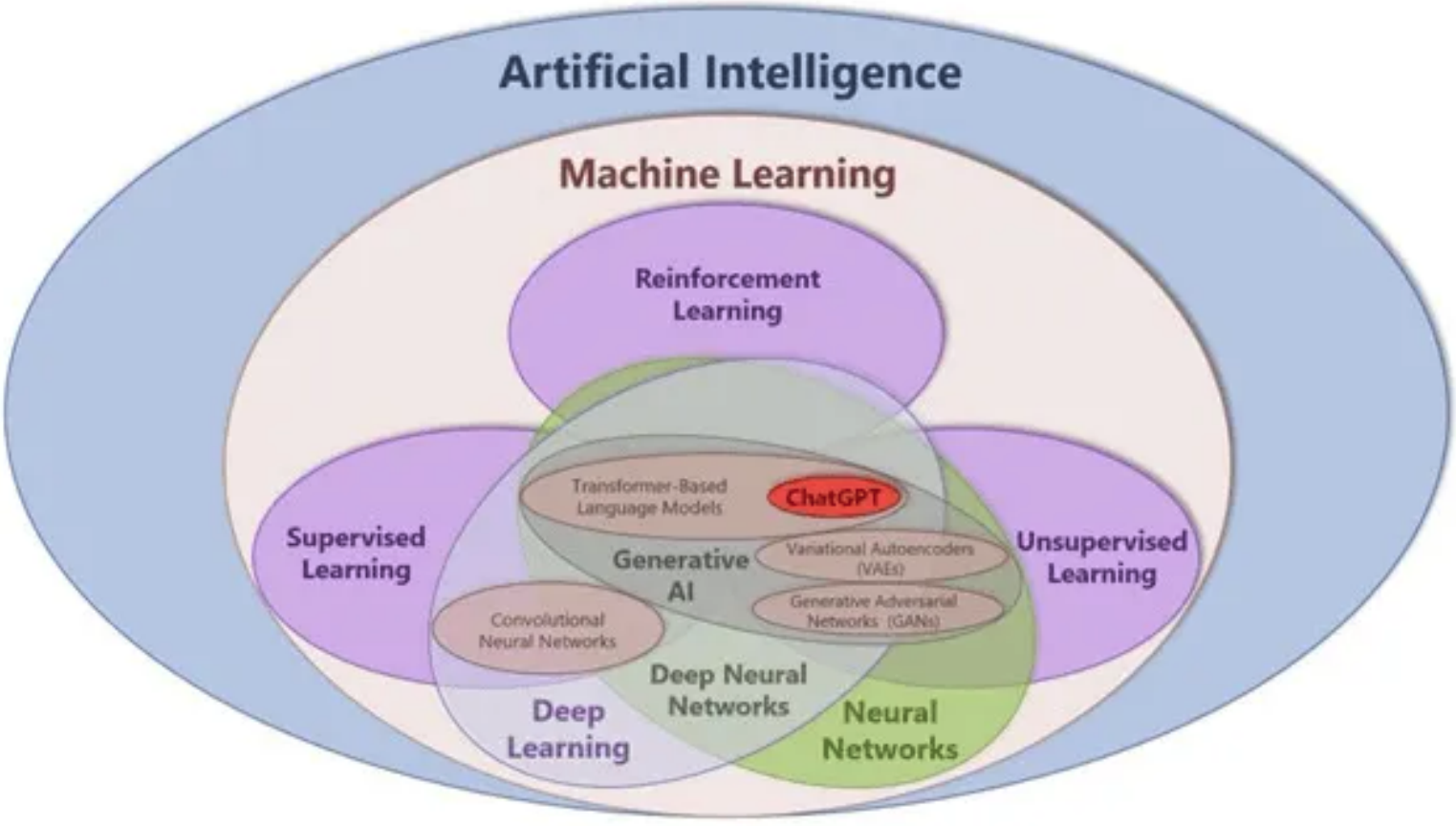
Applied statistics and Machine learning in Python with subsurface applications

