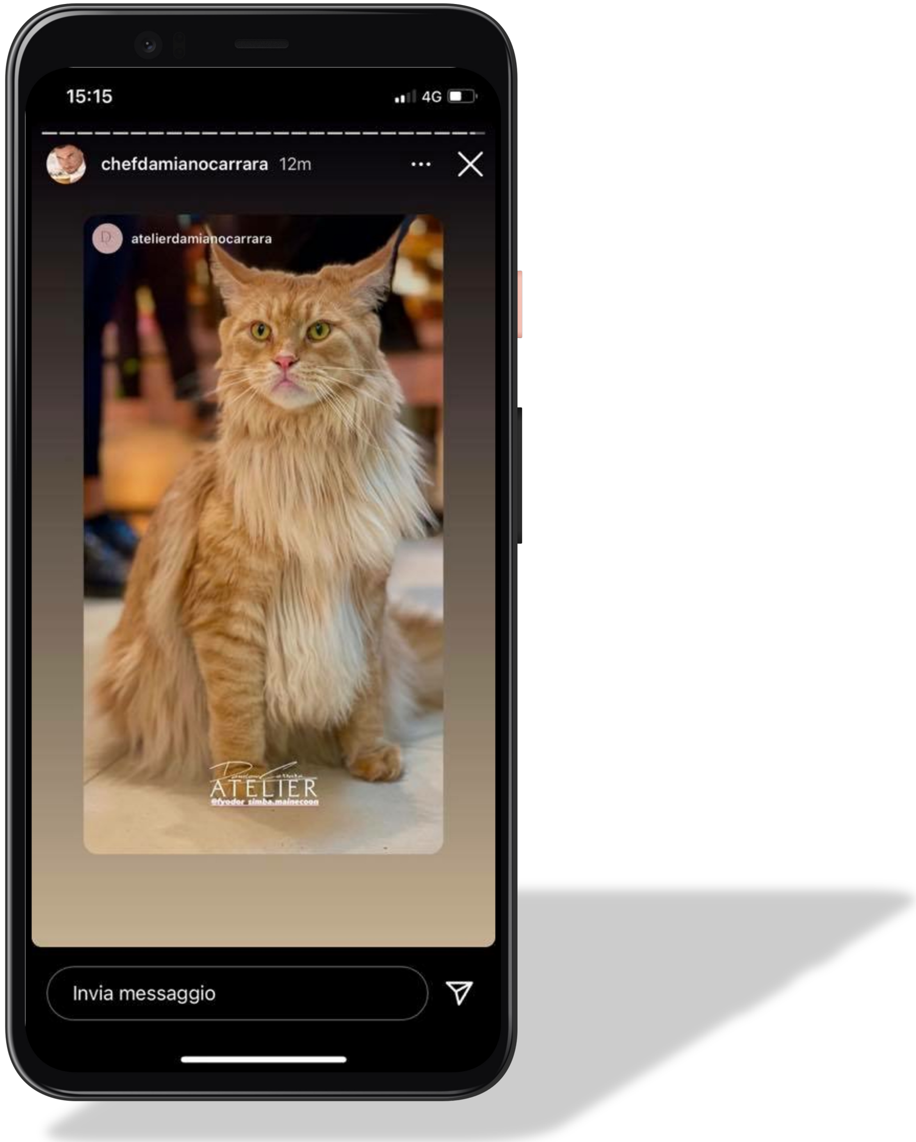
Practical AI

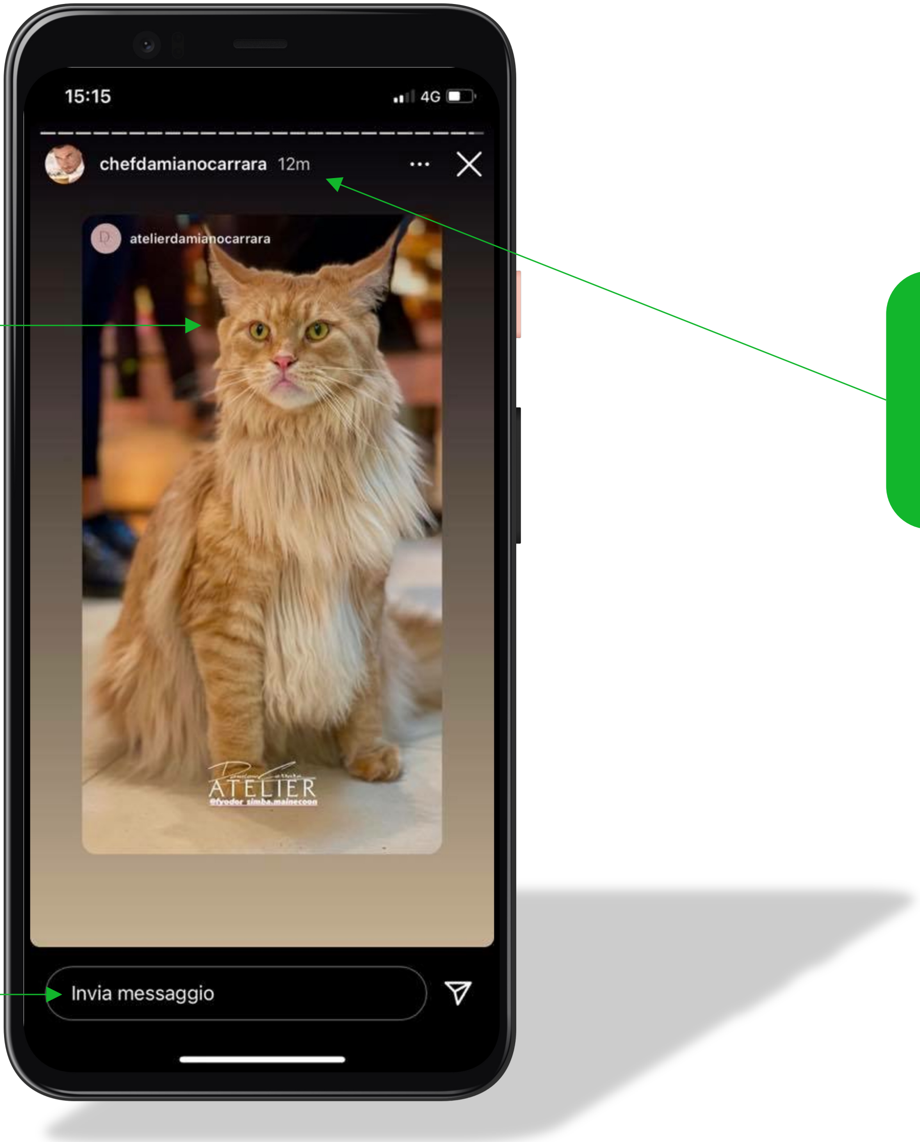
Emanuele Fabbiani

2 XTREAM


15:15
4G
chefdamianocarrara 12m
atelierdamianocarrara
ATELIER
Invia messaggio

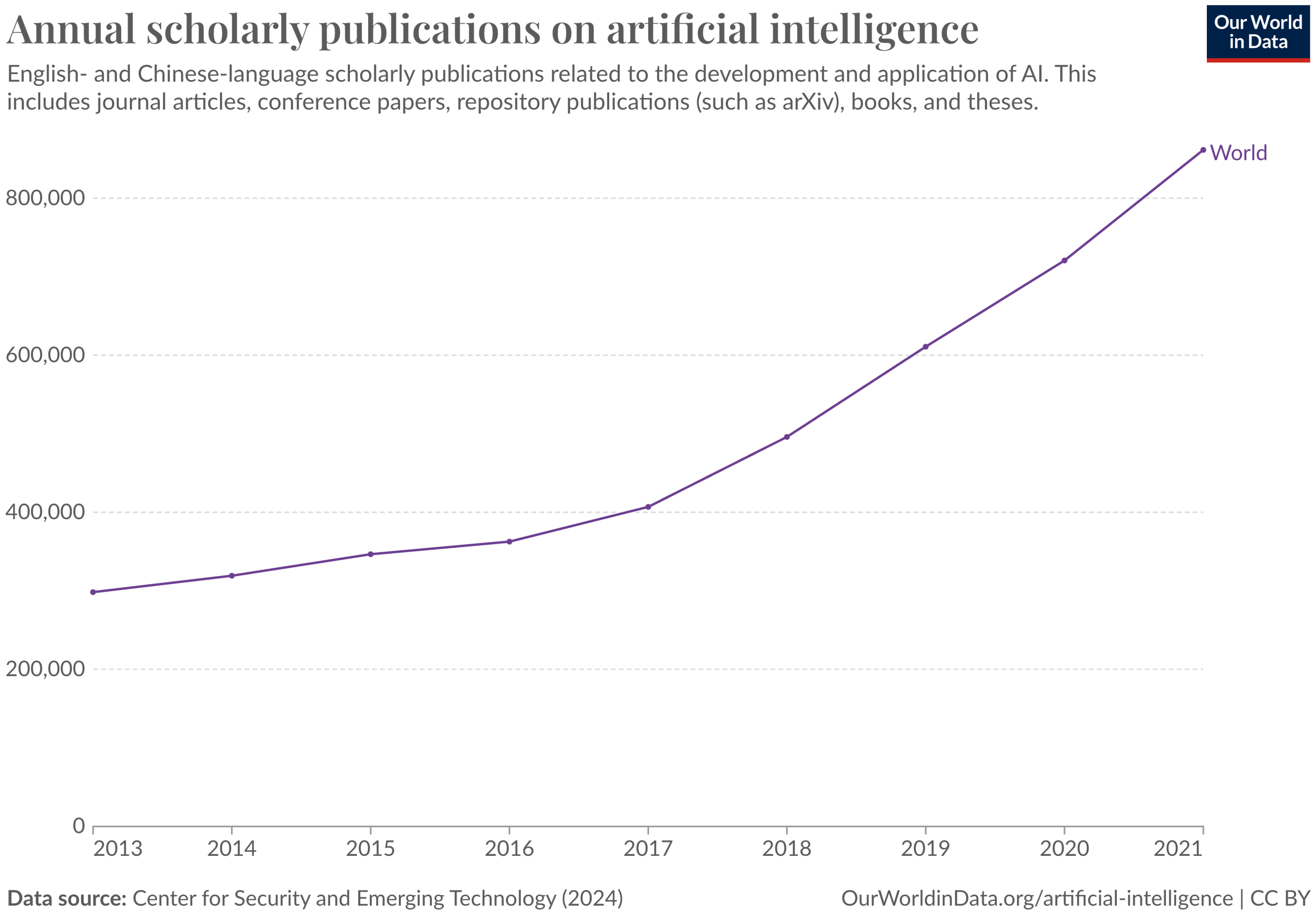
Modern smartphone cameras leverage AI models to enhance image quality. [1]

Smartphone keyboards use AI to power their auto-completion feature. [2]



Social media posts displayed to a user are selected using AI models.

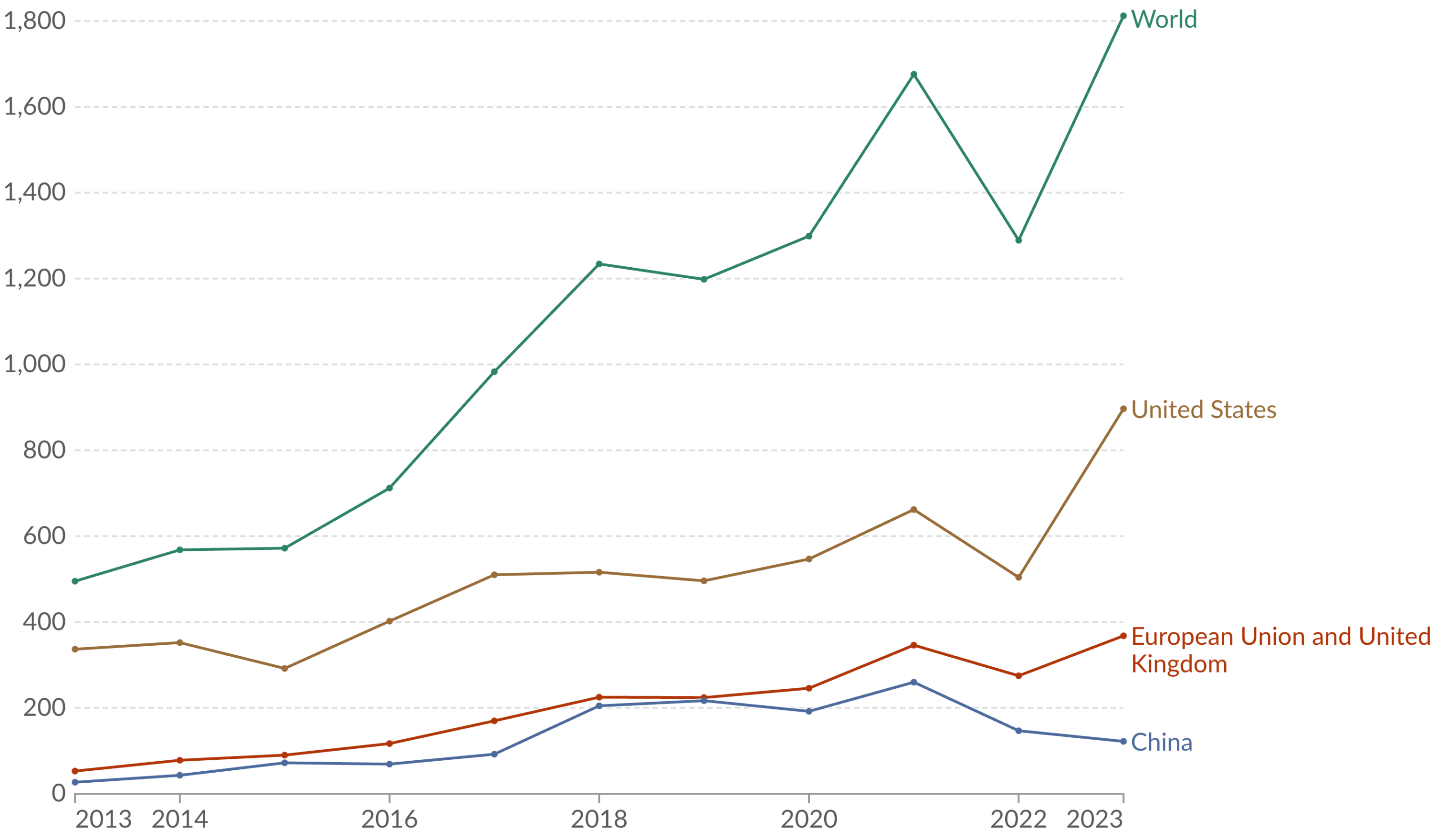
[1] https://www.samsung.com/semiconductor/minisite/exynos/technology/ai-camera/
[2] https://en.wikipedia.org/wiki/Microsoft_SwiftKey



