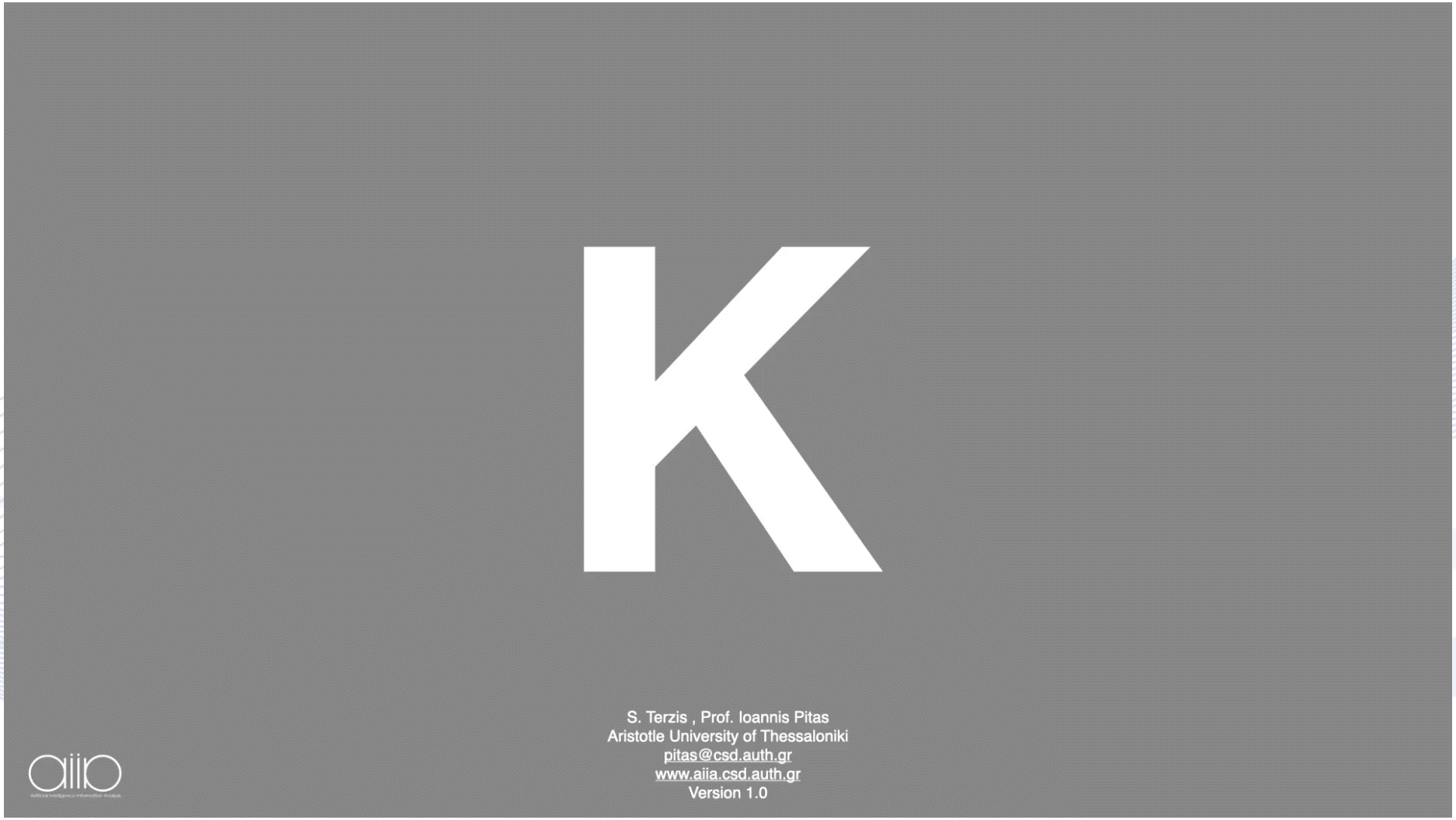


Data clustering

Set partitioning. Data clusters should: a) be homogeneous; b) distant from each other.

Data clustering

Clustering using ***K-means algorithm***.



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Data clustering

Data clustering offers:

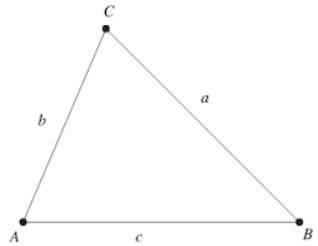
- Description of data geometry.
- Data visualization.

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

Abstraction

- ***Concept instances***

Instances of a triangle.



Concept ‘triangle’.

- ***Abstraction and generalization***:
  - Simplification and data compression.

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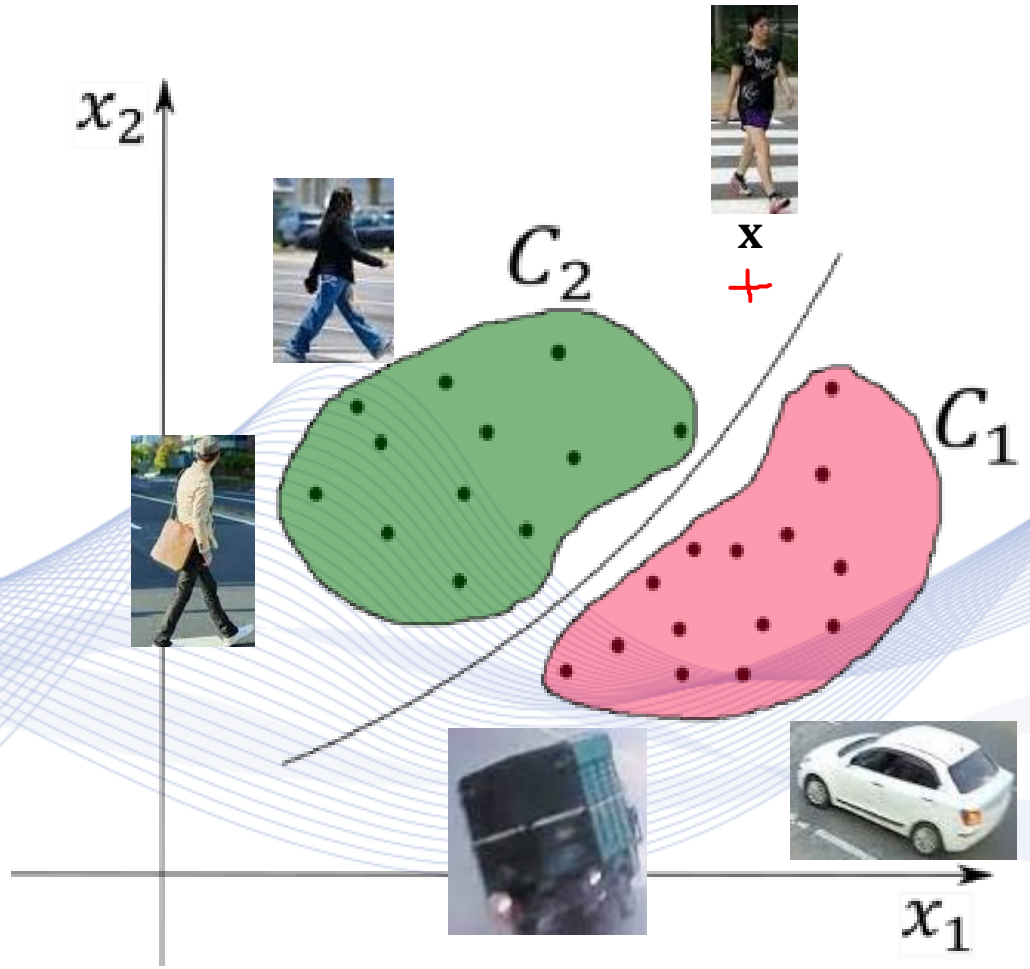
Classification

Supervised Machine Learning

Decision-making theory:

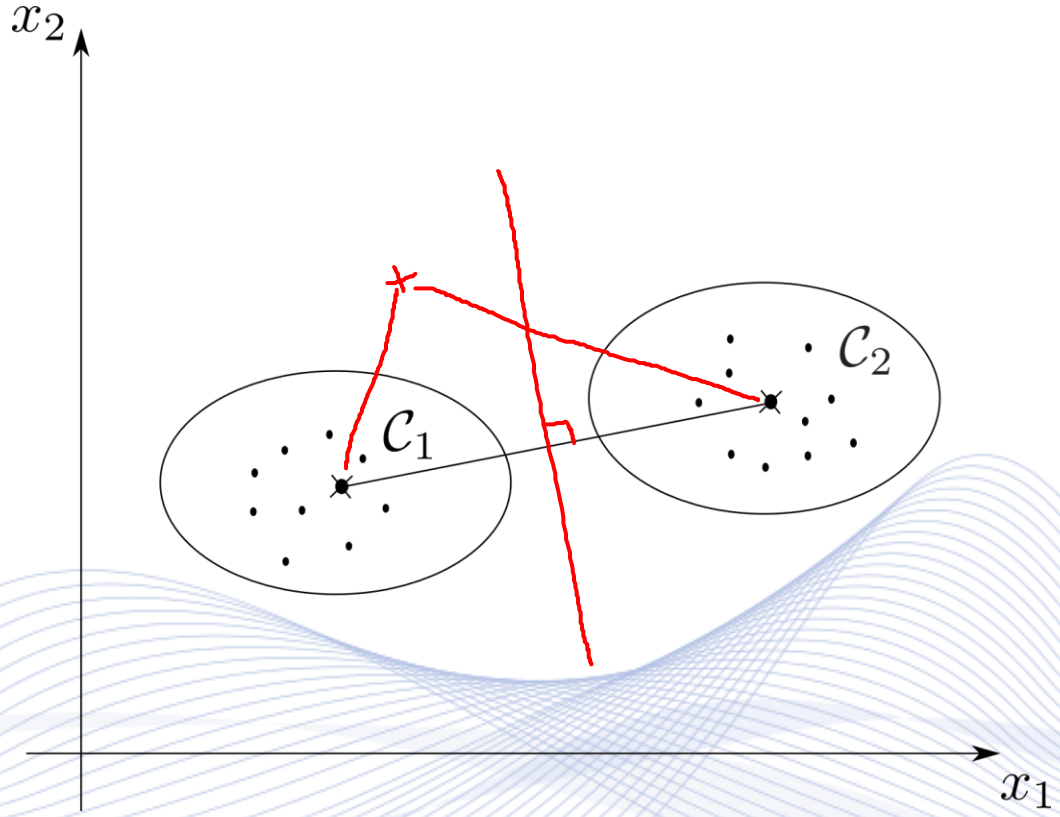
- Does object $\mathbf{x}$ belong to class $\mathcal{C}_1$ or class $\mathcal{C}_2$?
- E.g., ‘car’ or ‘pedestrian’?



