

# Fundamentals of Machine learning for and with engineering applications

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1 Statistics, Machine learning or Artificial intelligence?

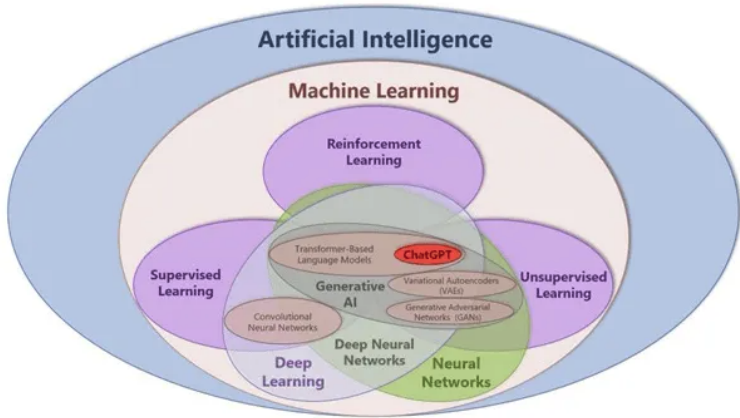
2 Machine Learning intro

3 Coding quality

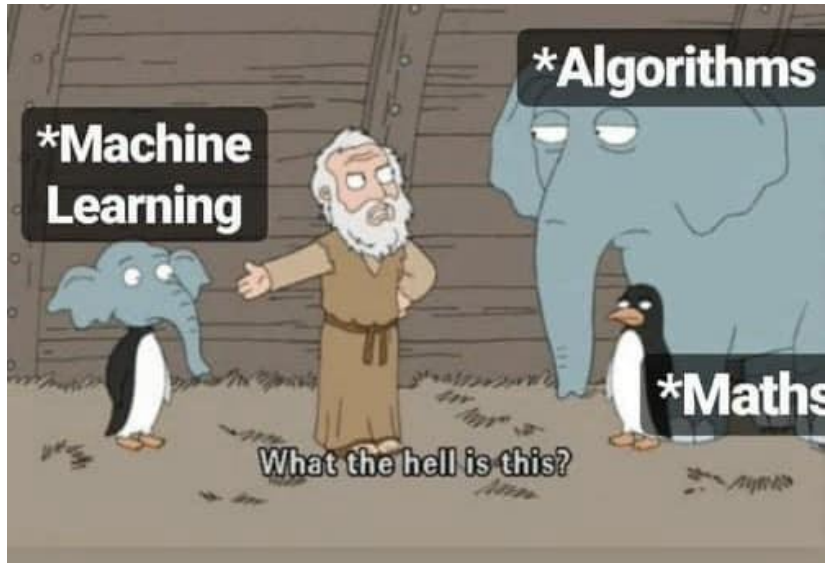
4 Version control

# Statistics, Machine learning or Artificial intelligence?

What is the main difference between the three fields?



# How Machine Learning Started?



## Let's start from the definition

- Statistics (origin "description of a state/country") is the discipline that concerns the collection, organization, analysis, interpretation, and presentation of data.
- It is conventional to begin with a statistical population or a statistical model to be studied. Populations can be diverse groups of people or objects such as "all people living in a country" or "every atom composing a crystal".
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- Machine learning is a branch of artificial intelligence (AI) and computer science which focuses on the use of data and algorithms to imitate the way that humans learn, gradually improving its accuracy. [IBM]
- Machine learning (ML) is a field of study in artificial intelligence concerned with the development and study of statistical algorithms that can learn from data and generalize to unseen data, and thus perform tasks without explicit instructions. [WIKI]
- Machine learning is a subfield of artificial intelligence that uses algorithms trained on data sets to create models that enable machines to perform tasks that would otherwise only be possible for humans, such as categorizing images, analyzing data, or predicting price fluctuations. [Coursera]

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# Machine learning

## One technical definition

Machine learning is a set of computer based statistical approaches that aim to minimise the loss function to maximise inference accuracy. [Enrico, 5.2.2024]

**The loss function** is the actual engine in machine learning.

## Loss function

It quantifies the difference between the predicted outputs of a machine learning algorithm and the actual target values.