Source: https://ourworldindata.org/artificial-intelligence#all-charts

Newly-funded artificial intelligence companies

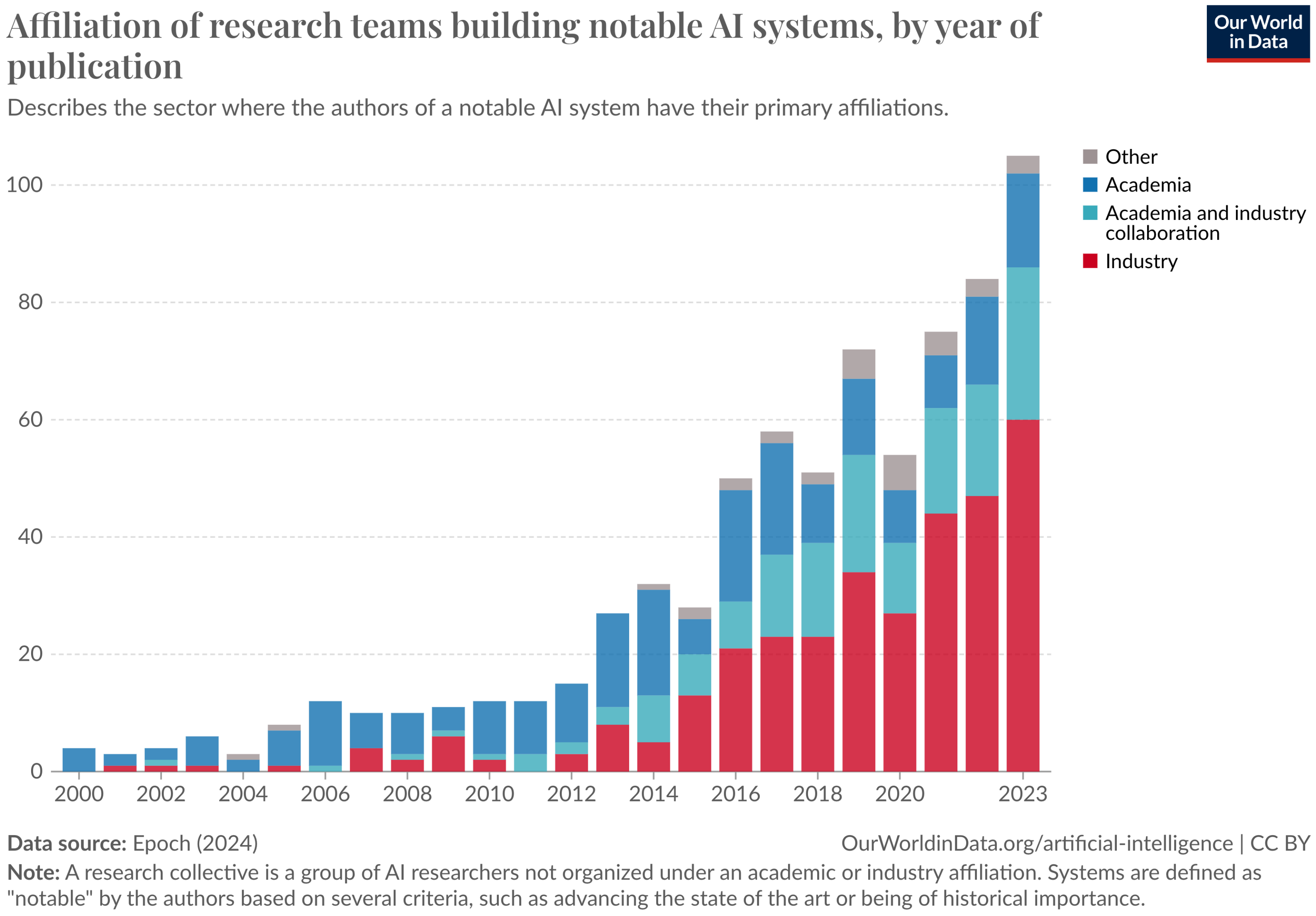
Newly-funded AI companies in each year that received an investment of more than $1.5 million (not adjusted for inflation).



Data source: Quid via AI Index (2024)

OurWorldinData.org/artificial-intelligence |

Source: https://ourworldindata.org/artificial-intelligence#all-charts

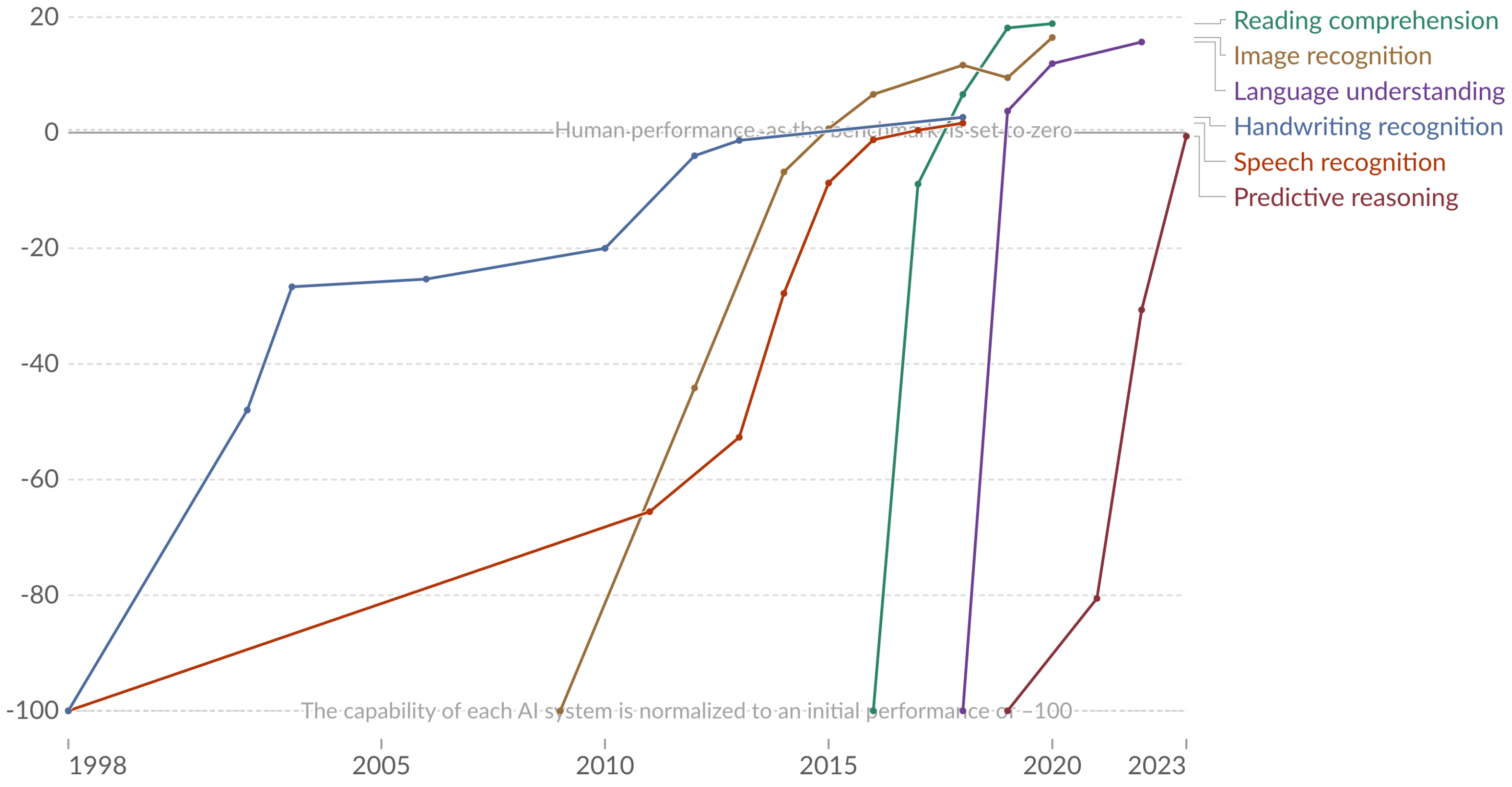


Source: https://ourworldindata.org/artificial-intelligence#all-charts

Test scores of AI systems on various capabilities relative to human performance

Our World in Data

Within each domain, the initial performance of the AI is set to –100. Human performance is used as a baseline, set to zero. When the AI's performance crosses the zero line, it scored more points than humans.



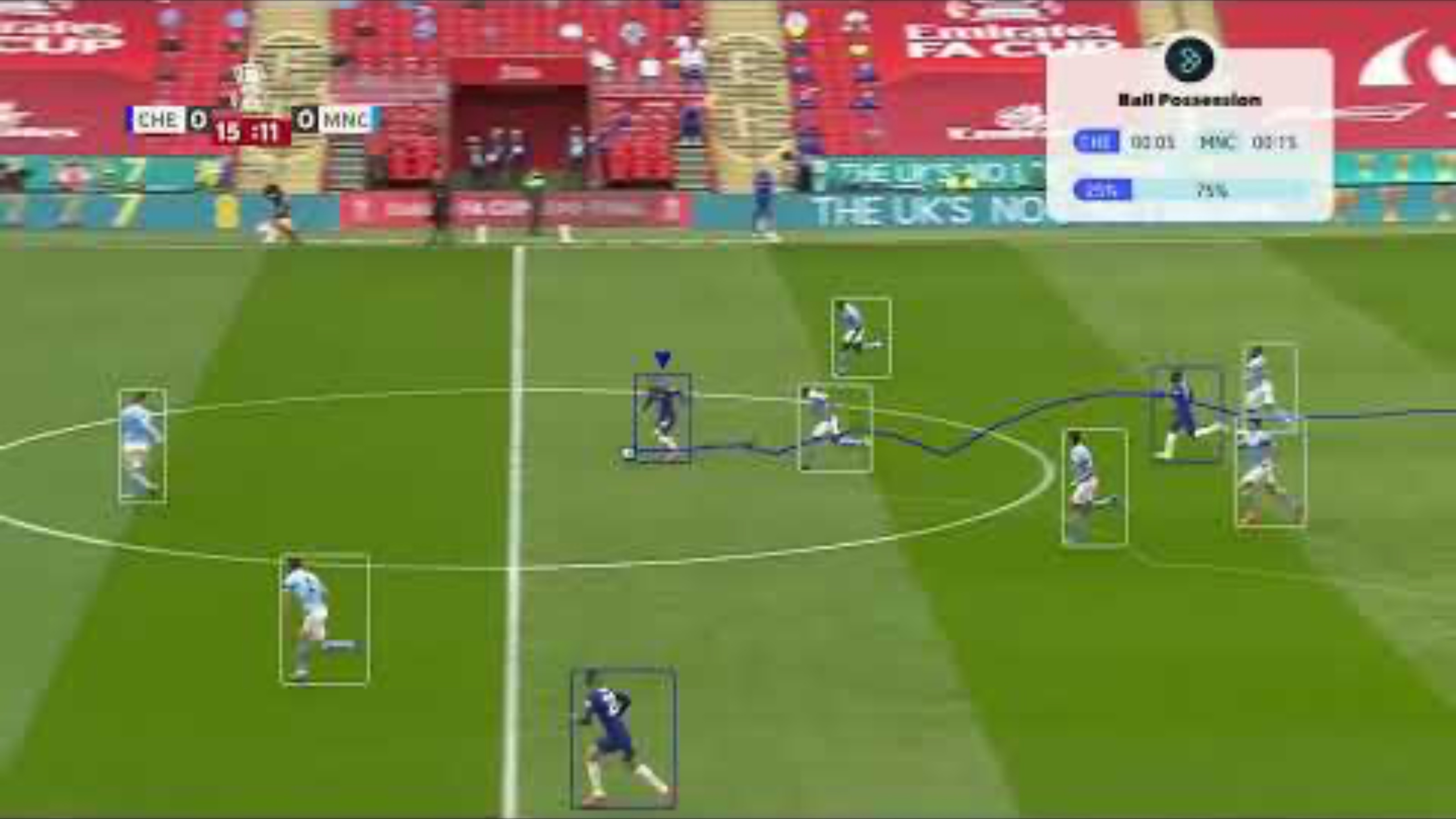
Data source: Kiela et al. (2023) OurWorldinData.org/artificial-intelligence | CC BY

Note: For each capability, the first year always shows a baseline of –100, even if better performance was recorded later that year.

Source: https://ourworldindata.org/artificial-intelligence#all-charts

A.I.