Enrico Riccardi, University of Stavanger

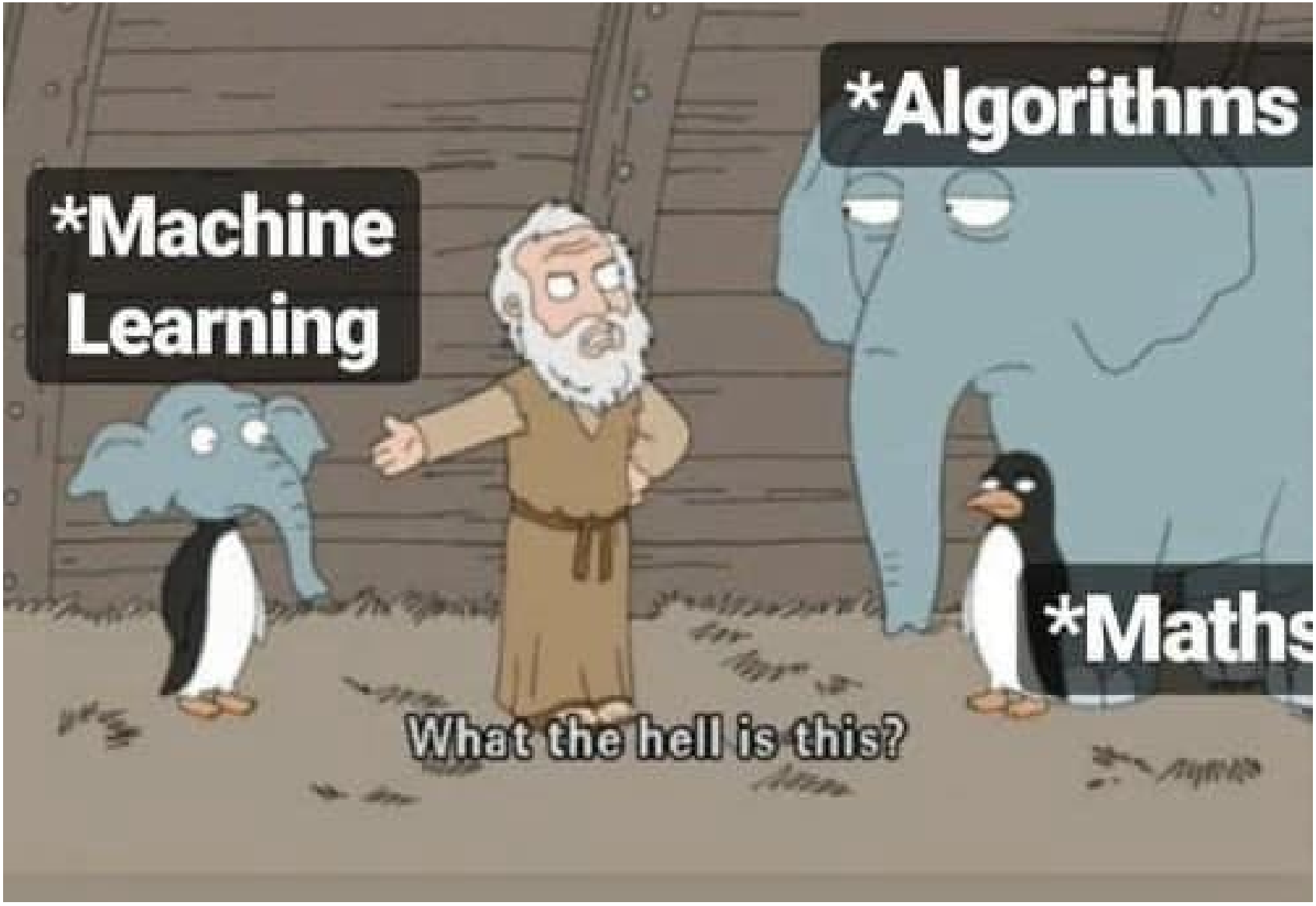
Mar 2, 2024

Statistics, Machine learning or Artificial intelligence?