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## And more definitions:

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- Artificial intelligence (AI) is the theory and development of computer systems capable of performing tasks that historically required human intelligence, such as recognizing speech, making decisions, and identifying patterns [Coursera]
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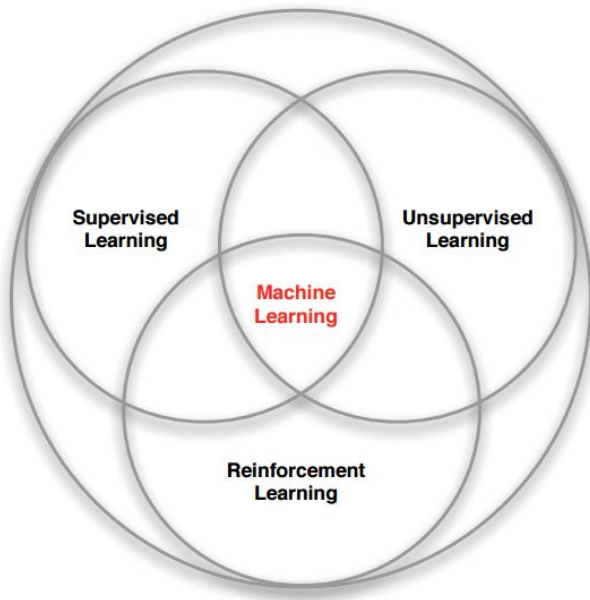
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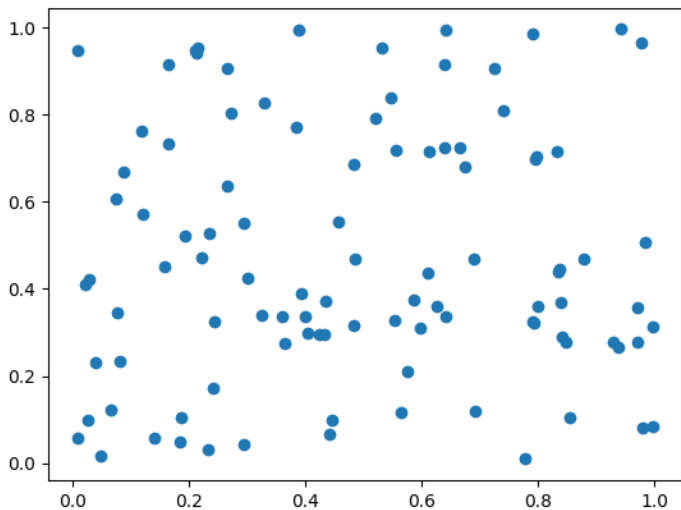
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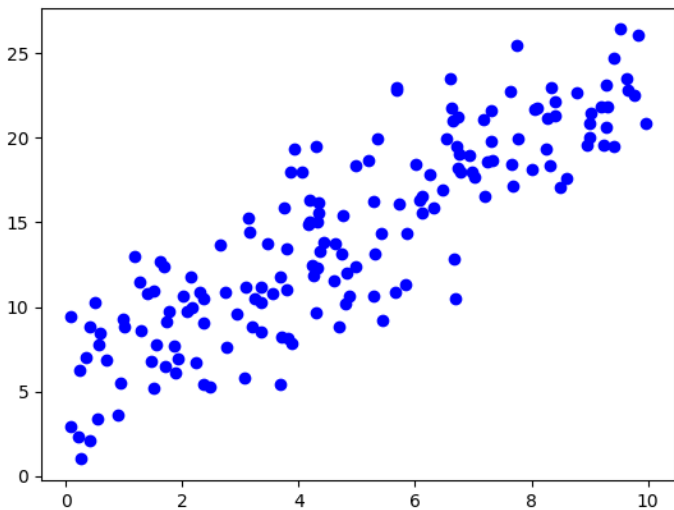
# Families of Machine learning



# What can we do with that?



What about in this case?





# Python Source code 1

```
import numpy as np
import matplotlib.pyplot as plt

# Generate some sample data
data = np.random.rand(100, 2) # 100 data points with 2 features

plt.scatter(data[:, 0], data[:, 1])
plt.show()
```