"KETCHUP"

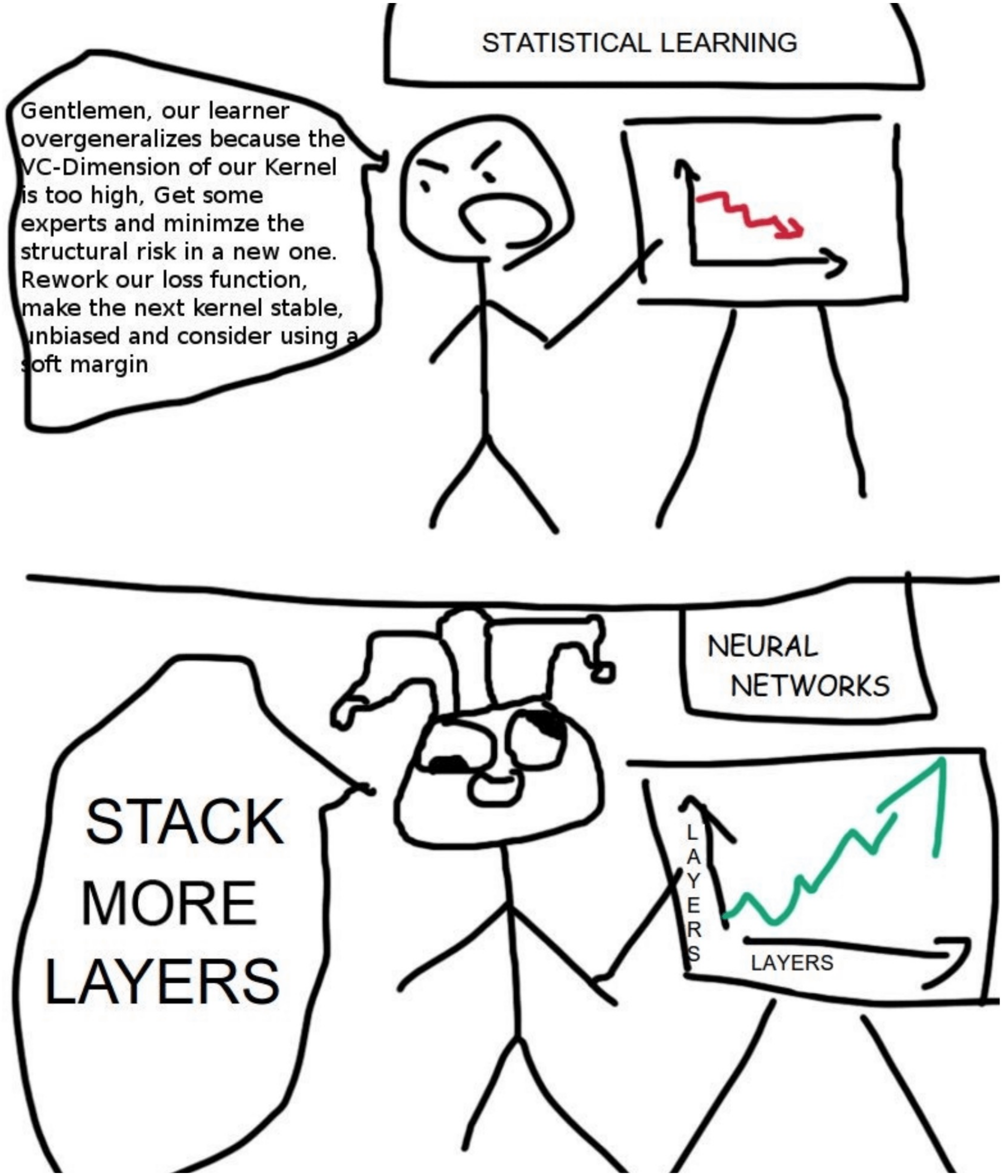

CHE 0
15 :11
0 MNC
Ball Possession
CHE
MNC
75%
Emirates
FA CUP


Live

Suno AI

11Labs

V0 by Vercel



STATISTICAL LEARNING
Gentlemen, our learner overgeneralizes because the VC-Dimension of our Kernel is too high, Get some experts and minimze the structural risk in a new one. Rework our loss function, make the next kernel stable, unbiased and consider using a soft margin
NEURAL NETWORKS
STACK MORE LAYERS
LAYERS
LAYERS

Purpose

This class is not designed for engineers and **will not teach you how to build AI models.**

Instead, it focuses on **how to apply AI in business.**

You will explore where AI can be utilized, the challenges and benefits of its adoption, and how to communicate effectively with engineers when needed.

Syllabus

1. Introduction to AI
2. Data
3. Problem Statement
4. Exploratory Analysis
5. Modelling
6. Deployment & Change Management
7. AI for Computer Vision
8. Generative AI

Emanuele Fabbiani
(ego slide)

xtream

- 💼 Co-founder and Head of AI @ xtream
- 🎓 PhD in Applied AI from UniPV
- 🇨🇭 Visiting Researcher at EPFL Lausanne
- 🧑‍💻 Codemotion Ambassador for AI
- 🎤 Speaker at 30+ Tech Conferences

Disclaimer

AI has evolved into a vast, complex, and fascinating field.

While this class **will not cover every topic**, we will provide free resources to help you explore further and satisfy your curiosity.

Class Schedule & Exam

Class Schedule

8 lectures, 4 hours each.

Every **Friday at 13:30.**

Room G.119 S. Pio X (not this room!)

Next Friday's lecture will **start at 14:30.**

No lecture on 7th February.

Will need to move the lecture on 14th February.

Lecture Schedule

Lecture	Lecture
13:30 – 15:20	15:40 – 17:30

Lecturer Interview

There is **no fixed slot**.

Please email me at emanuele.fabbiani@unicatt.it so we can arrange a date and time for a Teams call.

Each Friday, I am happy to **stay after the lecture** to answer questions or discuss ideas.

Exam

4 sessions – see schedule on the website.

Grading policy:

- **Written exam**: multiple choice questions (28 points)
- **Project work:** 12-slide presentation + 3-min video (4 points)

The final grade for this exam will be the **average** of the marks for Module A (Andrea Pozzi) and Module B (this class).

The two modules (Andrea Pozzi and this class) **cannot be split** apart from the first session.

Project Work

Solve a Business Problem with AI

This project allows you to explore a business problem that genuinely interests you. The scope is intentionally broad, so you have the freedom to choose a topic that resonates with you.

Deliverables

Presentation: Prepare a clear, concise presentation with no more than 12 slides.

Video: Create a video (up to 3 minutes) explaining the problem, solution, and results.

Project Work – Guidelines

Identify a Relevant Problem

Find a business challenge that can be addressed using AI: it should be impactful and relevant to your interests.

Find a Dataset

If your solution requires data, find a suitable dataset to support your work (hint: check out Kaggle or Google Data Commons).

Propose a Solution

Develop an AI-driven solution to address the problem. You may choose to code analysis, build a model, or create a prototype: coding is encouraged but not mandatory.

Project Work – Evaluation

Your project will be assessed based on the following criteria:

- **Relevance** of the problem within the field of interest
- **Depth** of problem analysis
- **Critical evaluation** of potential solutions
- **Feasibility** of the proposed solution
- **Clarity** of the explanation
- **Quality** of the deliverables

Project Work – Deadline & Rules

The project work must be submitted **before** the start of the written exam. Late submissions will result in 0 points, irrespective of the quality of the work.

Submission and completion of the written exam **cannot** be done separately.

If you retake the written exam, you may **resubmit** the same project work, but the mark will remain unchanged.

Alternatively, you may submit a **different** project work when retaking the written exam.

Material – GitHub Repository

All the material for this class is available at the following link.

https://github.com/donlelef/practical-ai-class

Quiz

Artificial Intelligence

Discussion

What is AI?

What is AI?

Artificial intelligence (AI) is the technology that enables computers and machines to **simulate human** learning, comprehension, problem-solving, decision-making, creativity and autonomy.

AI, ML, Data Science

Data Science

Data science is a multi-disciplinary field that uses scientific methods, processes, algorithms and systems to extract knowledge and insights from structured and unstructured data. [1]

In plain English, statistics performed by a software engineer.

Machine Learning

Machine Learning is the use of algorithms and statistical models to make a computer system perform a specific task without using explicit instructions, relying on patterns and inference from data instead. [2]

It is a broad and imprecise term, not to be confused with precisely defined Statistical Learning.

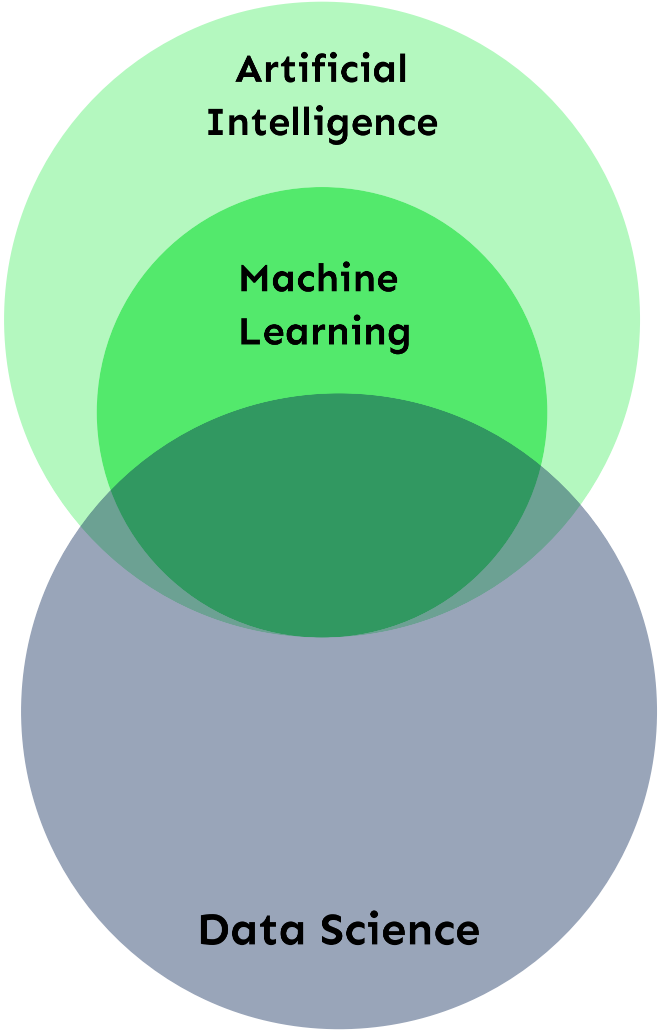
Artificial Intelligence

Artificial intelligence (AI) is the technology that enables computers and machines to simulate human learning, comprehension, problem-solving, decision-making, creativity and autonomy. [3]

Machine Learning is a sub-field of Artificial Intelligence

[1] source: Wikipedia
[2] adapted from Wikipedia
[3] source: IBM

AI, ML, Data Science



Data Science

Data science is a multi-disciplinary field that uses scientific methods, processes, algorithms and systems to extract knowledge and insights from structured and unstructured data. [1]

In plain English, statistics performed by a software engineer.

Machine Learning

Machine Learning is the use of algorithms and statistical models to make a computer system perform a specific task without using explicit instructions, relying on patterns and inference from data instead. [2]

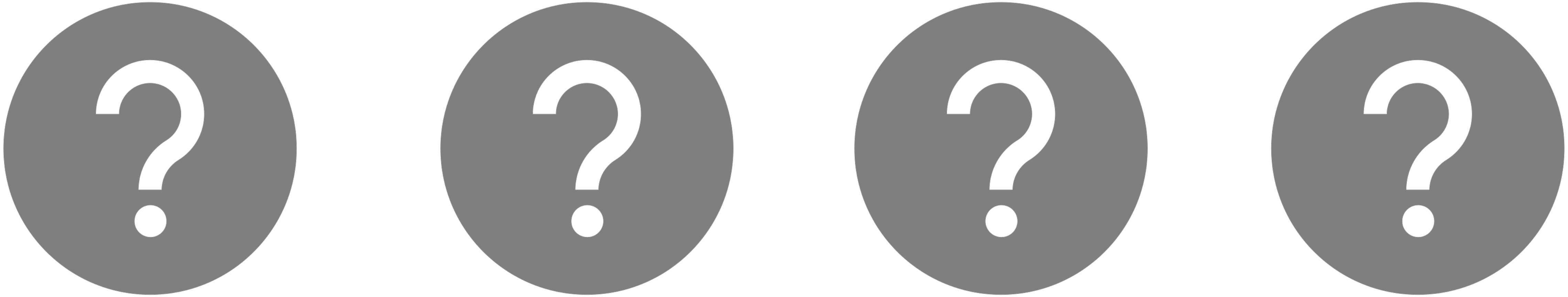
It is a broad and imprecise term, not to be confused with precisely defined Statistical Learning.

Artificial Intelligence

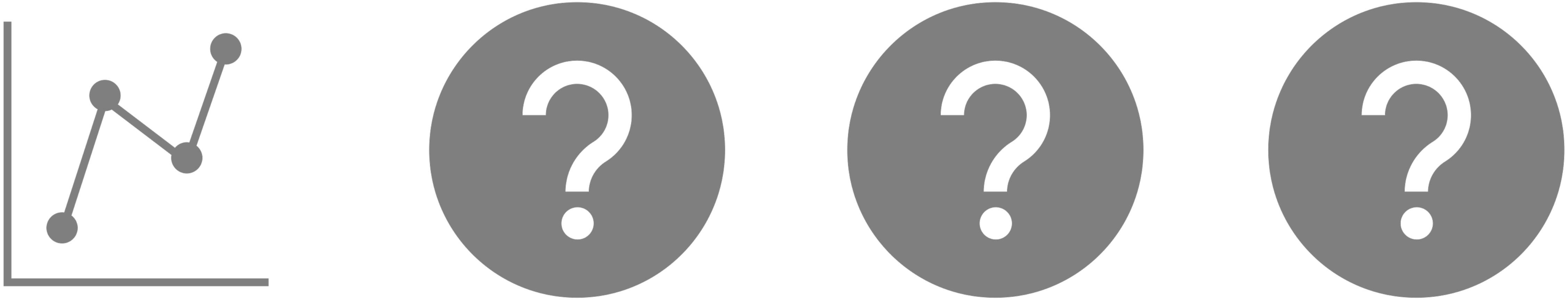
Artificial intelligence (AI) is the technology that enables computers and machines to simulate human learning, comprehension, problem-solving, decision-making, creativity and autonomy. [3]