Examples:

- Autonomous systems.
- Medical diagnosis.

Classification



Distance-based classification.

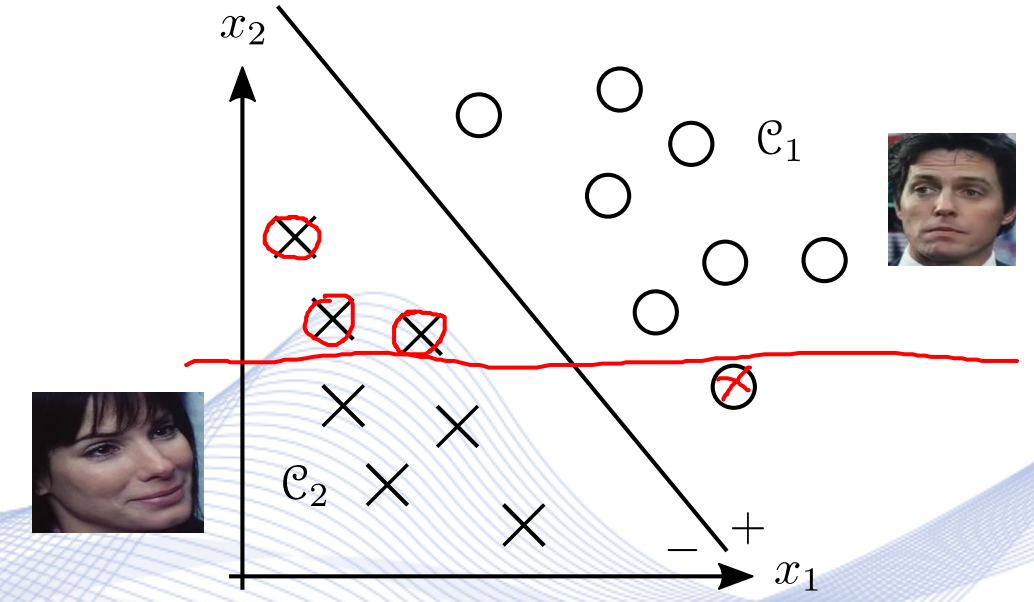
Classification

2D perceptron: Recognize women vs man using:

- x_1, x_2: weight, height.

Decision line: $w_1 x_1 + w_2 x_2 + b > 0$.

Four errors!



Optimization problem.

- Try to minimize errors!

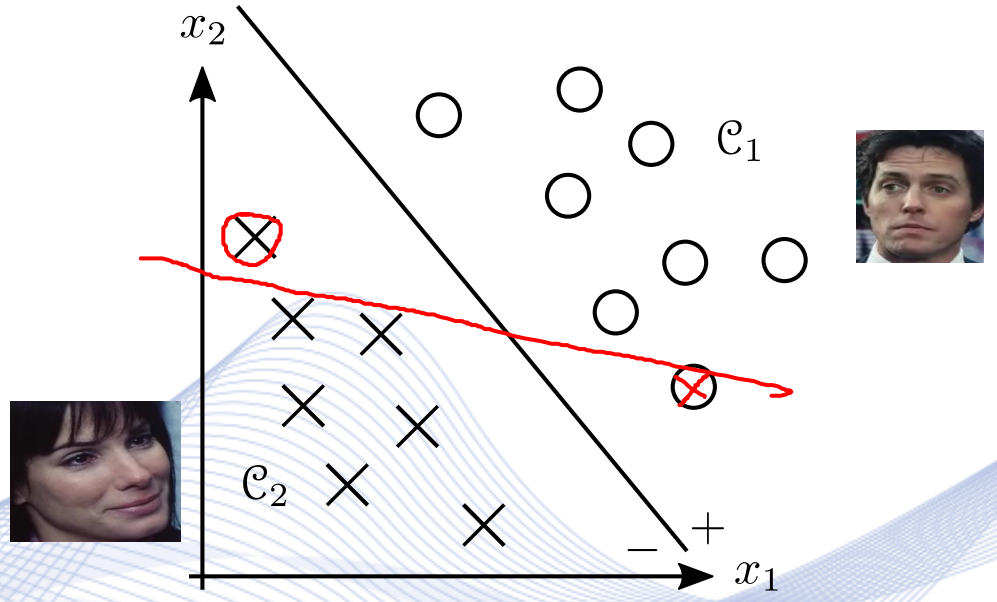
Classification

2D perceptron: Recognize women vs man using:

- x_1, x_2: weight, height.

Decision line: $w_1 x_1 + w_2 x_2 + b > 0$.

Two errors!



Optimization problem.

- Try to minimize errors!

Classification

2D perceptron: Recognize women vs man using:

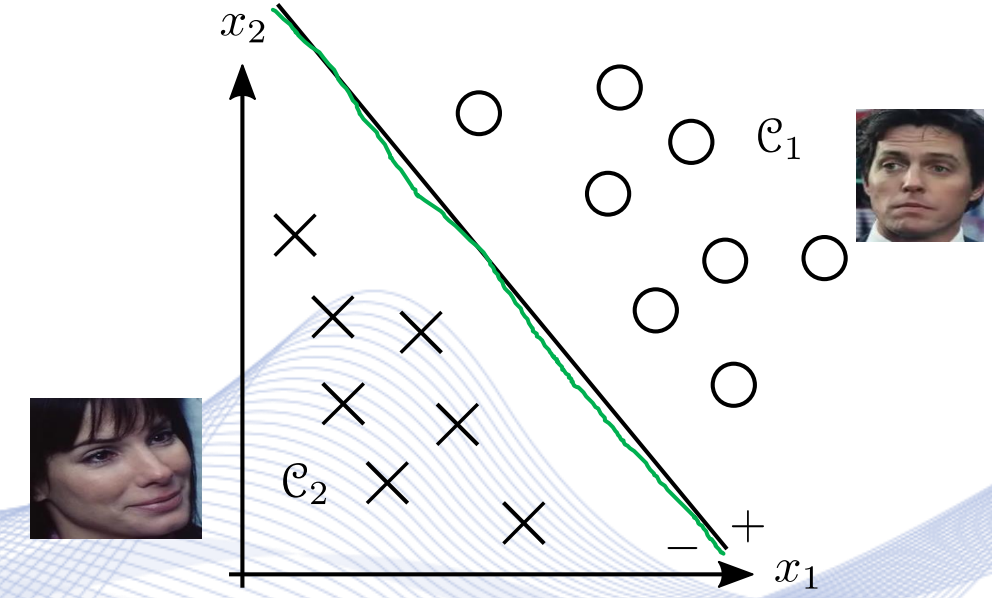
- x_1, x_2: weight, height.

Decision line:

$x_1 + 29x_2 - 50 > 0.$

Zero Errors!

Mission accomplished!