## Python Source code 2

```
import numpy as np
import matplotlib.pyplot as plt

def generate_linear_data(n_random_points, noise=16):
    x = np.random.rand(n_random_points) * 10

    # Make 'perfect' data
    true_slope, true_intercept = 2, 5
    y = true_slope * x + true_intercept

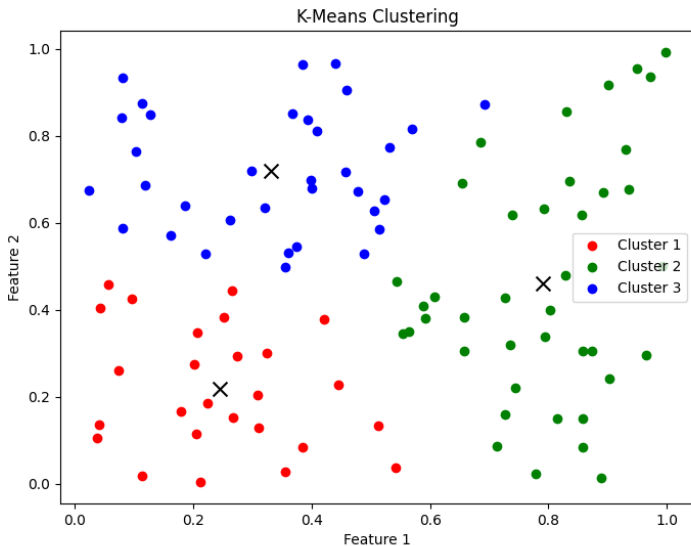
    # Add noise
    y += np.random.randn(n_random_points)*noise

    return x, y, true_slope, true_intercept

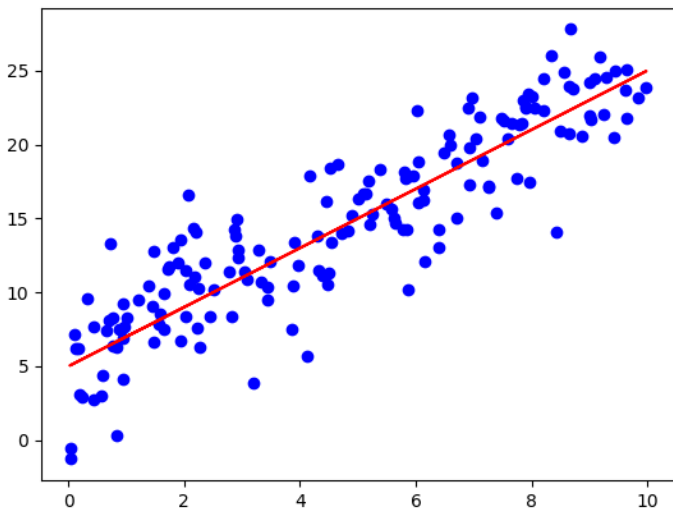
# Use the function to generate data
x, y, true_slope, true_intercept = generate_linear_data(
    n_random_points=166,
    noise=3)

# Plot all
plt.scatter(x, y, color='blue', label='Data Points')
plt.show()
```

# Unsupervised learning



# Supervised learning



# The data decides

This is why we focus so much on the data type.

The data properties dictate what statistical model can be adopted.

An statistical model has leverages our understanding of the data structure to improve its **predictions** (inference).

The numerical recipe that we used to generate the data is defined the **truth**

Psychology or data science?

Most Machine learning tools are aimed to find the truth. In most cases, we are happy to not find lies.

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Unsupervised learning, a term that resonates with the autonomy of machine intelligence, operates on the principle of identifying patterns and structures in datasets without labelled responses.

This branch of machine learning is distinguished by its lack of explicit guidance, where algorithms are tasked with uncovering hidden structures from unlabeled data.

The most common clustering strategies are :

- filtering
- clustering
- dimensionality reduction
- association learning

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# Application of unsupervised learning

It is a bit of a holy grail: a computer that finds patterns without guidance. (Yes, it doesn't work, most of the time)

Still, it has been shown efficient for:

- Computer vision
- Anomaly detection
- Exploratory data analysis

## Main challenge

The right result is quite undefined, Uncertain goal.

We will demonstrate it with a famous problem.

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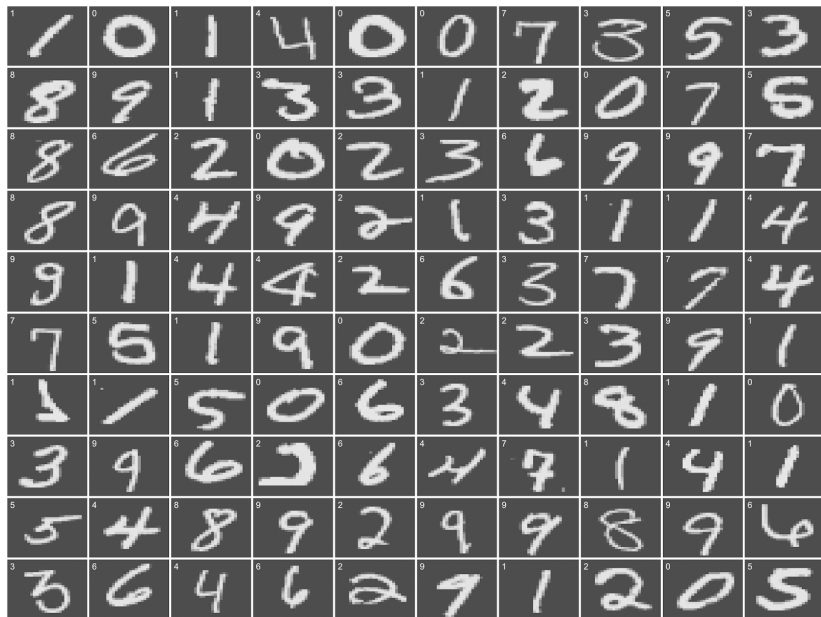
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# Uncertain goal