Machine Learning is a sub-field of Artificial Intelligence

[1] source: Wikipedia
[2] adapted from Wikipedia
[3] source: IBM

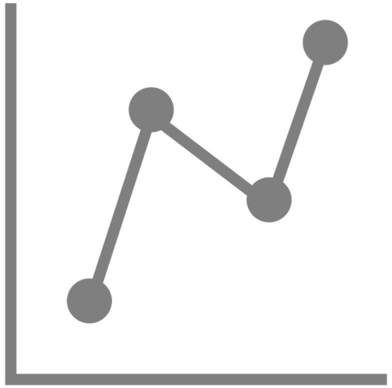


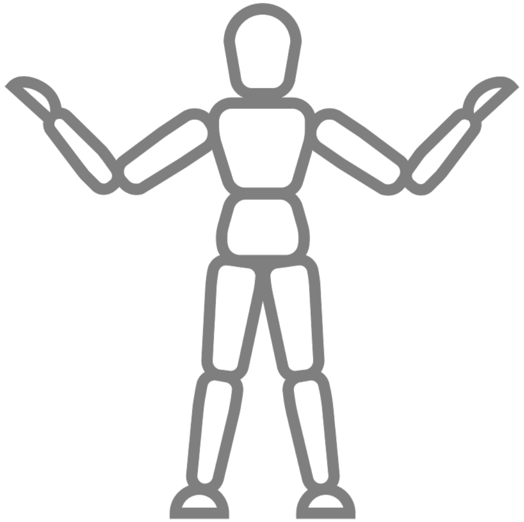
Data



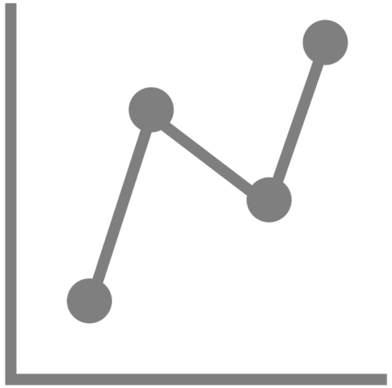
Data

Model

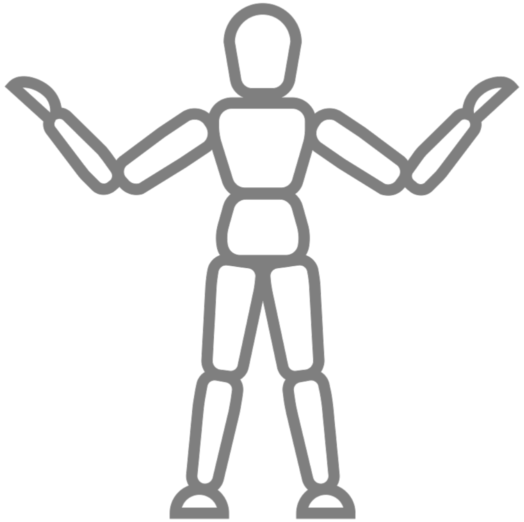




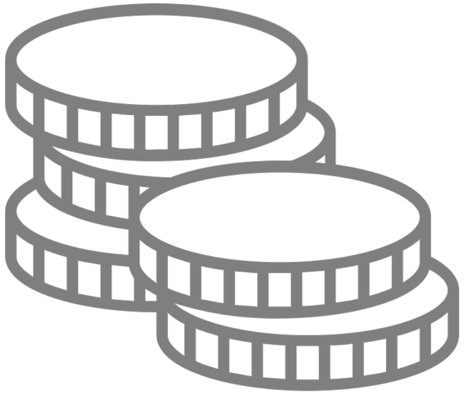
Data



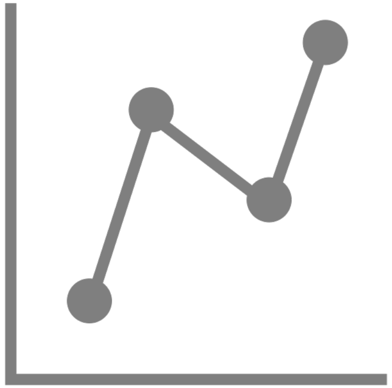
Model



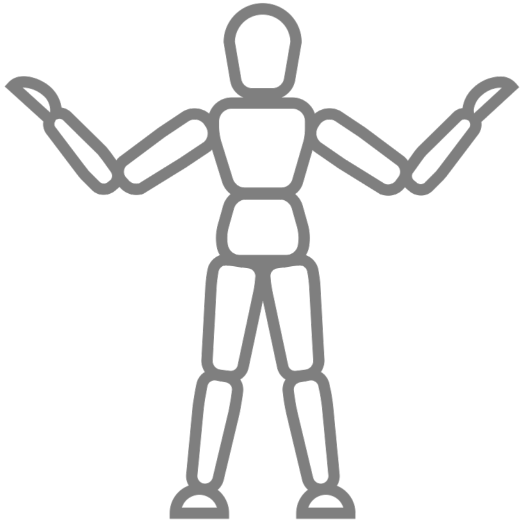
Loss



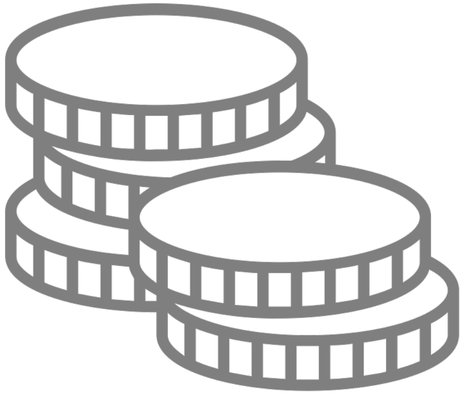
Data



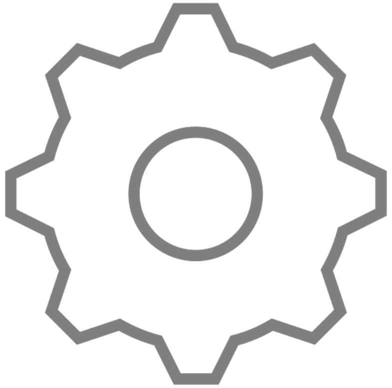
Model



Loss



Learning algorithm




WHAT DID YOU SAY?

Data

What is data?

Information, especially facts or numbers, collected to be examined and considered and used to help decision-making, or information in an electronic form that can be stored and used by a computer. [1]

[1] https://dictionary.cambridge.org/it/dizionario/inglese/data

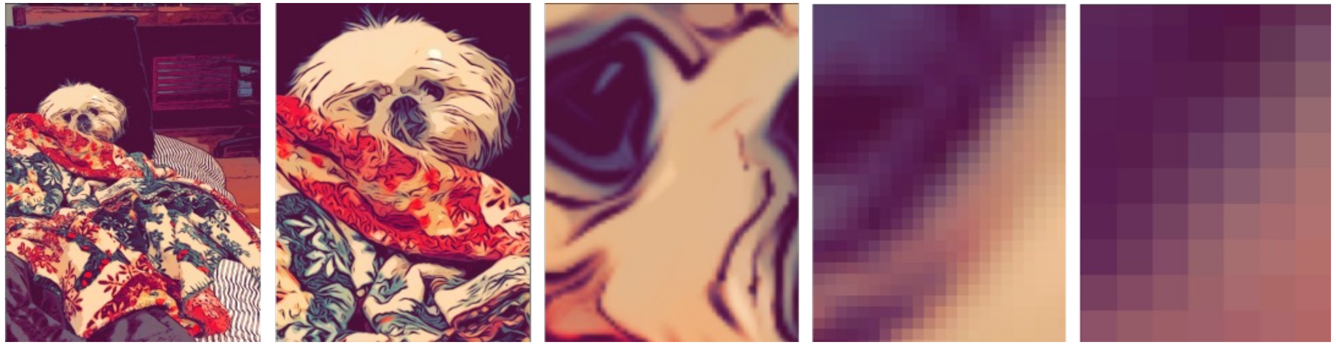
Yes, but...
What is data, exactly?

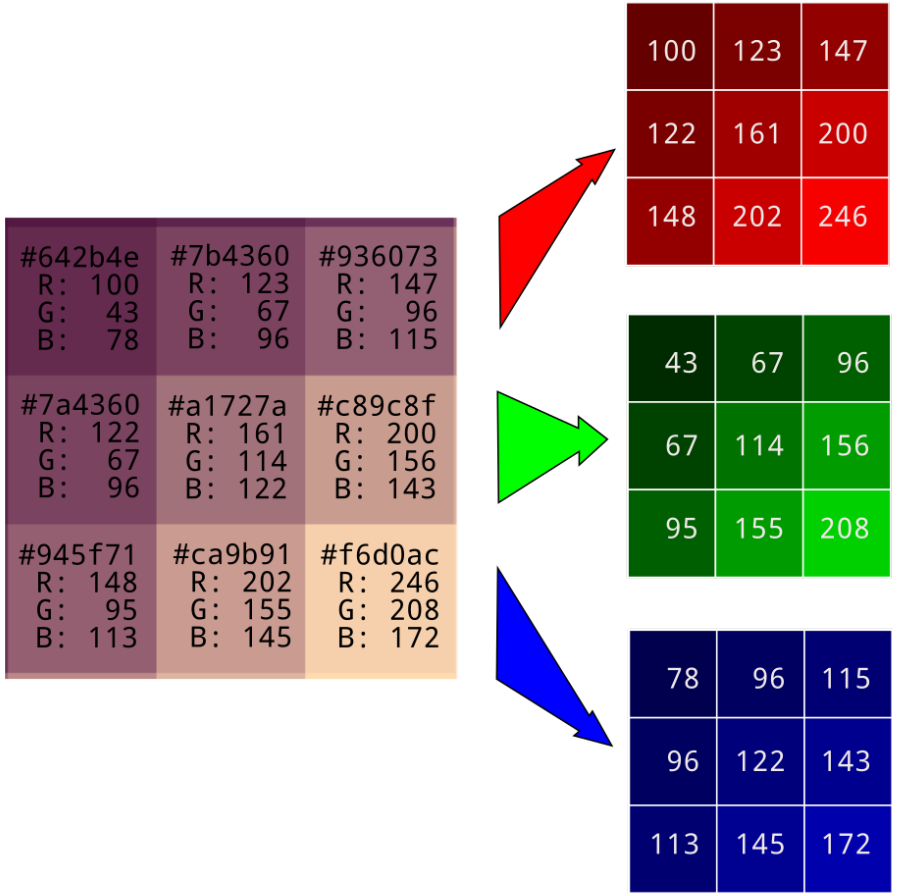
The only data which can be fed into a machine learning model are

NUMBERS

every other form of data must be converted first.

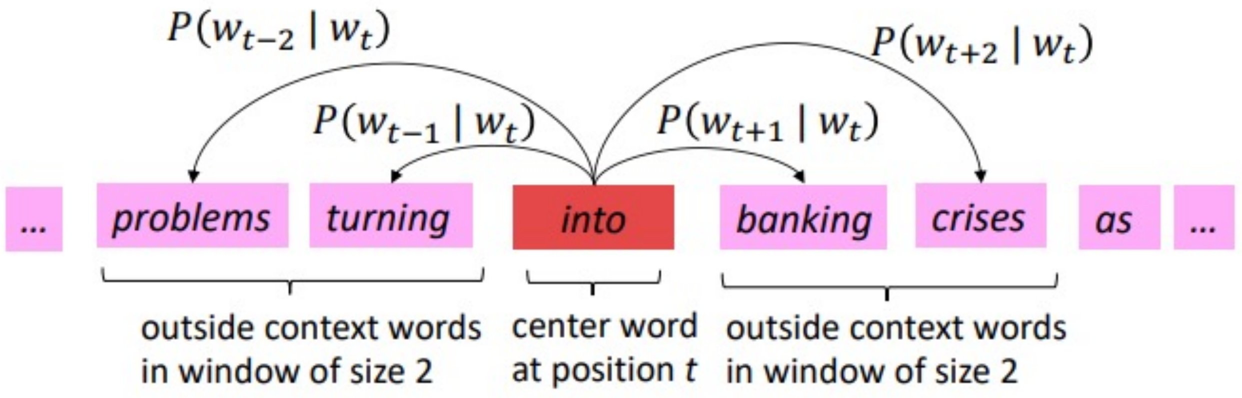
Converting to numbers?





https://www.kdnuggets.com/2020/01/convert-picture-numbers.html

Converting to numbers?



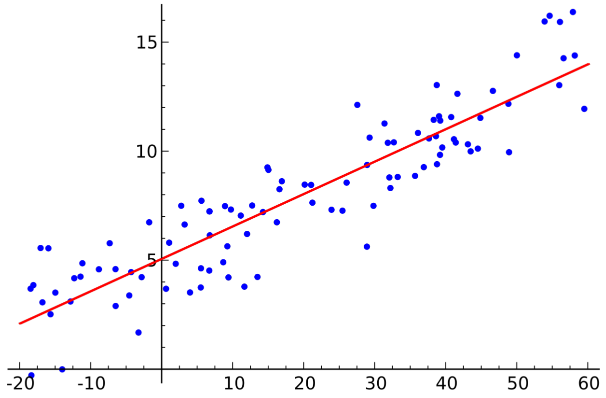
$$\text{soccer} = \begin{pmatrix} 0.123 \\ 0.312 \\ 0.532 \\ 0.883 \\ -0.232 \\ -0.876 \end{pmatrix} \qquad \text{football} = \begin{pmatrix} -0.007 \\ 0.522 \\ 0.432 \\ 0.773 \\ -0.212 \\ -0.376 \end{pmatrix}$$

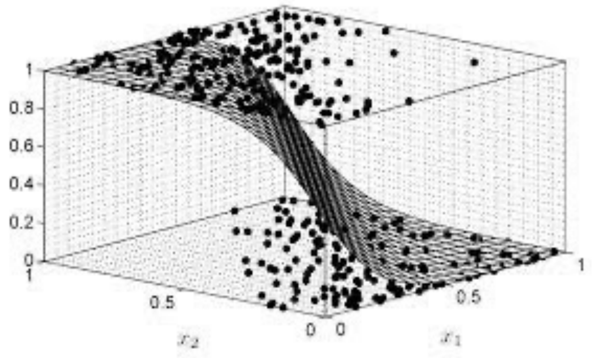
https://web.stanford.edu/class/cs224n/index.html

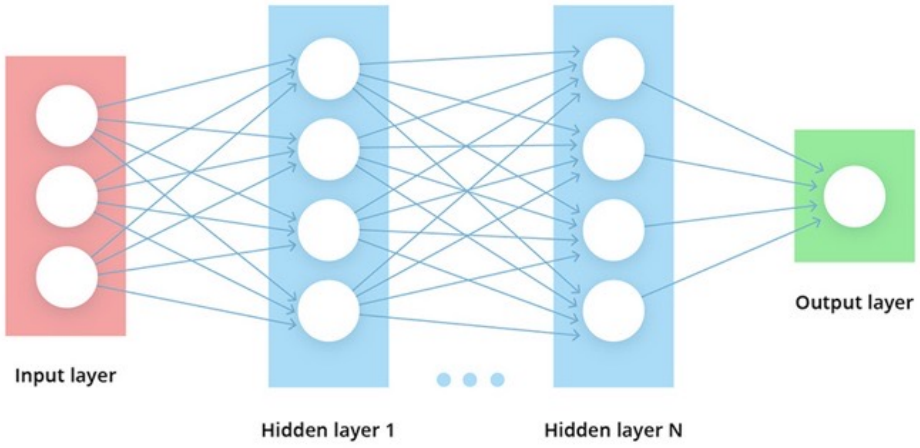
Model

What is a model?