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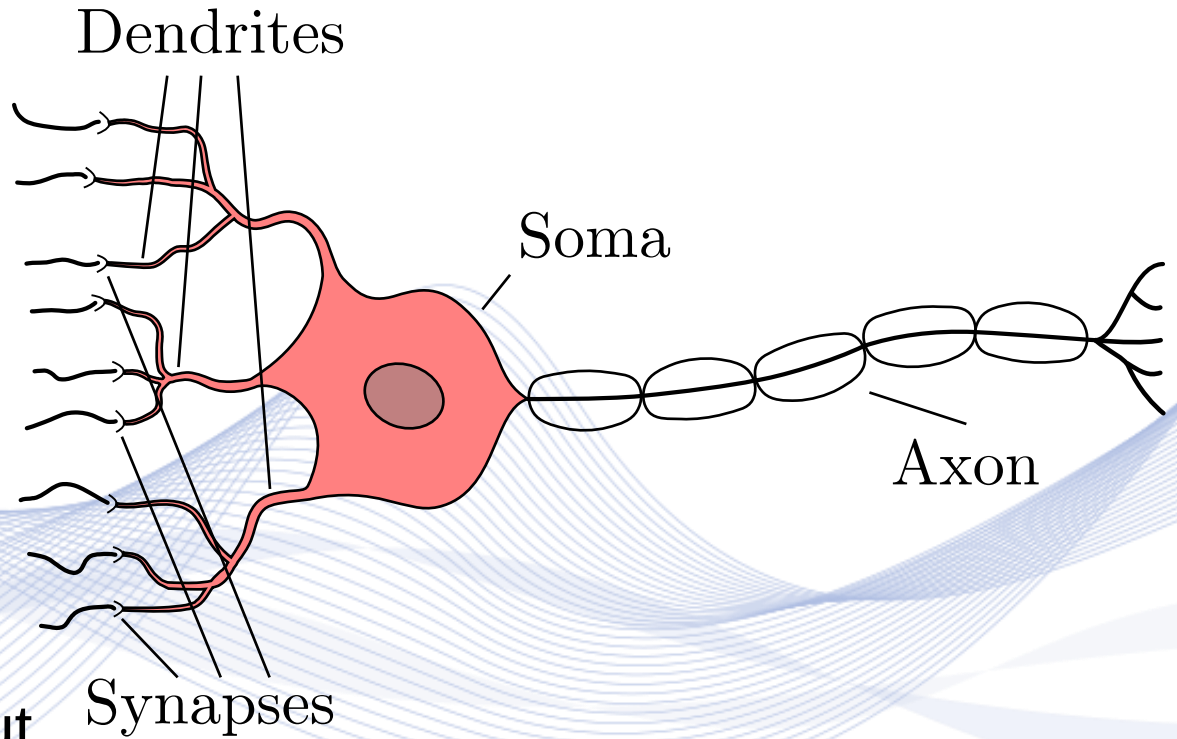
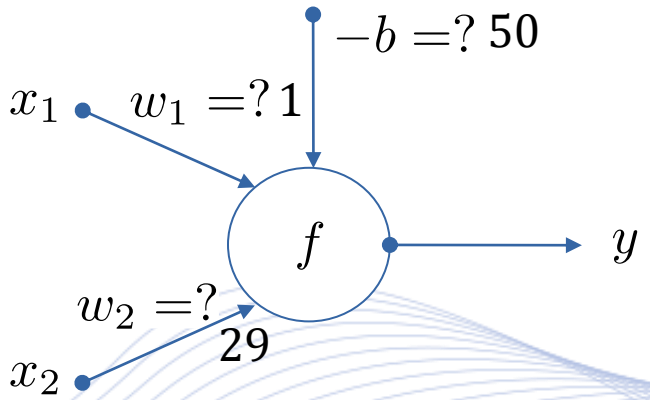
Neural Networks

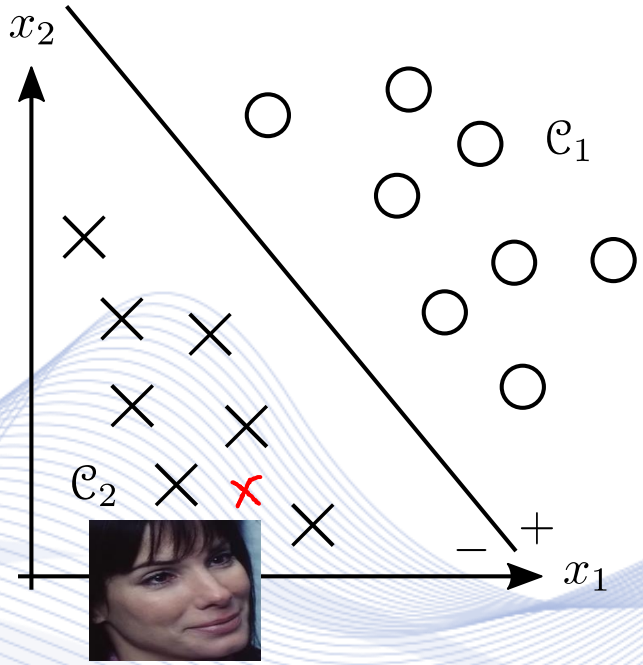
- Basic computational unit of the brain.
- Main parts:
  - ***Dendrites***
    - They act as inputs.
  - ***Soma***
    - Main body of neuron.
  - ***Axon***
    - It acts as neuron output.



Neural Networks

Artificial Neural Networks





2D perceptron for woman/man reognition

- x_1, x_2: weight, height.

Separating line: $x_1 + 29x_2 - 50 > 0$.

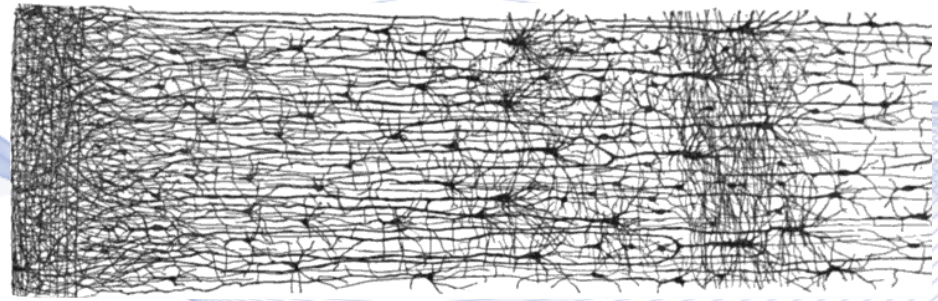
Neural Networks

Perceptron training. Minimization of classification error.

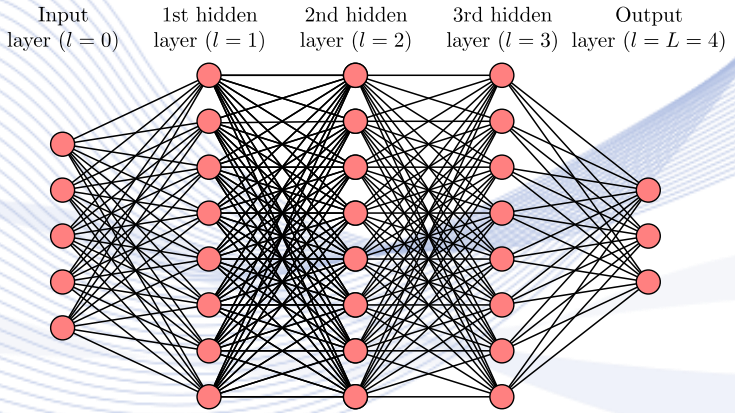
Neural Networks

Artificial and Biological Neural Networks

- Neurons can form ***Artificial Neural Networks*** (***ANNs***).
- ***Deep NNs*** (DNNs) have many neuron layers.
- Is ***network complexity*** the basis of both the biological and artificial intelligence?



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



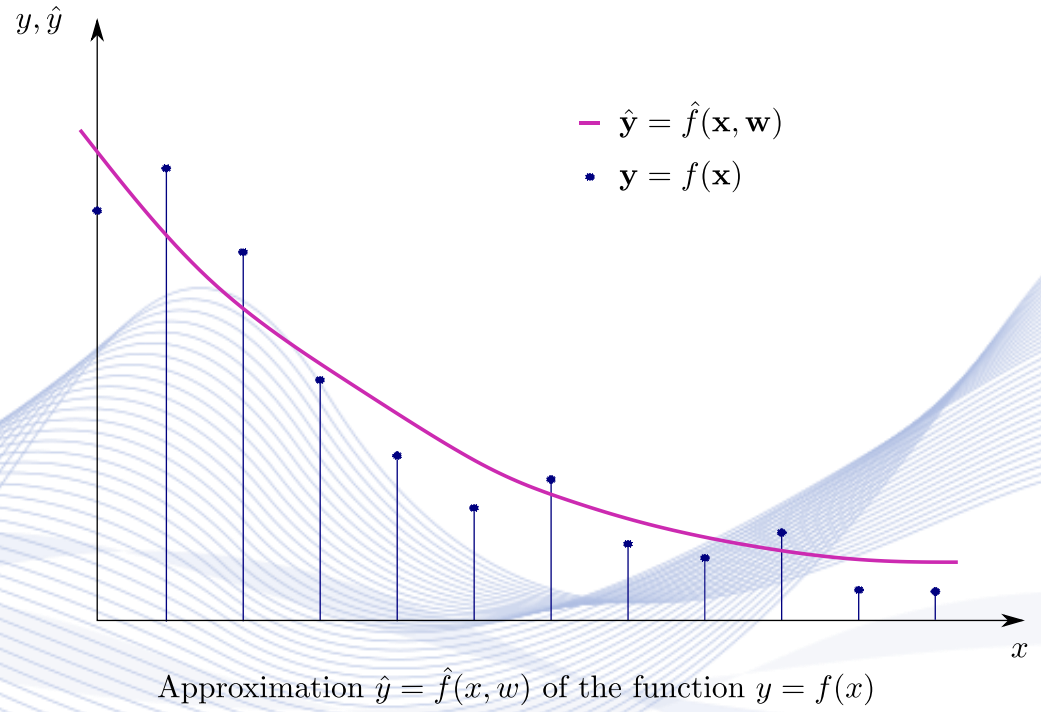
Deep neural Network.

Neural Networks

Neural regression provides an approximation of a function

$$y = f(t).$$

- t***: input*** (time).
- $\hat{y}$: ***output*** (approximated function values).
- Very useful in ***time series prediction.***
- ***Applications***: financial prediction, weather forecasting.



Approximation $\hat{y} = \hat{f}(x, w)$ of the function $y = f(x)$

Neural Networks

Advantages

- Very good decision accuracy
  - (frequently above human performance).
- Wide range of applications.
- New generative (creative) arts.