# Weak supervised learning

A less popular type of machine learning problem is when labels are assigned to groups of instances.

The group of instances is called **bag**.

The question is, what is the level of a previously unforeseen bag?

This data structure and question type request a hybrid treatment between supervised and supervised learning.

## Multiple instance learning

Multiple instances are needed to learn (quite clear name)

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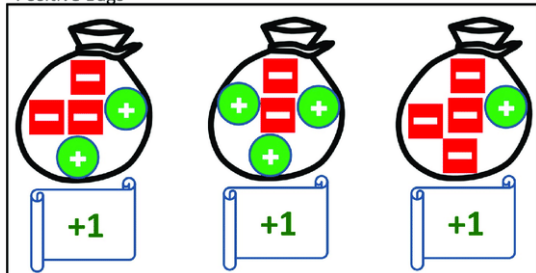
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Positive Bags



Positive Example



Negative Example

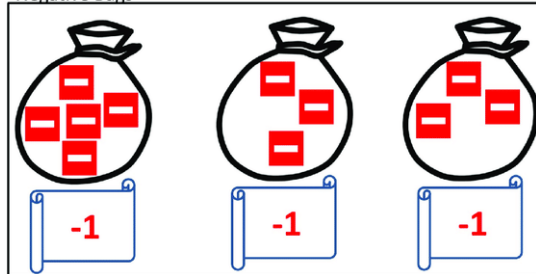


Positive Bag

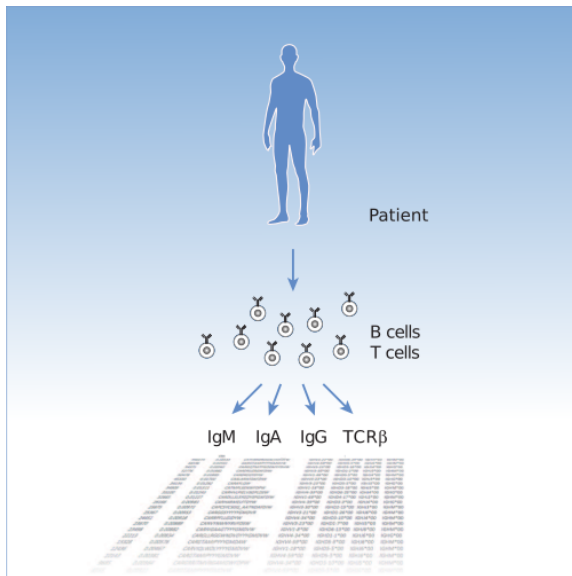


Negative Bag

Negative Bags



# Weak Supervised learning



# Reinforcement learning

Finally, there is a further approach.

## Reinforcement learning (RL)

It aims to train an intelligent agent to take actions in a dynamic environment in order to maximise the cumulative reward.

It learns from outcomes and decides which action to take next. After each action, the algorithm receives feedback that helps it determine whether the choice it made was correct, neutral or incorrect.

It is a self-teaching system that essentially learns by trial and error.

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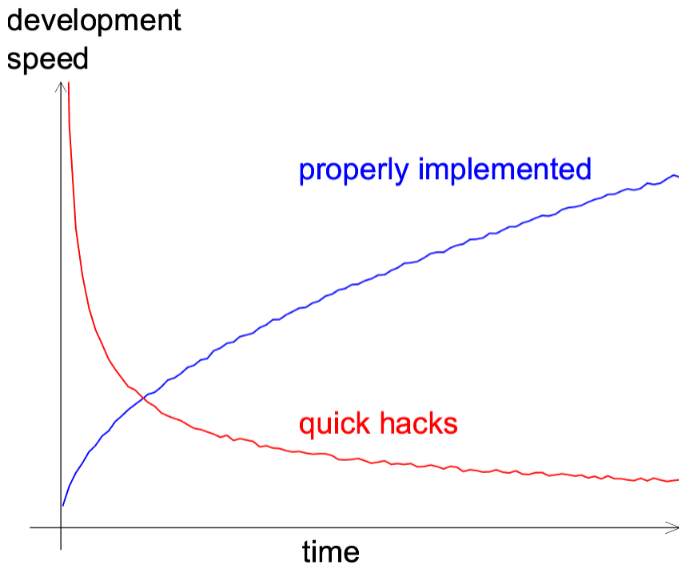
1 Statistics, Machine learning or Artificial intelligence?