A **mathematical law** that embeds assumptions on the relationships between some variables.







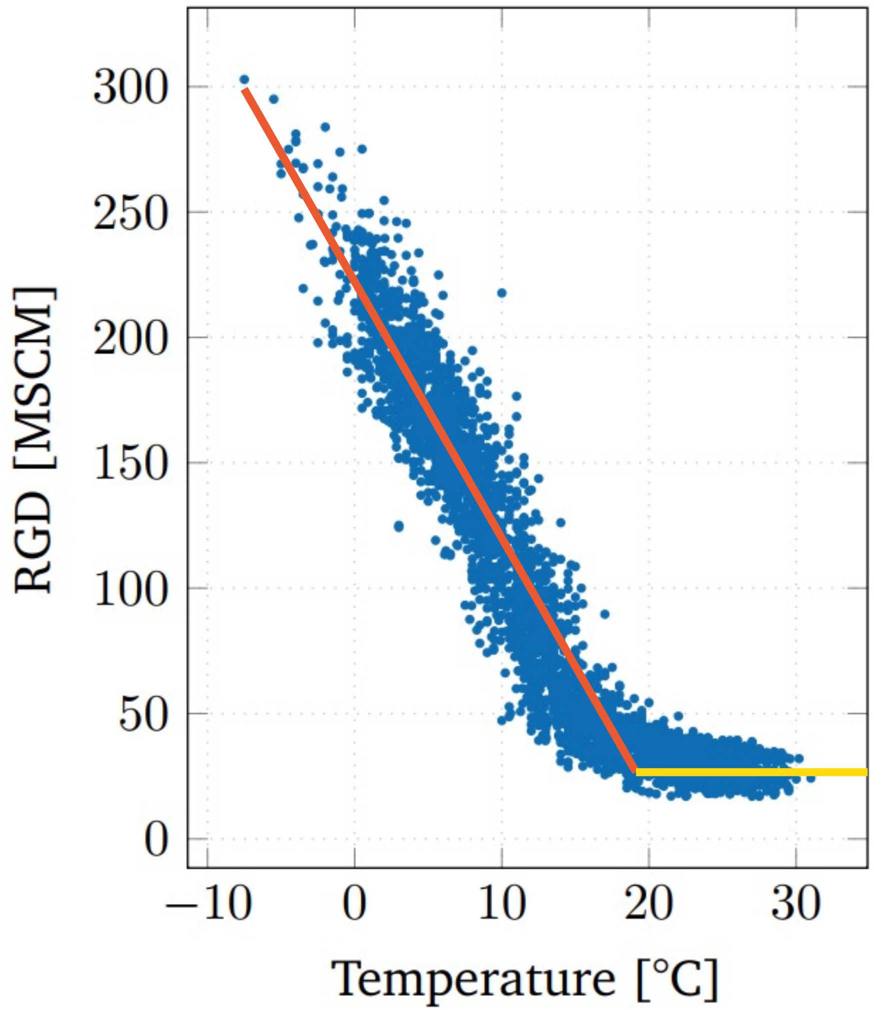
Simple models

The residential gas demand (RDG) depends on the temperature (T).

Just by observing the **data**, we can produce a simple model:

$$RDG = f(T) = \max(\alpha(\beta - T), \gamma)$$

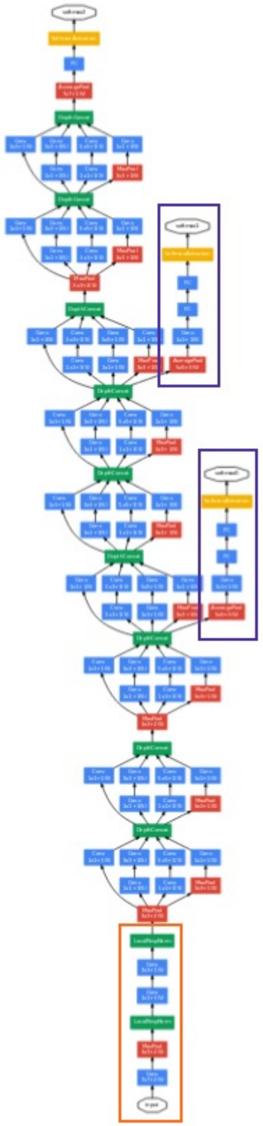
The model has parameters: α, β, γ.



And complex models

Deep learning models in computer vision and NLP are very complex and can have **billions of parameters.**

In the depicted Inception network, each block denotes a layer, that is a series of parametrized operations.



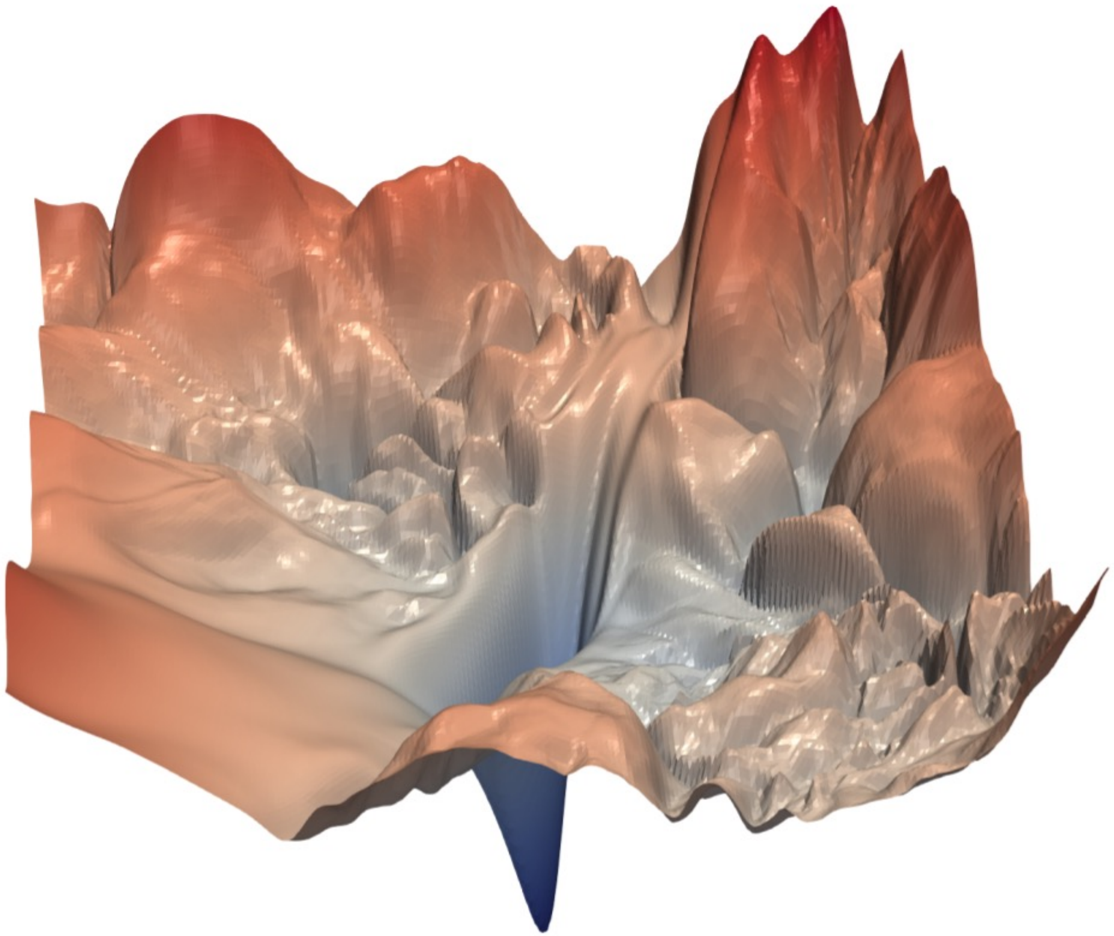
Loss (function)

What is a loss function?

Models are often parametrized. In order to pick the "**best**" set of parameters, we need to "**measure**" the model performance.

The loss function is a real-valued function which measures how well a model is performing.

The best model is the one with the lowest loss.



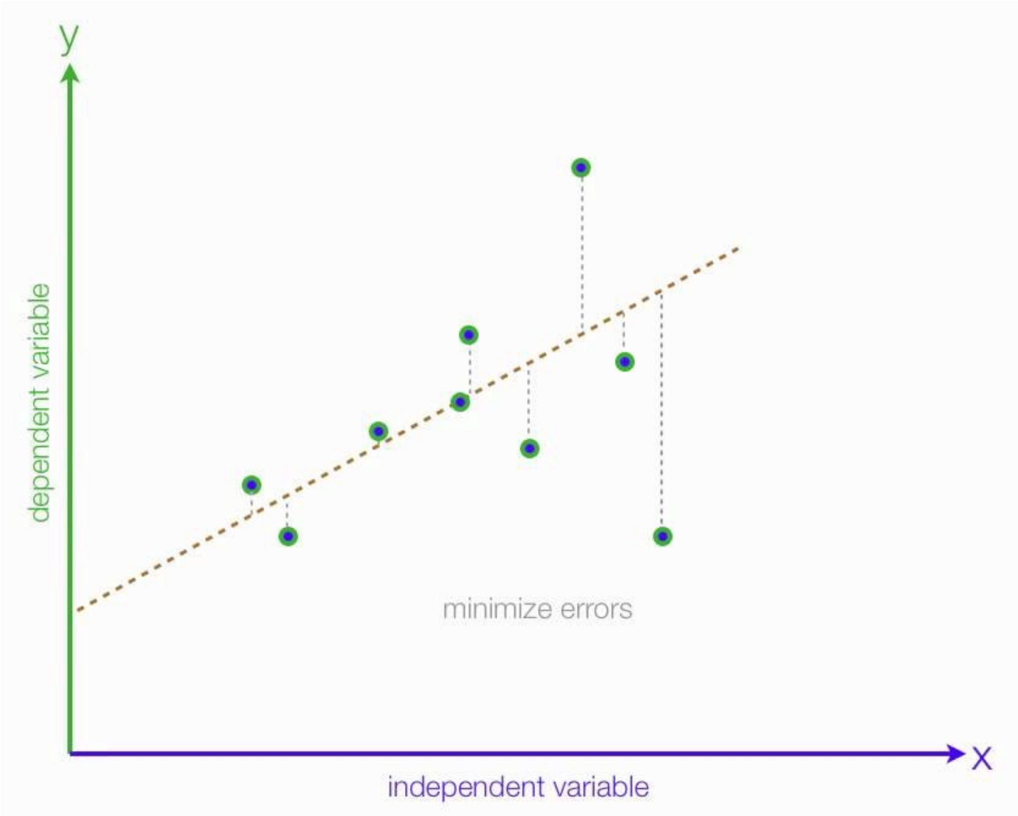
https://arxiv.org/pdf/1712.09913.pdf

What is a loss function?

The loss function is evaluated using the **data**.

Different problems result in different loss functions.

Different loss functions produce different **models**.

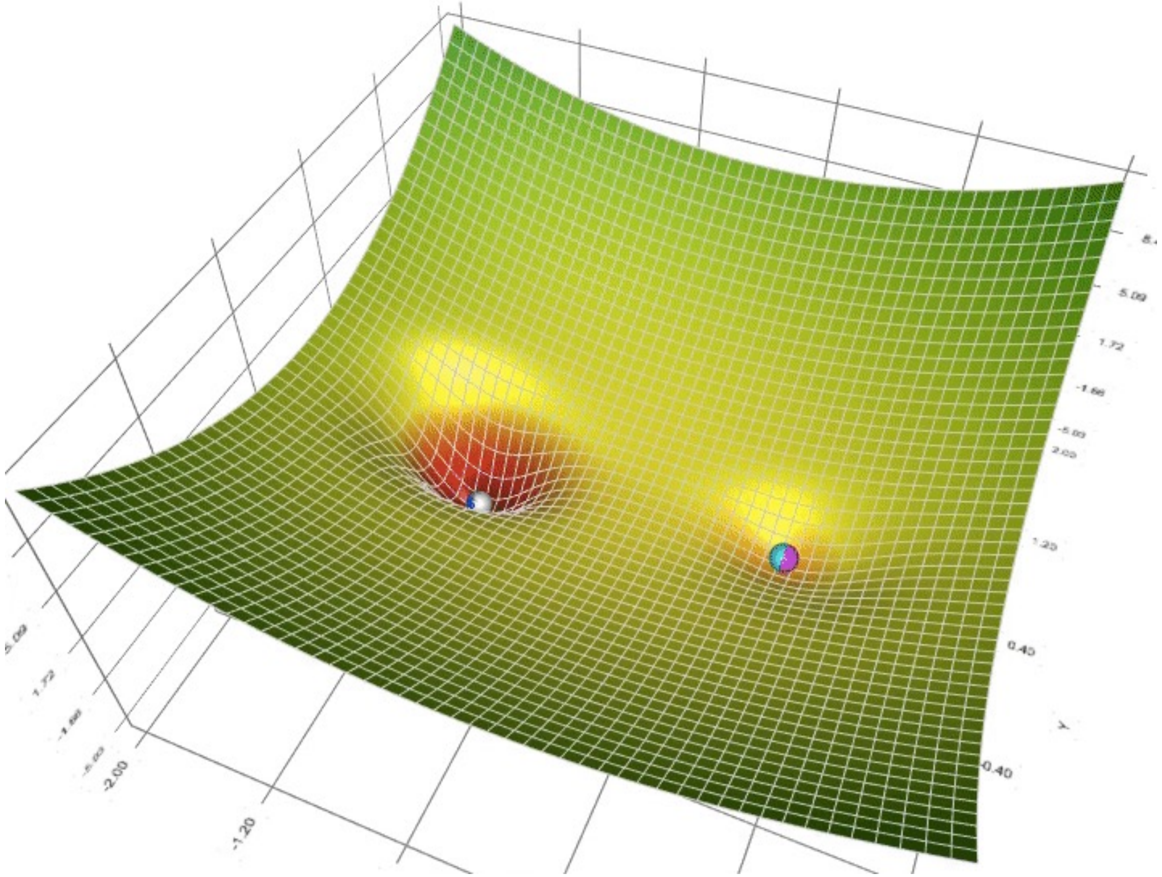


Learning Algorithm

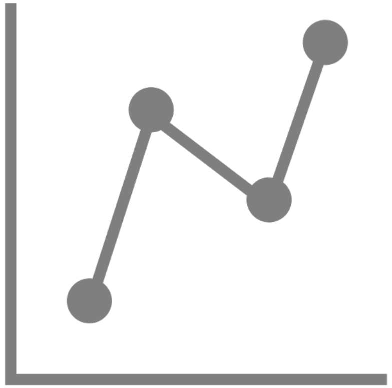
What is a learning algorithm?