Pitfalls

- Too many data/energy needed for their training.
- Poor explainability.
- Possible decision bias.
- Creation of fake data/news.

Neural Networks

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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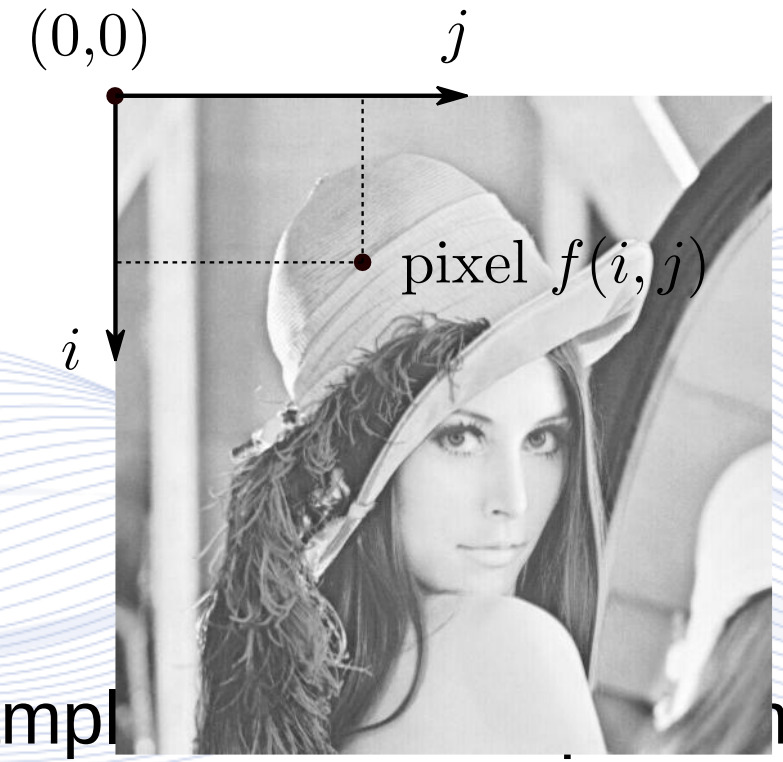
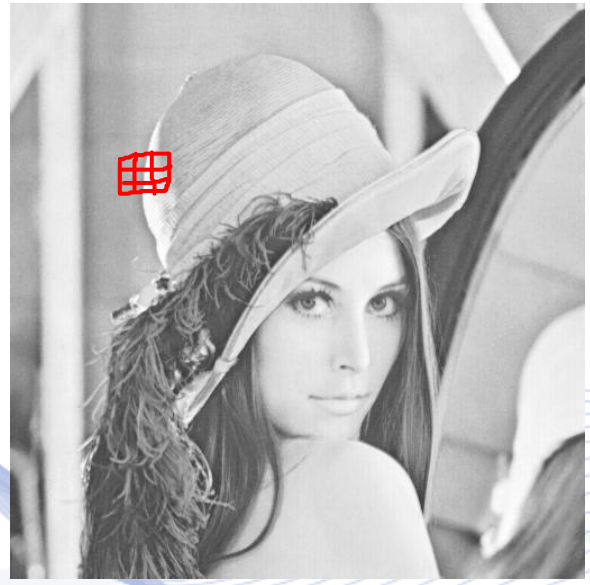
Computer Vision

Digital images consist of ***pixels***.



Exampl mage.

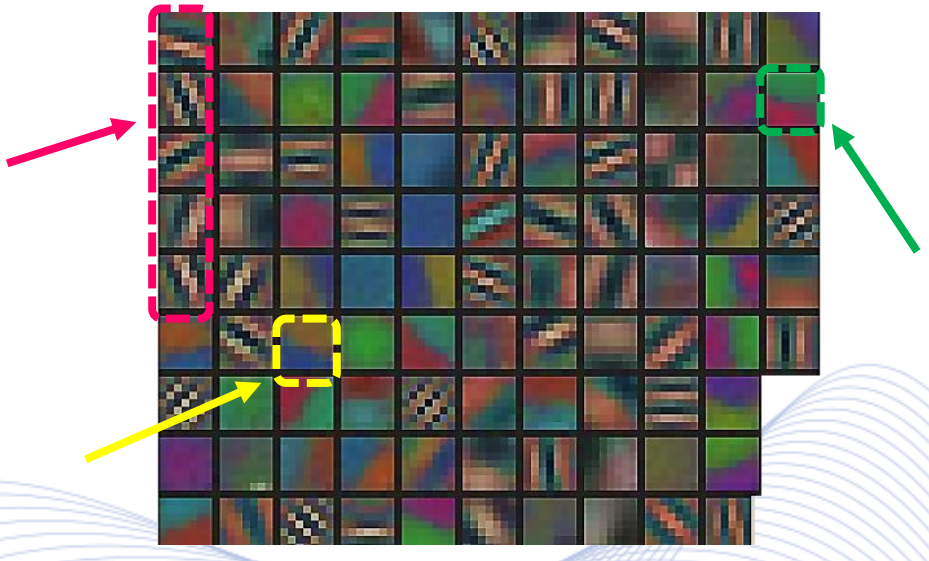
Computer Vision



Input image.

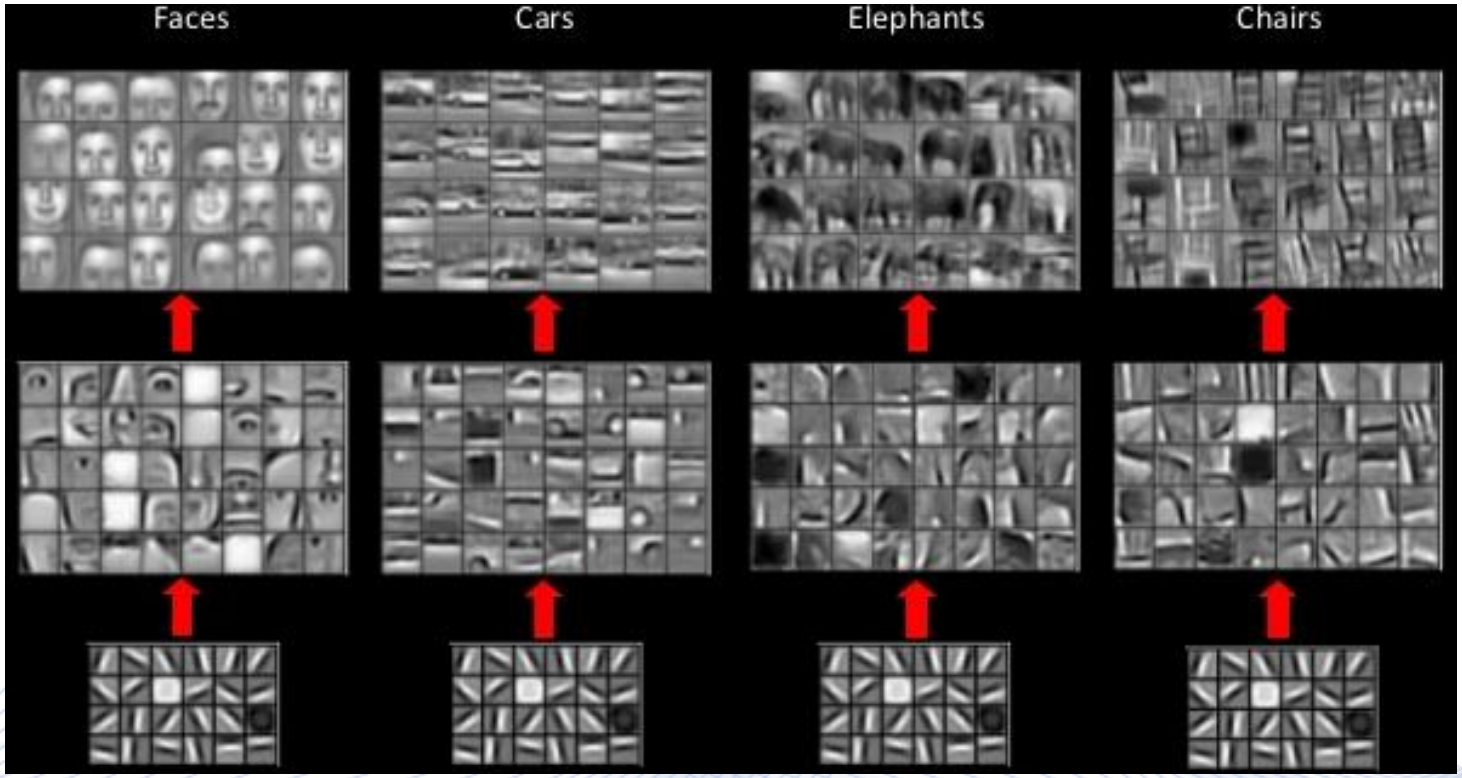
Vertical image edges.