2 Machine Learning intro

3 Coding quality

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# Flexible



# Developing approaches

Different code editors are available to interpret python language.

- jupyter notebooks are mostly dedicated to learning (Markdown)
- ipython is for interactive coding (similar to R, Matlab, etc)
- python packages (.py) developing suites (debug possibilities and git integration)

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# Introducing code standards

When developing code, there are **guidelines** and best practices aimed at improving the **quality, readability, and maintainability** of a code.

There are different levels of coding quality, mostly depending on the code intended usage (and developer skills).

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# Community level standards

## Principle of 'clean coding':

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2 Machine Learning intro

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## "FINAL".doc



FINAL.doc!



FINAL\_rev.2.doc



FINAL\_rev.6.COMMENTS.doc



FINAL\_rev.8.comments5.  
CORRECTIONS.doc



FINAL\_rev.18.comments7.  
corrections9.MORE.30.doc



FINAL\_rev.22.comments49.  
corrections.10.##\$%WHYDID  
ICOMETOGRADSCHOOL?????.doc

J. R. S. C. 2012

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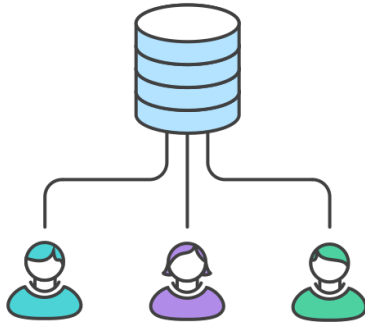
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# Centralized workflow



# A distributed version control system

## GIT

- Git facilitates users to track the various versions of files. It is not a necessary tool, but it can be very very helpful. Generally, the time spent to learn its syntax is well paid off

(do you remember to save some file like

*manuscript\_draft\_v4.02\_final\_definitive\_forreal\_lastcomments\_editedbyER\_submittedVersion*  
Exactly! Imagine to do that for a repository of files...)

- It permits to save and share the intermediate stages of a work in progress (which software is complete and always up to date?) in an accessible, consistent and structured way, allowing an effective version tracking. It allows retrieval of previous working versions, limiting the risk to overwrite useful files.

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# What is git actually for

The tool is particularly useful for programmers working in teams or in projects whose outcomes can be used by others.

- Git helps to co-develop a code, test its functions and the compatibility of the various code sections.
- A long list of further possibilities became possible by git.
- Different software integration on development platforms, based on git, will help you to develop and co-develop your code.
- The platform GitLab and GitHub have a large set of functionalities to further support code documentation and public releases.
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# What is git actually for

The tool is particularly useful for programmers working in teams or in projects whose outcomes can be used by others.

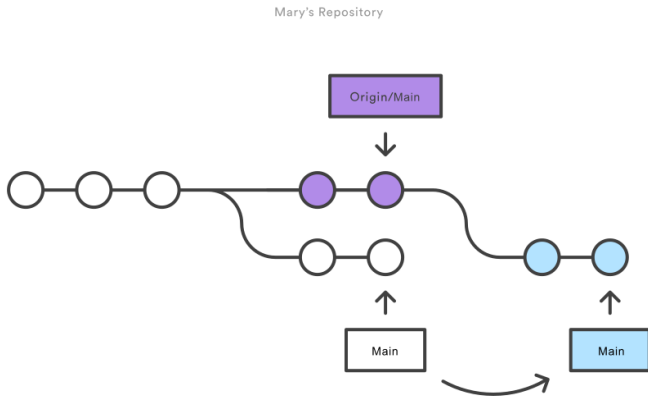
- Git helps to co-develop a code, test its functions and the compatibility of the various code sections.
- A long list of further possibilities became possible by git.
- Different software integration on development platforms, based on git, will help you to develop and co-develop your code.
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# How does it work -in short-



# Why should I care?

As the open libraries are exploding in numbers, you might need some criteria to assert the reliability of a project.

Unit test driven development!

That is taking full advantage of python object oriented structure.

## Community

Good project are not only used by communities, but also **supported**

Git allows the development of projects without a clear lead. Community engagement is generally a desirable target to help develop to directly integrate feedbacks by users (and fix bugs).

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