An algorithm is a **set of instructions** to achieve a task.

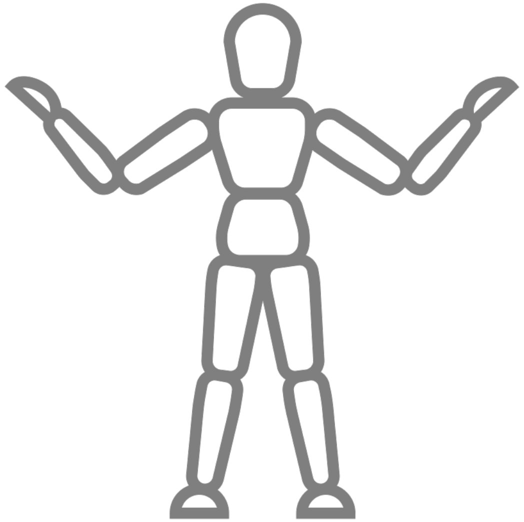
A learning algorithm (tries to) finds the model parameters which **minimize the loss** given a cost function **dependent on some data**.



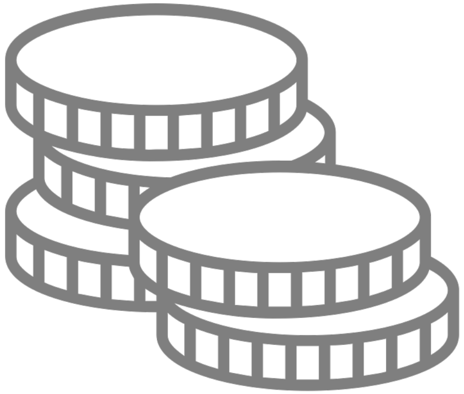
Data



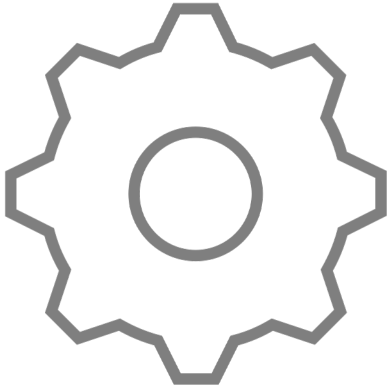
Model



Loss



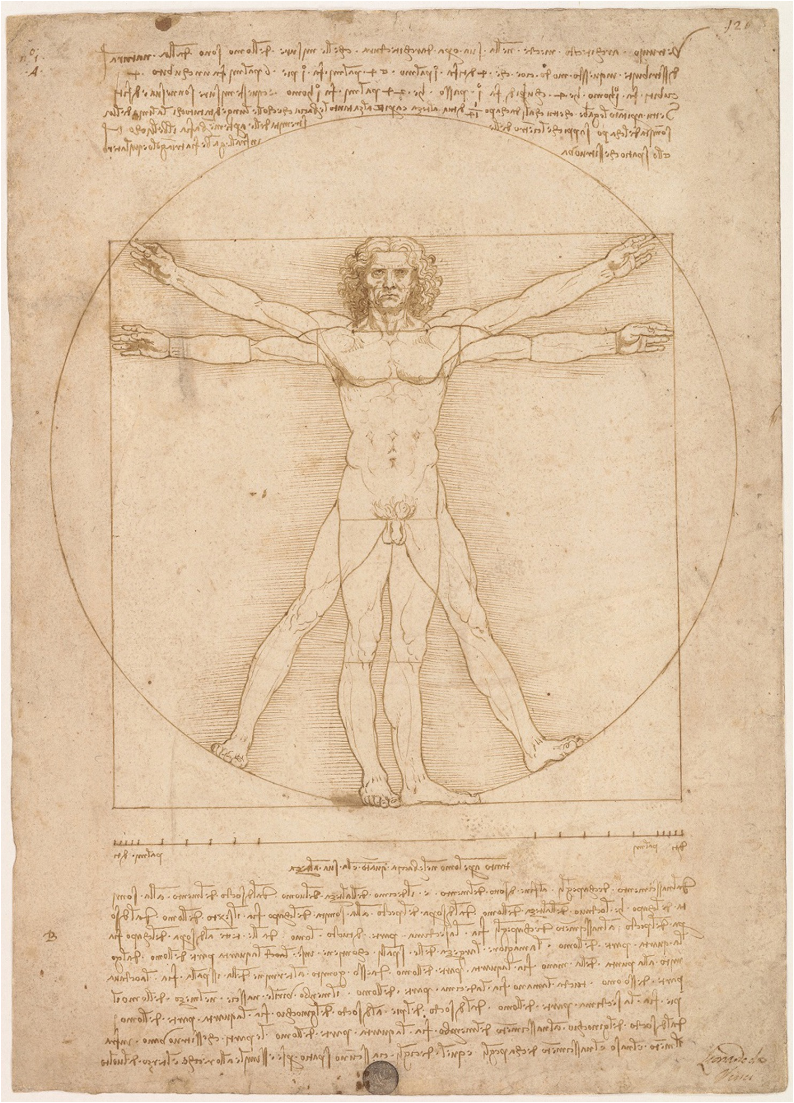
Learning algorithm




THIS IS MADNESS!

Examples

Problem Statement

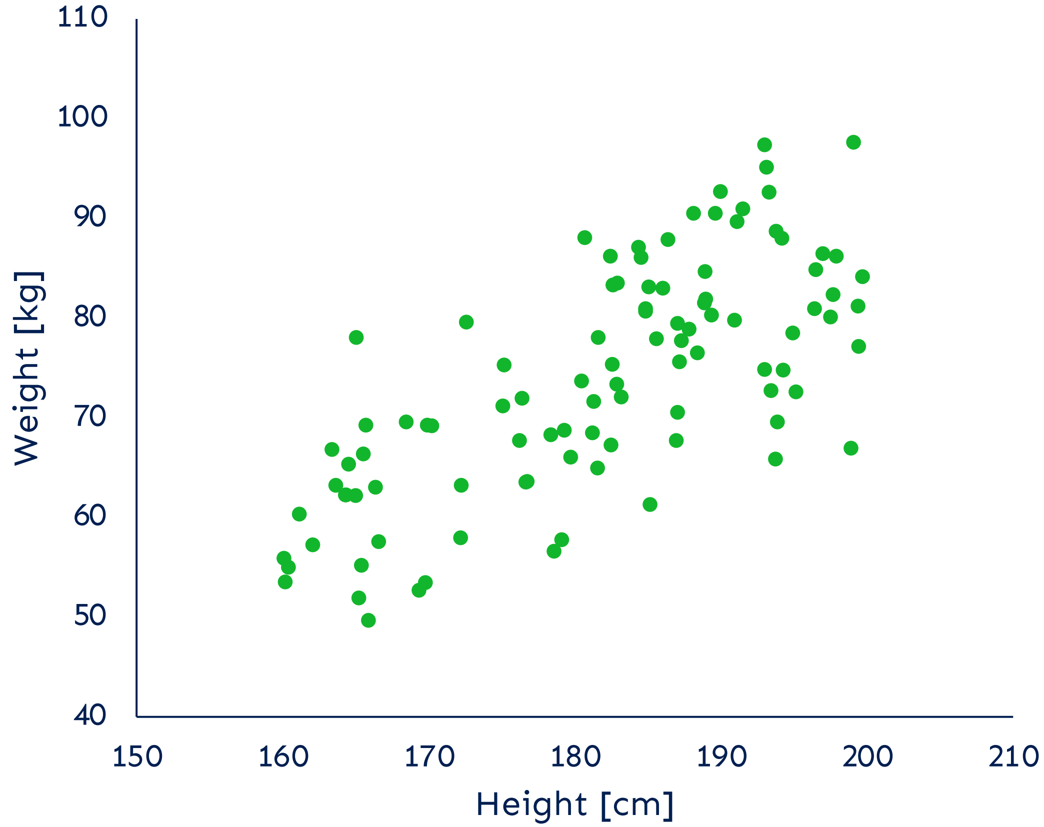


We are analyzing a **group of 23-year-old university students**, focusing on their physical characteristics.

Specifically, we have measured each student's **height and weight** and aim to develop a model to predict a student's weight based on their height.

Data

Height [cm]	Weight [kg]
182	78
183	84
191	80
175	75
193	97
190	91
170	69
193	95
199	81
172	58
166	66
187	71
...	...



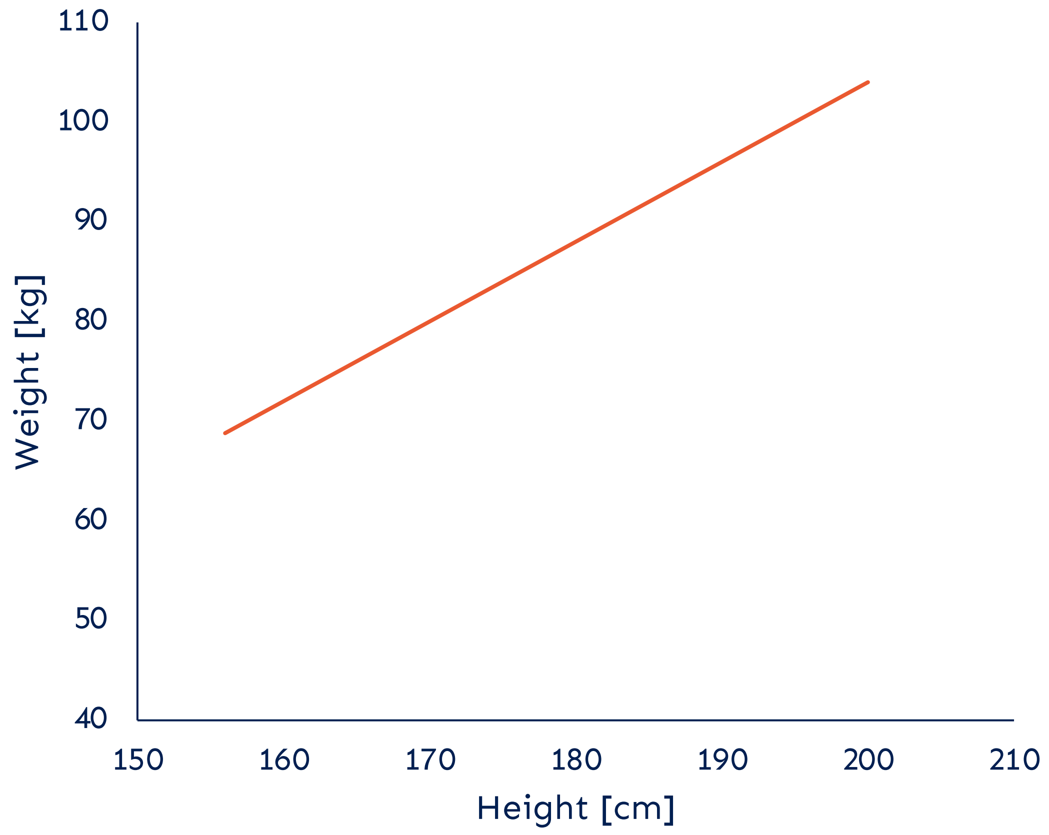
Model

The relationship between weight (P) and height (A) appears to be **linear and direct**: as height increases, weight increases proportionally.

Based on this, we propose the following model:

$$P = f(A) = \alpha A + \beta$$

where α and β are the model parameters.

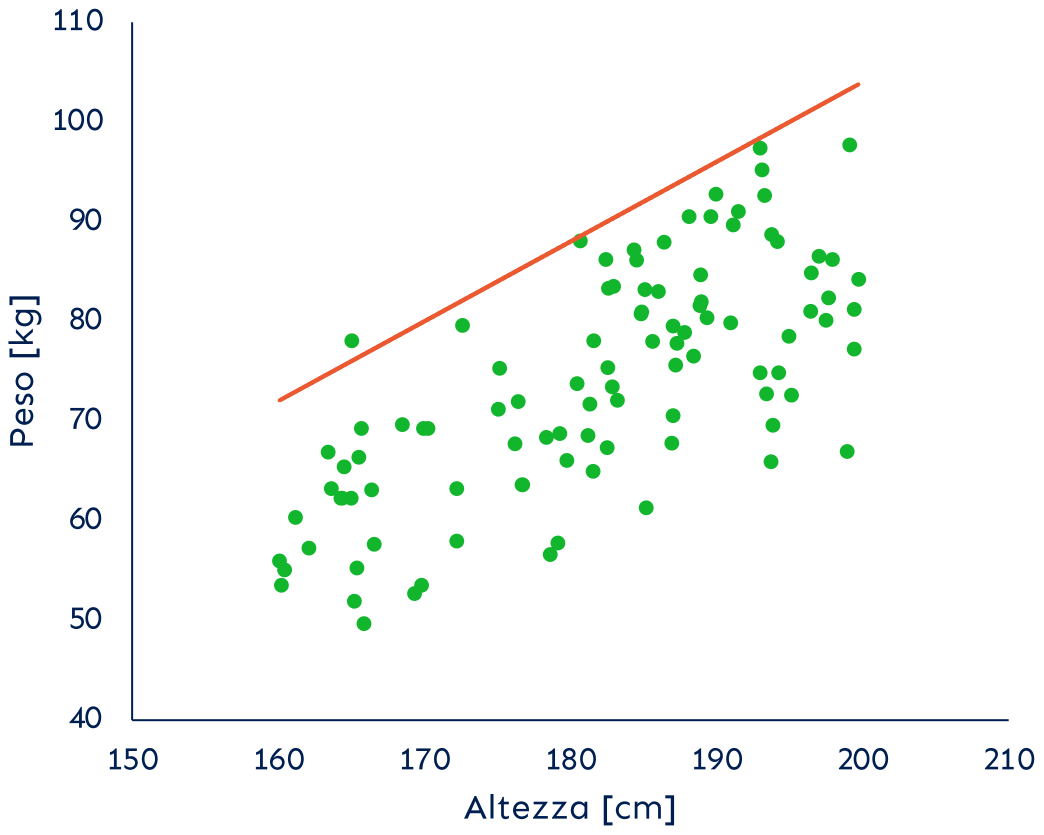


Loss Function

We want the model to explain the collected data.