Computer Vision



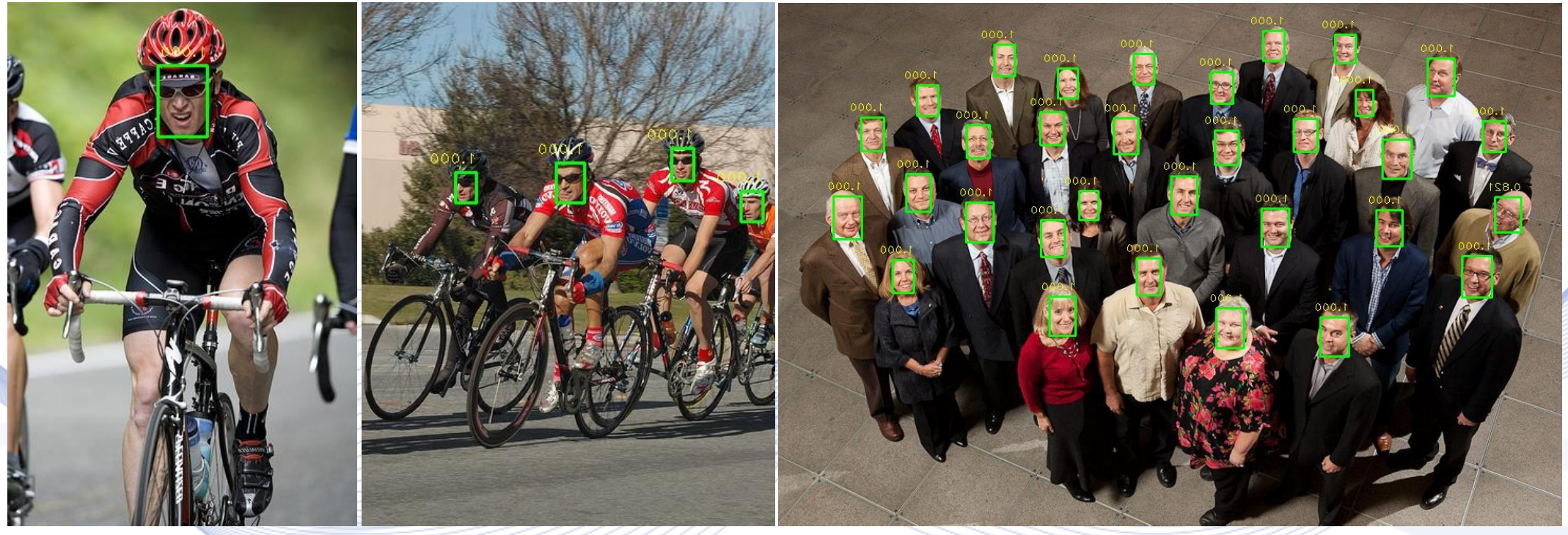
Neural Image Features.

Computer Vision



Convolutional Neural Networks: using neural image features for ML tasks.

Computer Vision



Face detection examples.

Computer Vision

Cyclist detection and tracking.

Computer Vision

Region segmentation.

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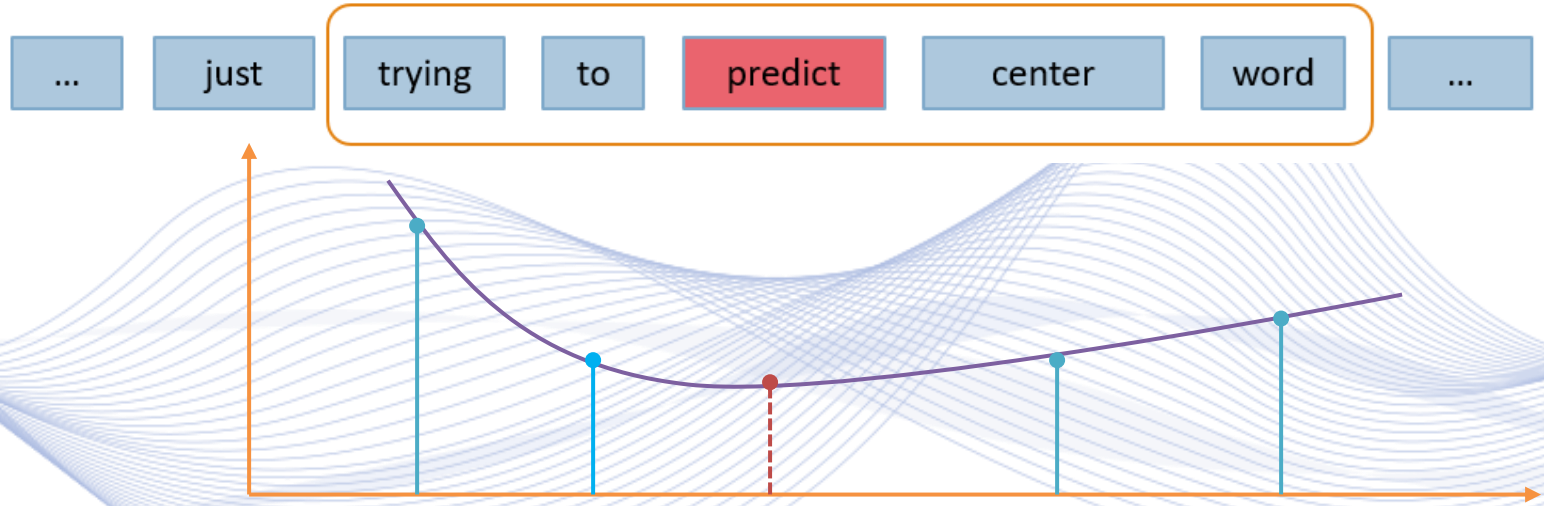
Natural Language Processing

Word embeddings

- Transforming words in series of numbers (vectors).
- Predicting word order.



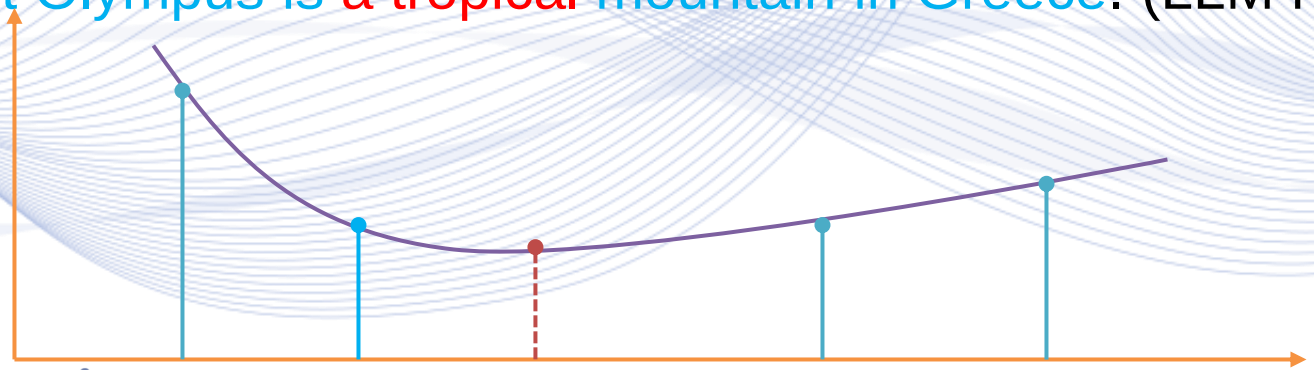
Vectors representing words ‘to’ and ‘center’ can best interpolate the ‘predict’ vector.

Natural Language Processing

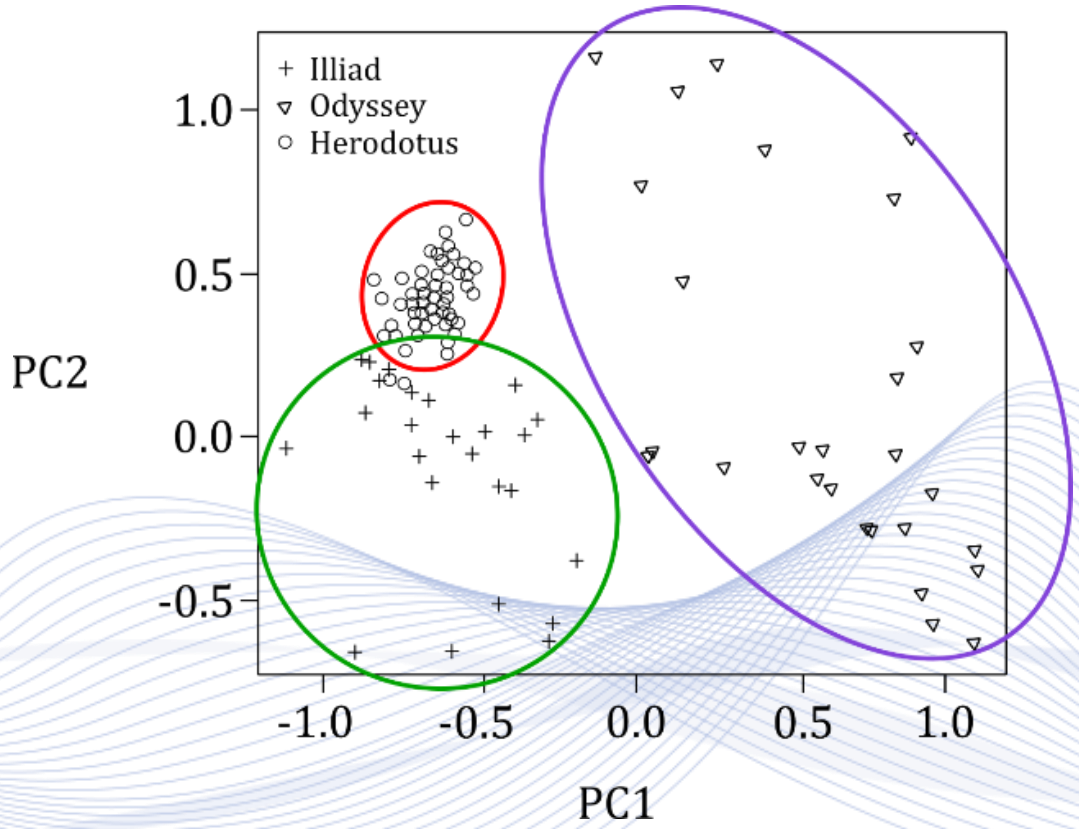
ChatGPT text production

- Question: What do you know about Mt. Olympus and Greece?
- Answer using word order prediction:

  - Mt Olympus is the highest mountain in Greece.
  - Mt Olympus is the loveliest mountain in Greece. (sentimental).
  - Mt Olympus is a tropical mountain in Greece. (LLM hallucination).

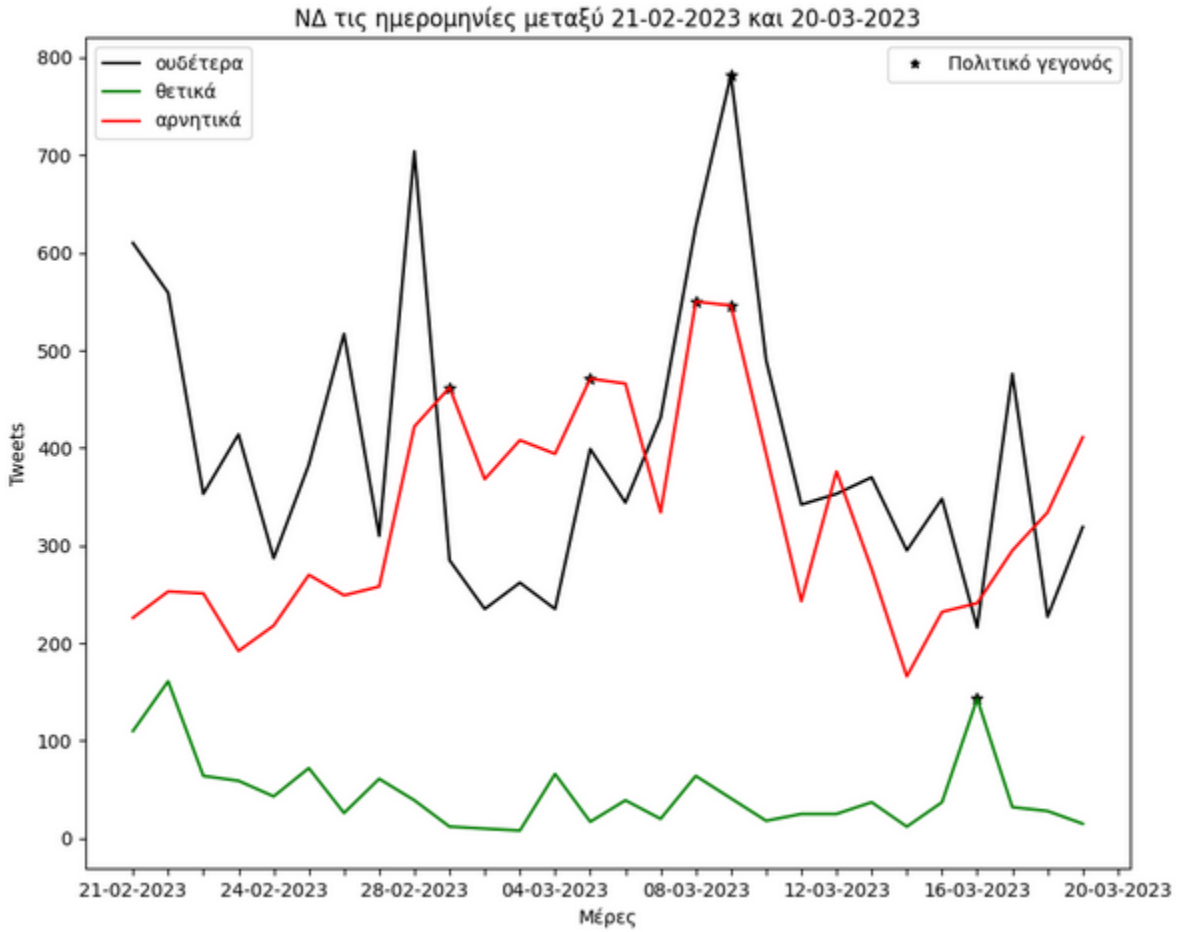


Natural Language Processing



Representing texts by vectors:
Principal component analysis of Homer's Iliad and Odyssey.

Natural Language Processing



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Sentiment Analysis of Greek Political Tweets.

Natural Language Processing

Large Language Models

- ChatGPT, GPT-4
- ***Mathematical Language Modeling*** (word embedding).
- Smooth text production.
- Not intended to offer inference capabilities.
- Code programming.
- Certain mathematical skills.

- Big question: ***what is its best use in education?***

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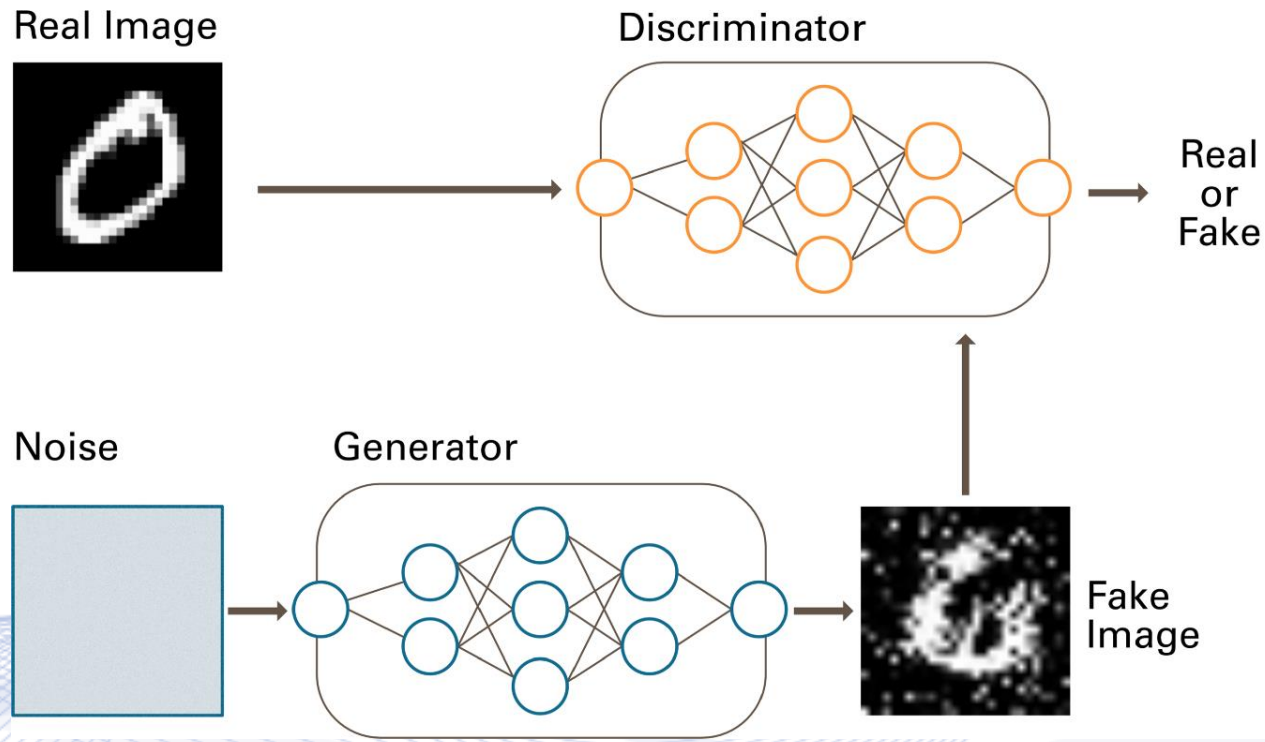
Generative AI

Generative AI creates synthetic data, e.g., images.