Therefore, we construct the cost function to penalize the difference between the value predicted by the model and the actual value.

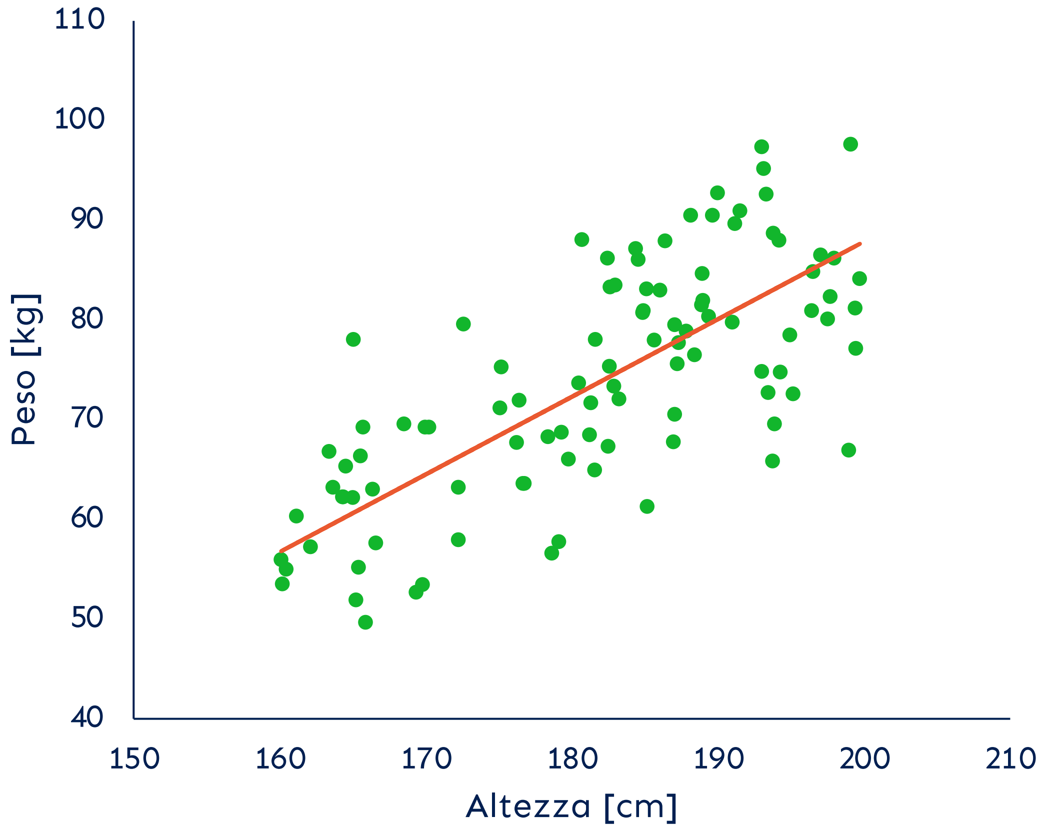
$$L = \sum_i (P_i - (\alpha A_i + \beta))^2$$



Training Algorithm

We want to minimize the value of the loss function L with respect to its parameters α and β.

We can do that by paper and pencil or by numerical algorithms. In the end, we will find the values for α and β!



Problem statement

We are studying a baseball player practicing with a ball-throwing machine.

With experiments, we have collected some measurements of the initial angle and shot distance.

We are interested in predicting the distance of new shots given the initial angle.

We are not allowed to use physics!

A quick highlight

This is a great example of where Machine Learning **should not be used**.

Learning from data is complex and error-prone: there is no need and no gain from doing it when the first principles are enough.

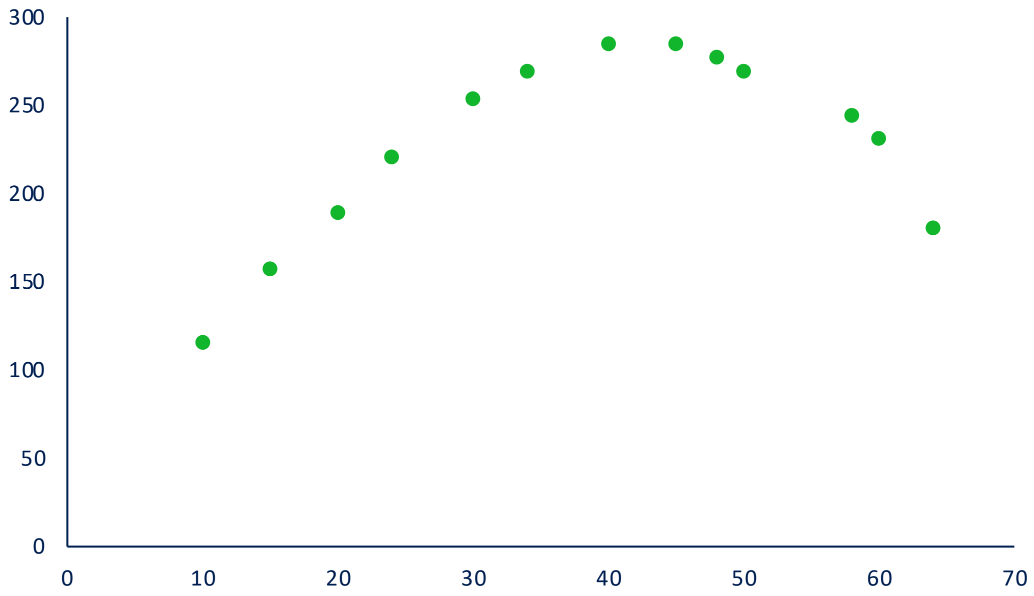
In this instance, we know from physics that:

$$D = \frac{v_0^2 \sin 2A}{g}$$

Where D is the distance, v_0 the initial velocity, A the initial angle with the soil and g the gravity acceleration.

Data

Angle [deg]	Distance [m]
10	115.6
15	157.2
20	189.2
24	220.8
30	253.8
34	269.2
40	284.8
45	285.0
48	277.4
50	269.2
58	244.2
60	231.4
64	180.4



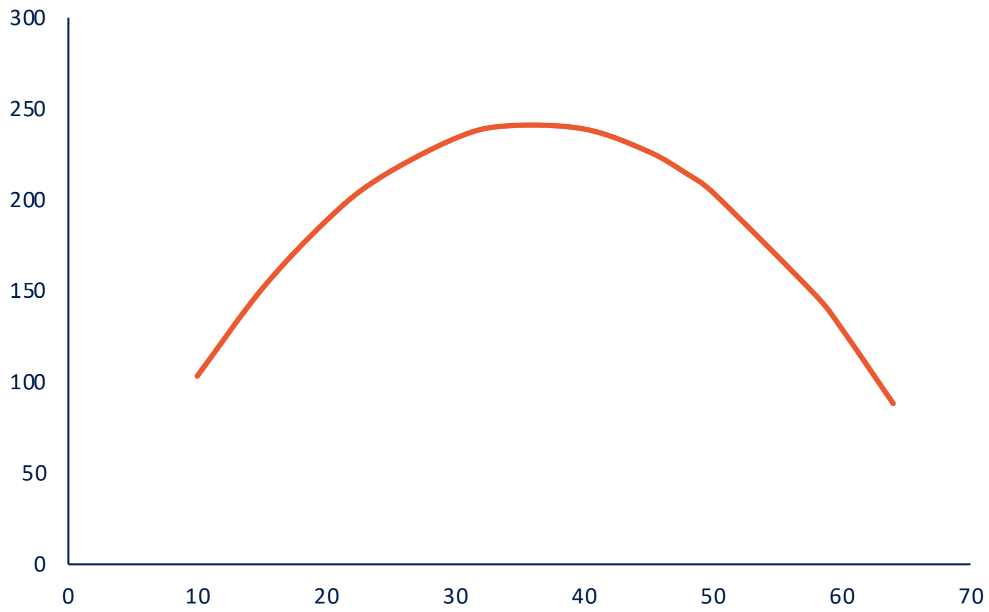
Model

The points seem to form a **parabola**.

So, we will use the model

$$D = f(A) = \alpha A^2 + \beta A + \gamma$$

with parameters α, β, γ.

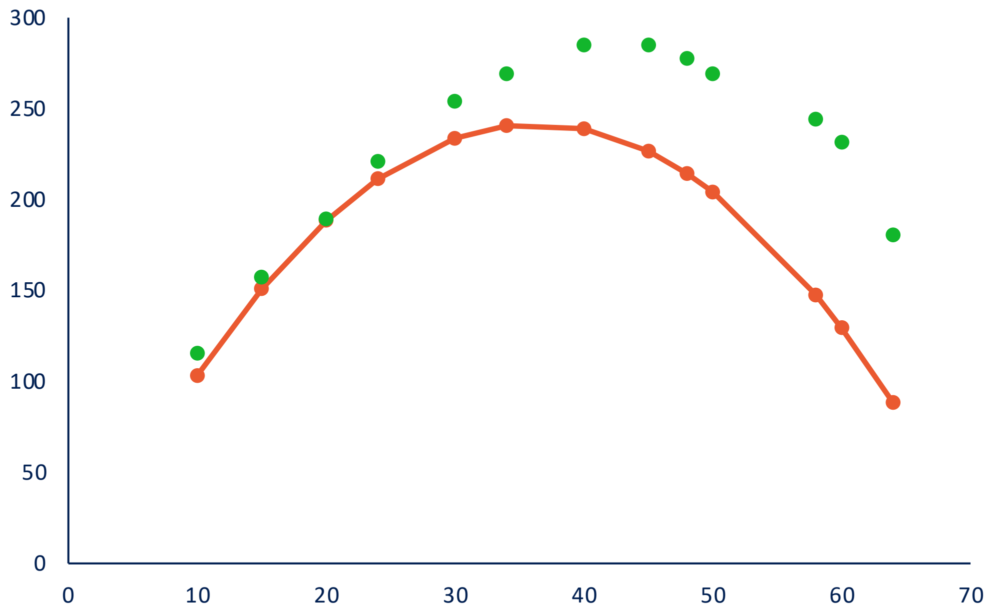


Loss function

We want our model to explain the data in the dataset.

We will penalize the distance between the actual data and the model prediction.

$$L = \sum_i \left(D_i - \alpha A_i^2 - \beta A_i - \gamma\right)^2$$



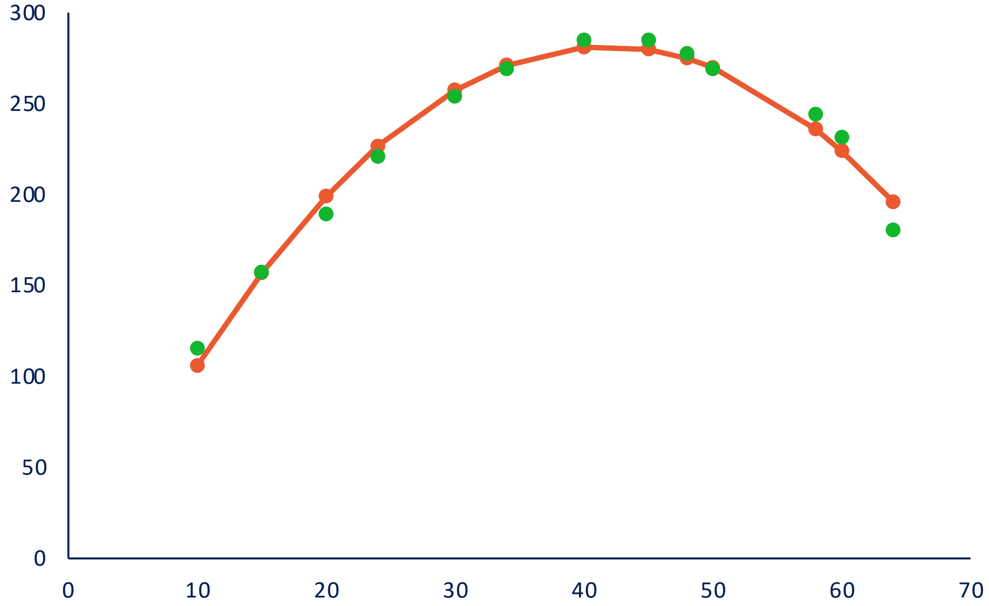
Learning algorithm

We want to minimize the cost function L with respect to the parameters α, β, γ.

$$L = \sum_i \left(D_i - \alpha A_i^2 - \beta A_i - \gamma\right)^2$$

We can do it with paper and pencil by setting the gradient to zero!