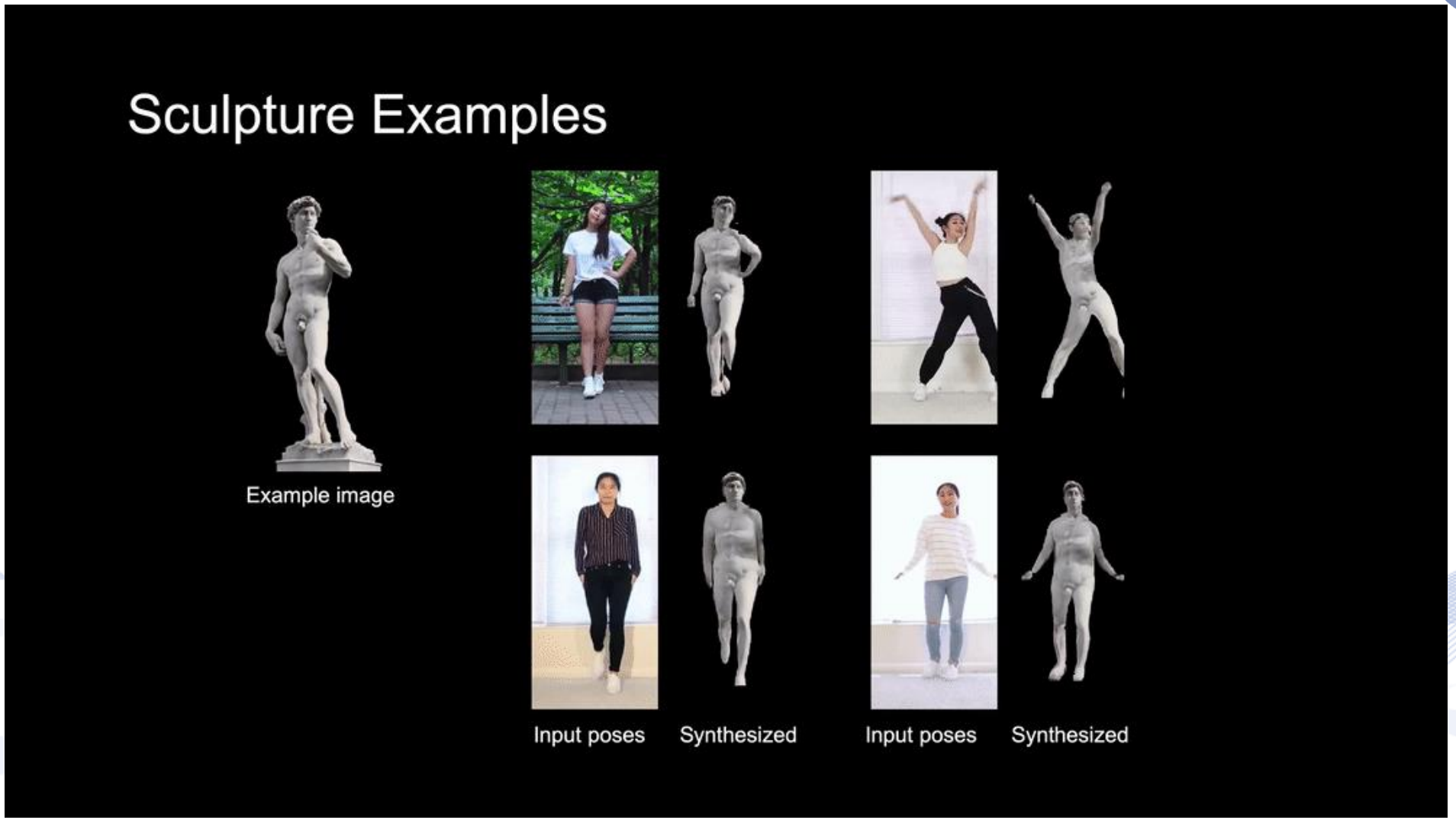
- They can be ***fake data.***

Generative Adversarial Networks (***GANs***).

- The ***generator*** NN generates an image.
- The ***discriminator*** NN decides:
  - Real or fake?



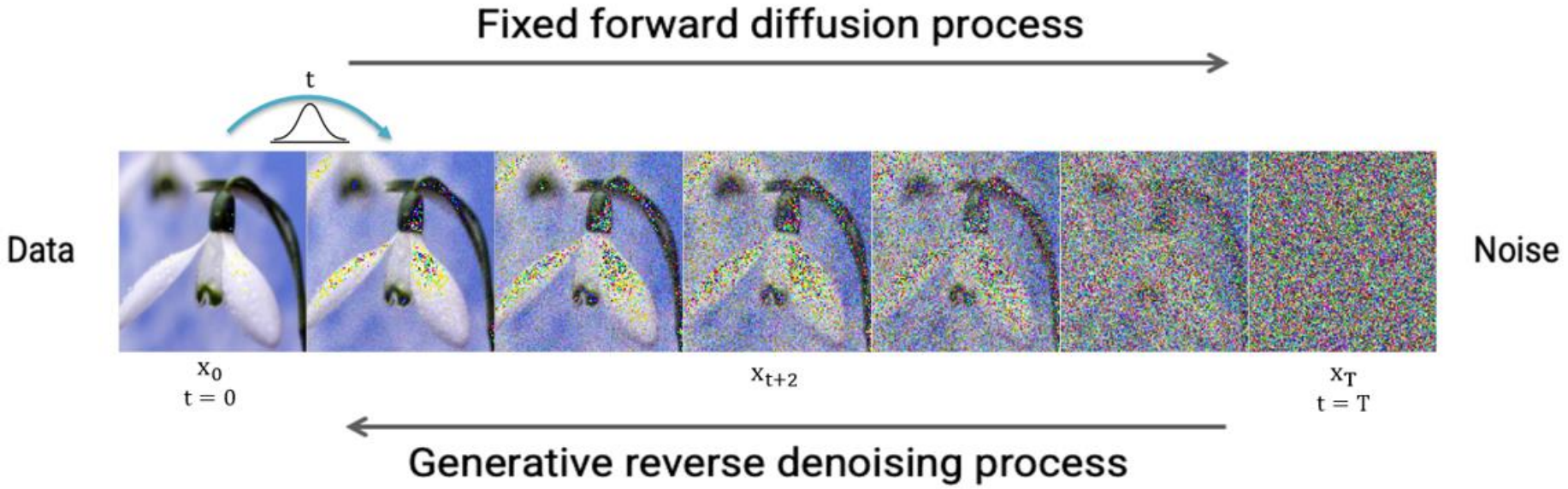
Generative AI



GANs in video synthesis.

Generative AI

- ***Diffusion Models*** (***DMs***) gradually degrade the training data (images) by adding noise, while attempting to learn to reverse this process to generate new data (images).



Diffusion Process

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Knowledge

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).

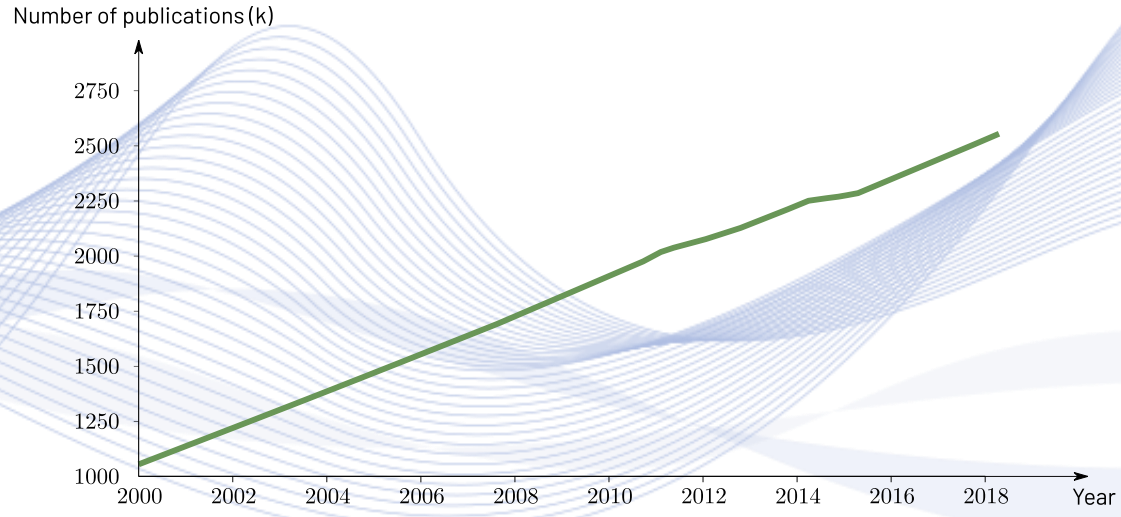
- ***Information theory/entropy: bits (once more)!***

Knowledge

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.

Knowledge

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.***

Knowledge

Knowledge society:

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

- ***Real danger: inability of humanity to grow and uptake knowledge.***
- Past devastating setbacks in knowledge uptaking:
  - Dark ages (beginning of the Medieval times).

Knowledge

Sustainability of knowledge growth:

- 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?***

Introduction to AI Science

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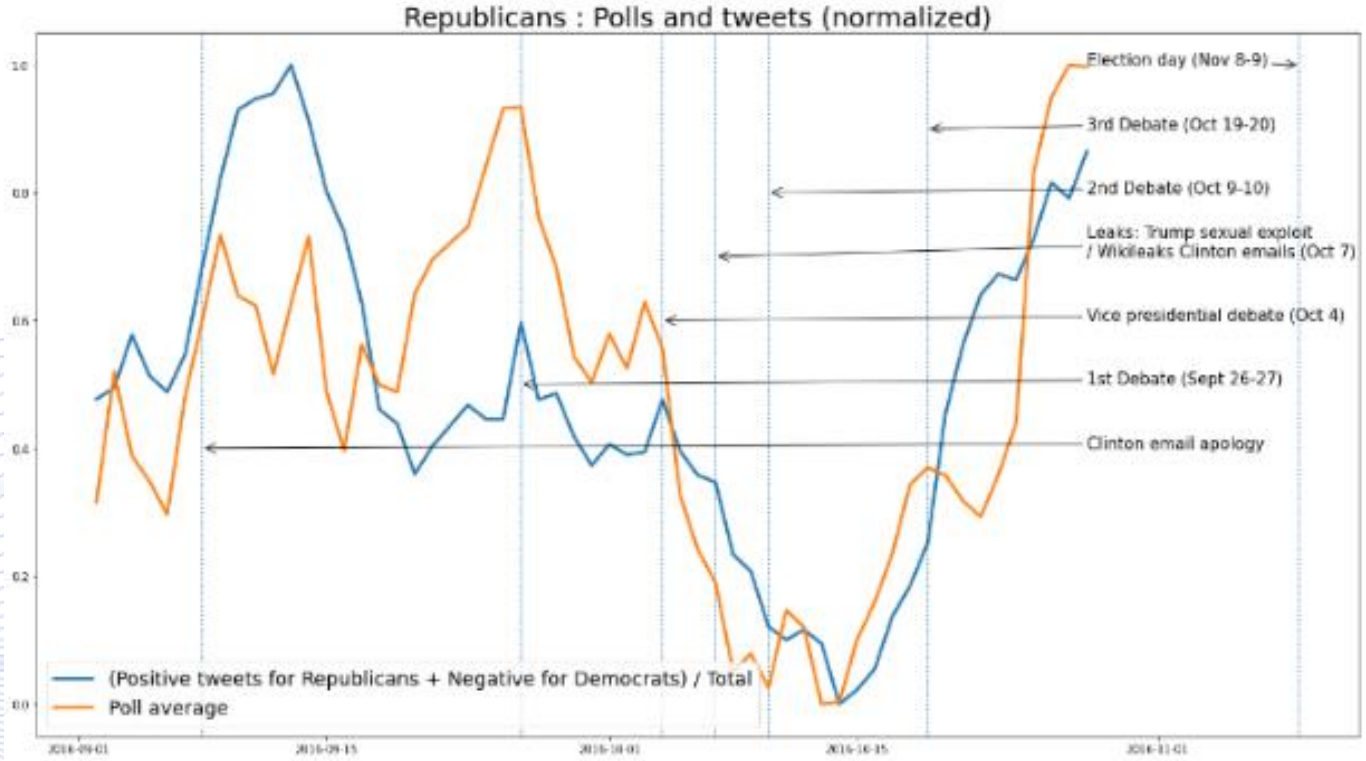
- Natural Language Processing
- Generative AI
- Knowledge
- **AI and Society**
- AI, Life and the Environment

AI and Society

AI and Politics: observing the society.

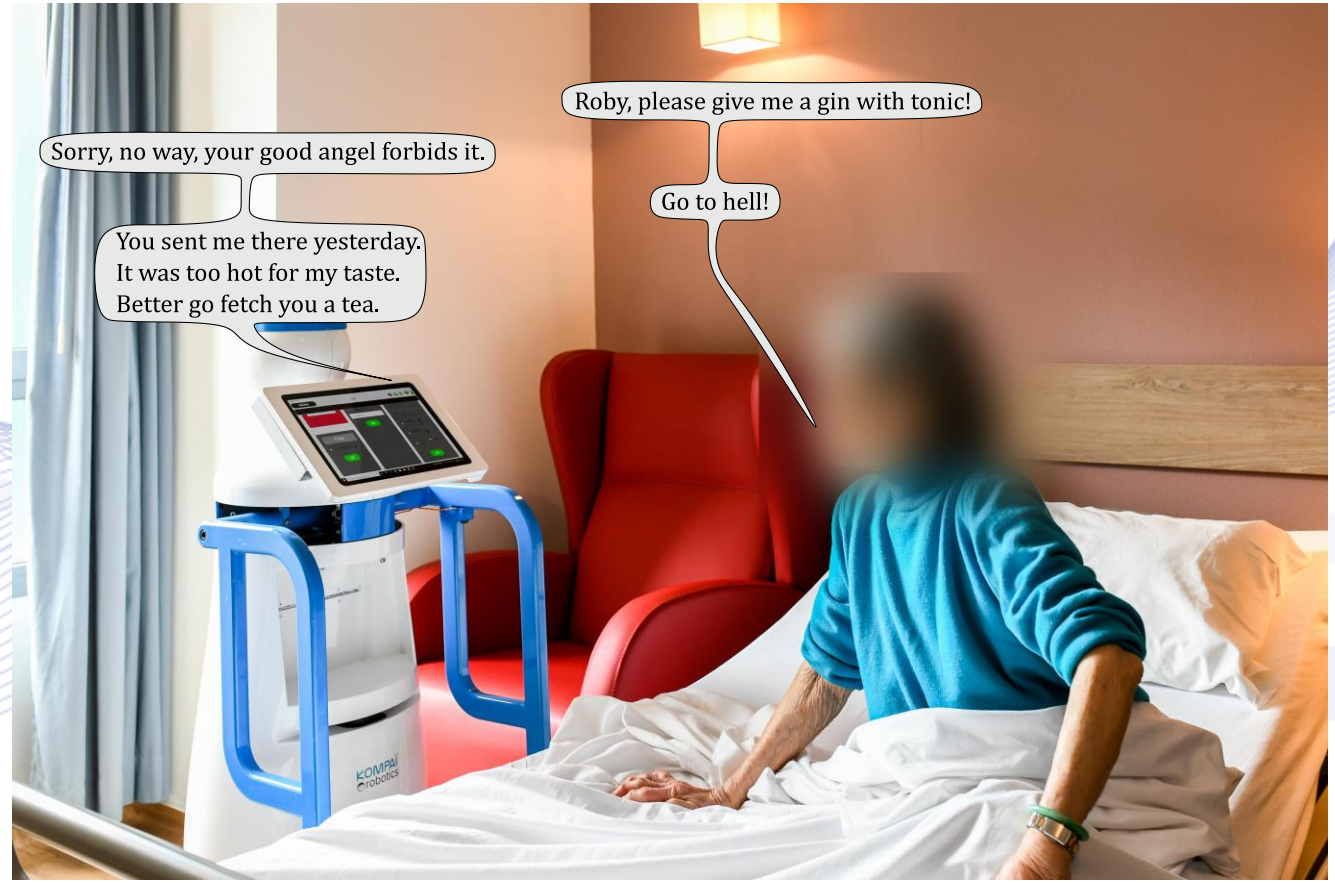
- Are opinion polls redundant?



Poll and tweet sentiment trends for the 2016 US presidential election.

AI and Society

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



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AI, Life and the Environment

Law of Complexity

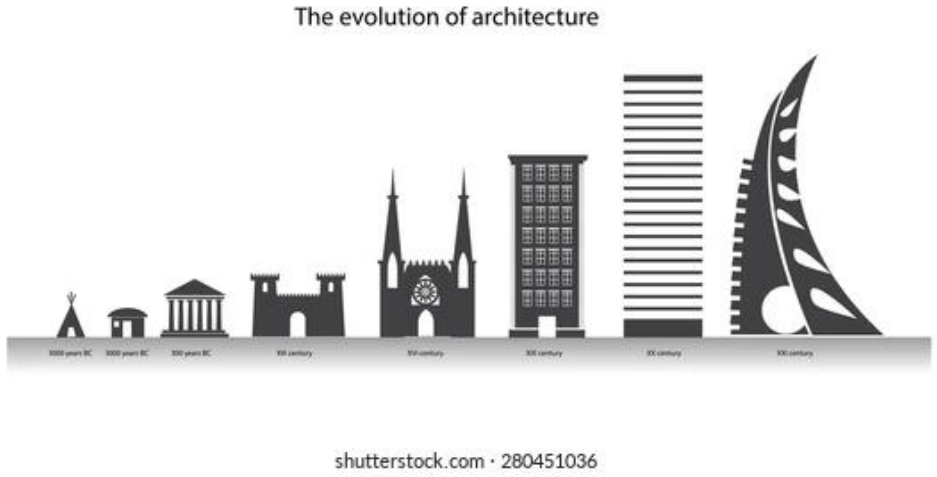
- Is ***matter complexity*** the basis of life and intelligence?

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

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

AI, Life and the Environment

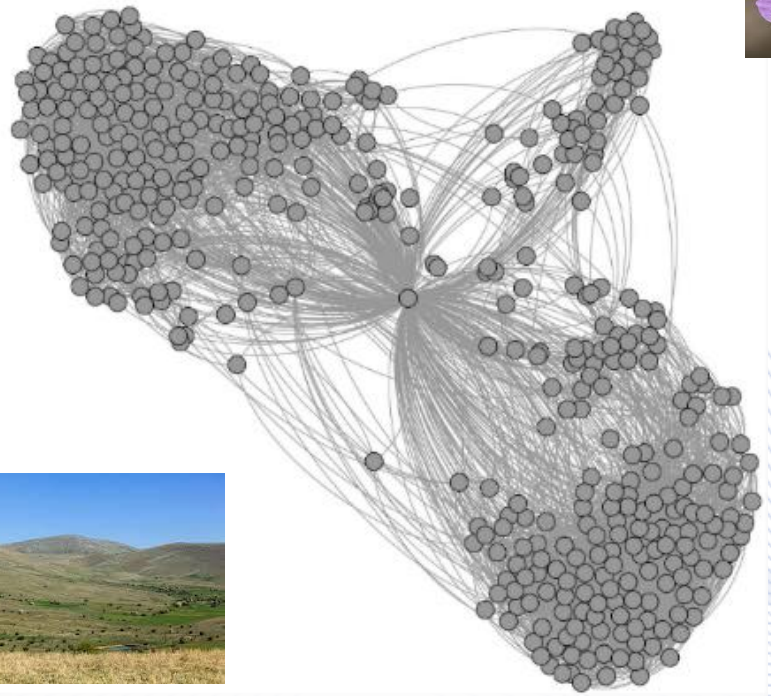
- Does living ***matter complexity*** ever increases?
- Do we see the same in man-made constructions?
  - Smart buildings, complex societal processes, intelligent machines?



- Do we move from ***life-through-evolution*** to ***life-by- design***?
- ***Is sky the limit in AI advances?***

AI, Life and the Environment

- ***There is no life/intelligence without matter complexity.***
- Life means interaction.



There is no lone flower. No two flowers are alike.

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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/

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