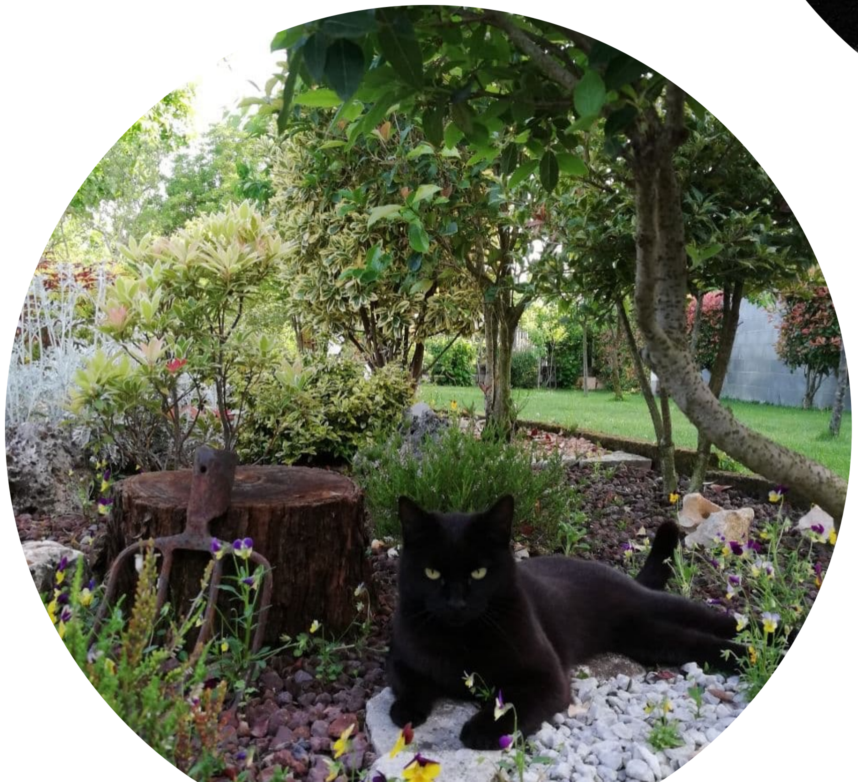
The result is the set of optimal parameters.



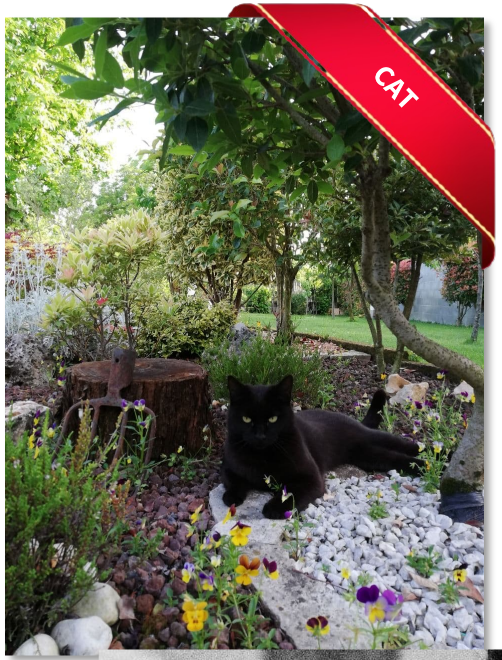
Problem statement

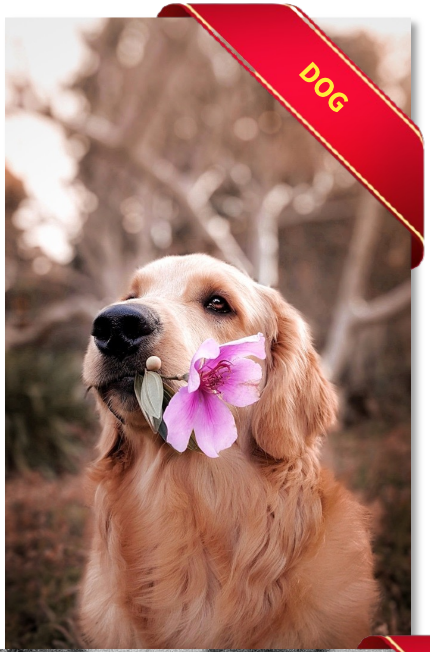
We are given a bunch of labelled pictures, containing either a **cat** or a **dog**.

We need to create a tool to classify new, unseen pictures as cats or dogs.

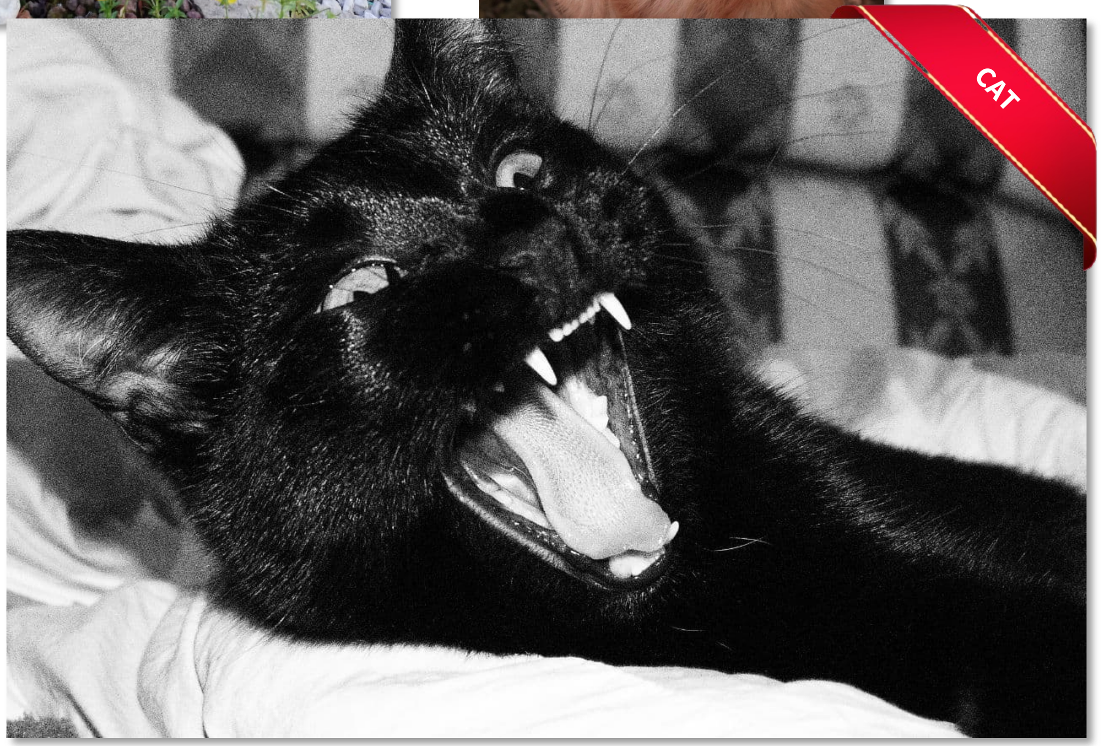


Data





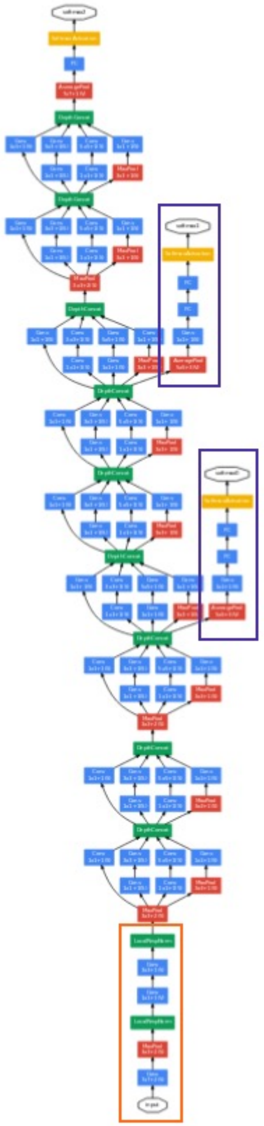
Data are labelled!



Model

The state of the art for most computer vision tasks is Deep Learning.

We can pick some standard network based on convolution, like **Inception** or **ResNet**.



Loss function

Binary classification, we will use binary cross-entropy.

$$L = -\frac{1}{N}\sum_{i=1}^{N} y_i \log(p_i) + (1 - y_i)\log(1 - p_i)$$

where:

y_i is the actual label for image i (0=dog, 1=cat)

p_i is the predicted probability for label 1 in image i

N is the number of images in the dataset

$L = 0.91$

$L = 2.30$

Learning algorithm

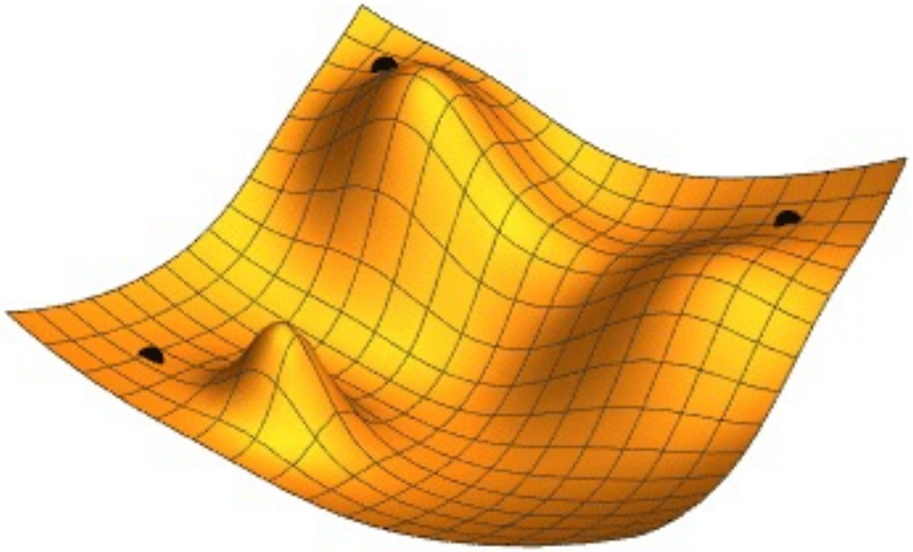
The loss function itself may seem easy.

$$L = -\frac{1}{N}\sum_{i=1}^{N} y_i \log(p_i) + (1 - y_i)\log(1 - p_i)$$

But p_i is computed by the model, which is very complex!

So, it is impossible to find a minimum with paper and pencil, and it may be **very hard** even with an algorithm.

Deep Neural Networks are generally trained by (some variant of) **gradient descent.**



Resources

Gareth James, Daniela Witten, Trevor Hastie, Rob Tibshirani, *An Introduction to Statistical Learning*: a great book for machine learning on tabular data.

Trevor Hastie, Robert Tibshirani, Jerome Friedman, *The Elements of Statistical Learning*: the advanced version of “Introduction”, with more math and deeper discussions.

AI Projects

Discussion

As a manager at De’ Paperoni Bank, you oversee the process of granting mortgages. The process involves **evaluating 300,000 houses** and apartments each year, resulting in an annual cost of €300 million.

Recently, you learned about AI. AI can make the evaluation faster, more accurate, and cost-effective.

What steps would you take to **build an AI solution**?

1. Business Understanding

- Workshop
- Evaluation metrics
- Literature review

2. Data Gathering

- Source discovery
- Data preparation
- Quality assessment

3. Data Exploration

- Explorative analysis
- Data cleaning

4. Modelling

- Feature engineering
- Model design
- Model implementation

5. Evaluation

- Performance evaluation
- Time evaluation

6. Deployment

- Execution scheduling
- Performance tuning
- Integration

1 – Business Understanding

Many AI projects fail because they answer the wrong question, even if the answer is correct.

To avoid this, start by **defining a clear and measurable business goal**. Focus on identifying one primary business metric to optimize—whether to maximize or minimize it.

Next, consider the **constraints**. Are there regulations to comply with? Technical limitations to address? Or existing processes that must remain unchanged?

Finally, summarize your discussions in a **formal problem statement**. This ensures clarity and alignment for everyone involved.

2 – Data Gathering

Ready-to-use datasets are only found on platforms like Kaggle.

In real-world business settings data is often scattered, poorly documented, and messy. During this stage, engineers collaborate with colleagues across the company to **locate the data and understand the meaning of each field**.

At this point, you may decide to discontinue the project if the required data is unavailable or opt to gather or purchase additional data as needed.

Additionally, this phase involves **assessing data quality**, addressing missing values, and correcting errors to ensure the dataset is reliable for analysis.

3 – Data Exploration

We are **exceptionally skilled** at identifying patterns. During this phase, the goal is to use charts and summary statistics to understand the features and characteristics of your variables.

Are there any abnormalities? Do relationships between variables reflect real-world phenomena? Is there anything you can't explain?

Based on your findings, you might **revisit and refine your problem statement**, collect additional data, or exclude certain datasets.

In fact, many data science projects **end at this stage** because exploratory analysis often provides the answers you need.

4 – Modelling

The type of problem you are addressing—whether regression, classification, clustering, or something else—will determine the set of models you can use. We'll cover these types in more detail in future lectures.

Every model is built on certain **assumptions** about the process it represents. Be thoughtful about what you want the model to learn versus what you decide to impose.

Remember to consider your **constraints**. For example, in regulated fields where transparency is crucial, using complex deep-learning techniques might not be the best option.

For data types like audio, video, images, or language, you typically **use a pre-trained model or fine-tune an existing one**. With tabular data, you still need to **train** your models.

5 – Evaluation

It's time to put the metrics from the Business Understanding phase into action: each model must be evaluated based **on the specific use case**.

To do this, you'll train the model on **part of the data** and reserve the rest for testing its ability to generalise. While multiple evaluation methods are available, they are all based on the same principle.

It's important to focus on a single primary metric to compare models—this metric is often different from the loss function.

Additionally, review **fairness indicators** and check visualizations to assess the model's **overall fit and performance**.

6 – Deployment

Once a model is ready, it must be **integrated with systems or made accessible to users**. This involves evaluating technical requirements and designing the infrastructure, usually handled by engineers.

A key consideration is whether the model operates in batch or real-time mode. Batch models process data periodically, while real-time models respond instantly, which can be more challenging. For example, a fraud detection model must evaluate credit card transactions in seconds to avoid delays for users.

After deployment, **managing changes** becomes crucial, a topic we'll explore in a later lecture.

Why a Cycle?

Developing a successful model rarely happens on the first try.

It often requires 3 to 5 cycles to create one that meets the business goals. The process typically **starts with a simple model**, gradually increasing in complexity with each iteration.

After evaluating a model's performance, any errors are analyzed to identify potential gaps or missed details. This often involves **revisiting the exploratory analysis** to refine the approach.

With each improvement, the model is **re-evaluated** to determine whether the updates have led to meaningful progress. Through this iterative process, the model is fine-tuned to achieve its desired outcomes.

Resources

IBM, *Cross-Industry Standard Process for Data Mining*: the first structured process for data science, machine learning, and AI projects.

Microsoft, *Team Data Science Process*: an evolution of CRISP-DM with more focus on the engineering aspects of the process.

The End