What is the main difference between the three fields?



How Machine Learning Started?



Statistics

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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One technical definition

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The loss function is the actual engine in machine learning.

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

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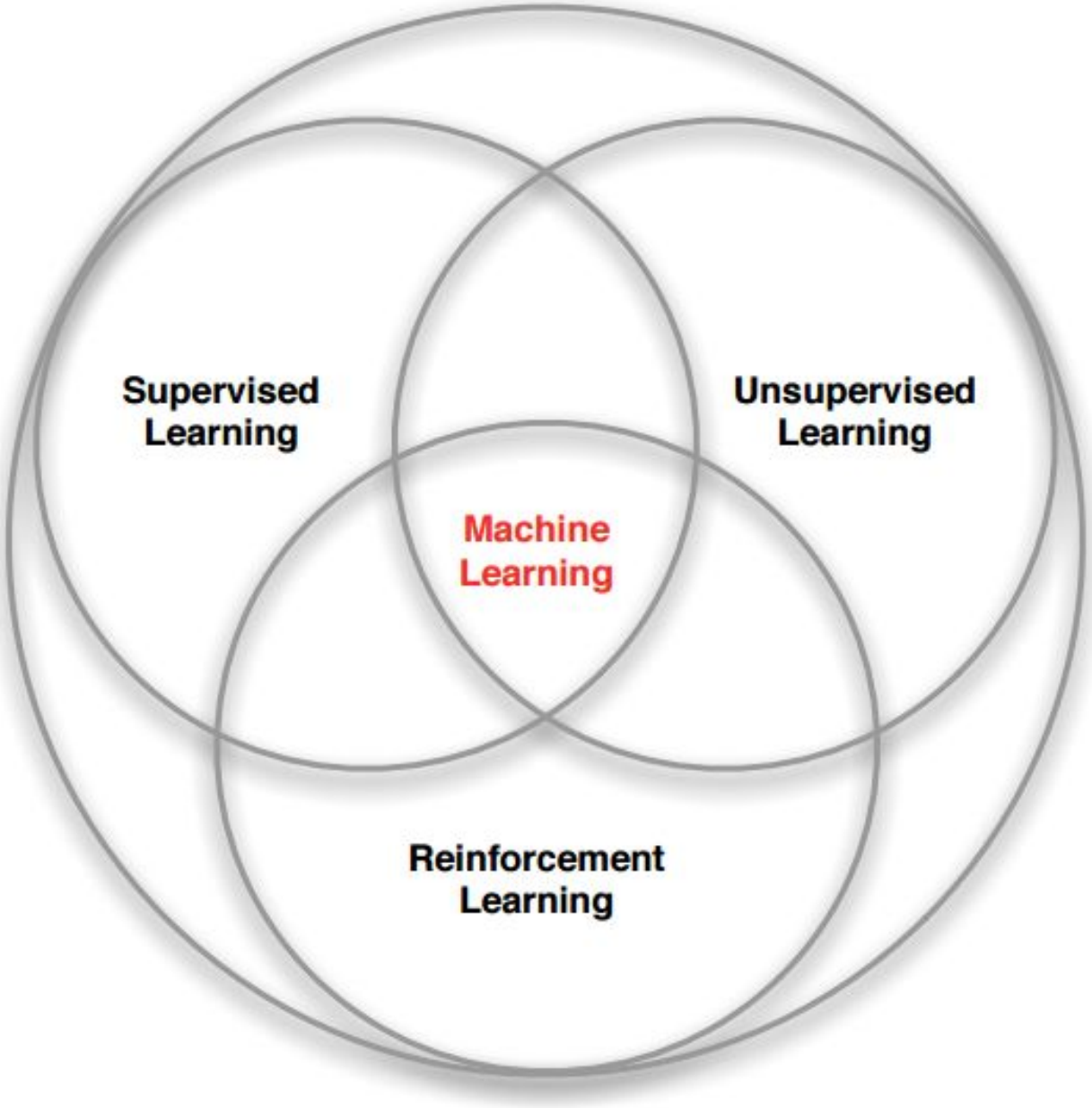
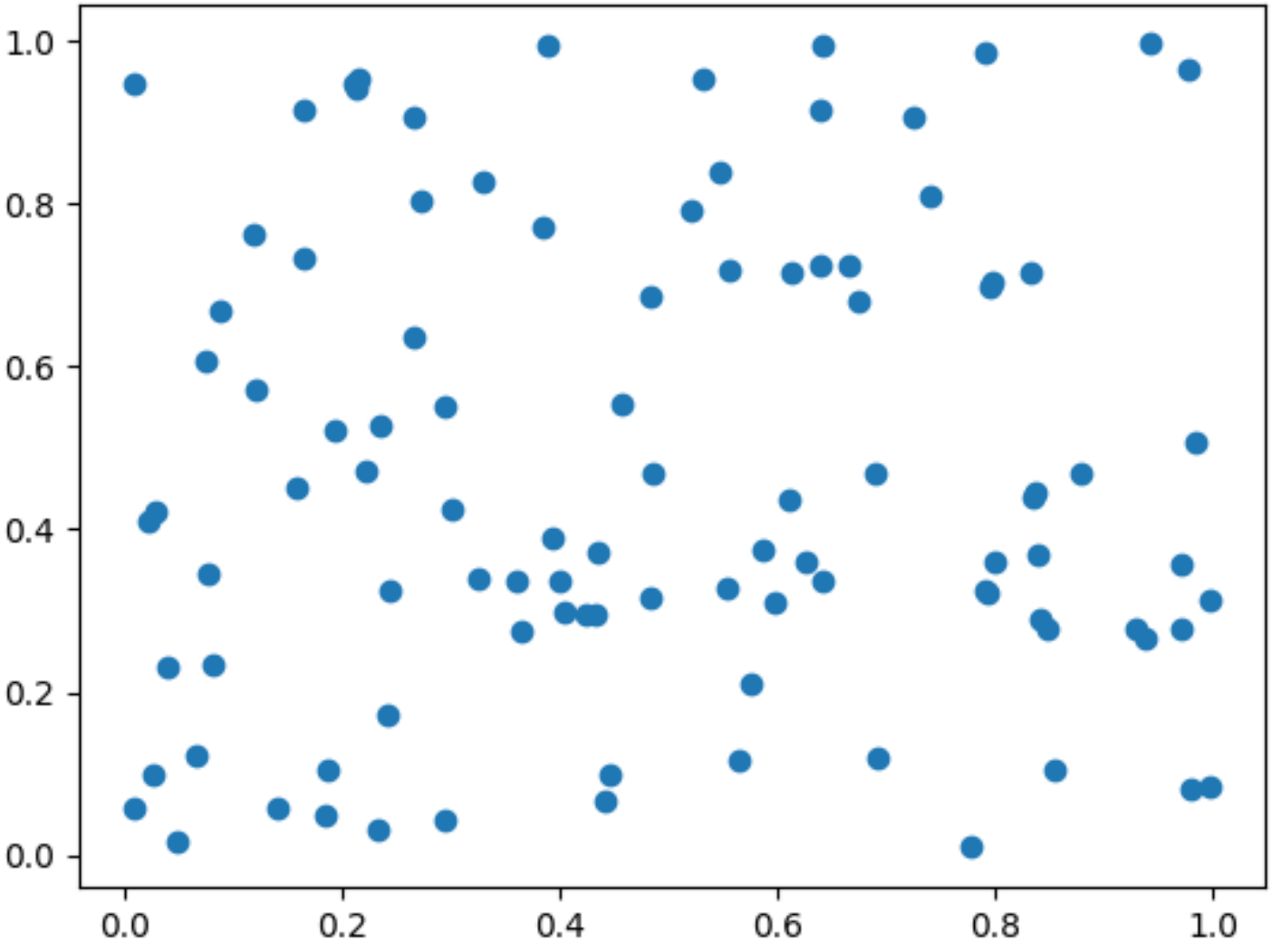
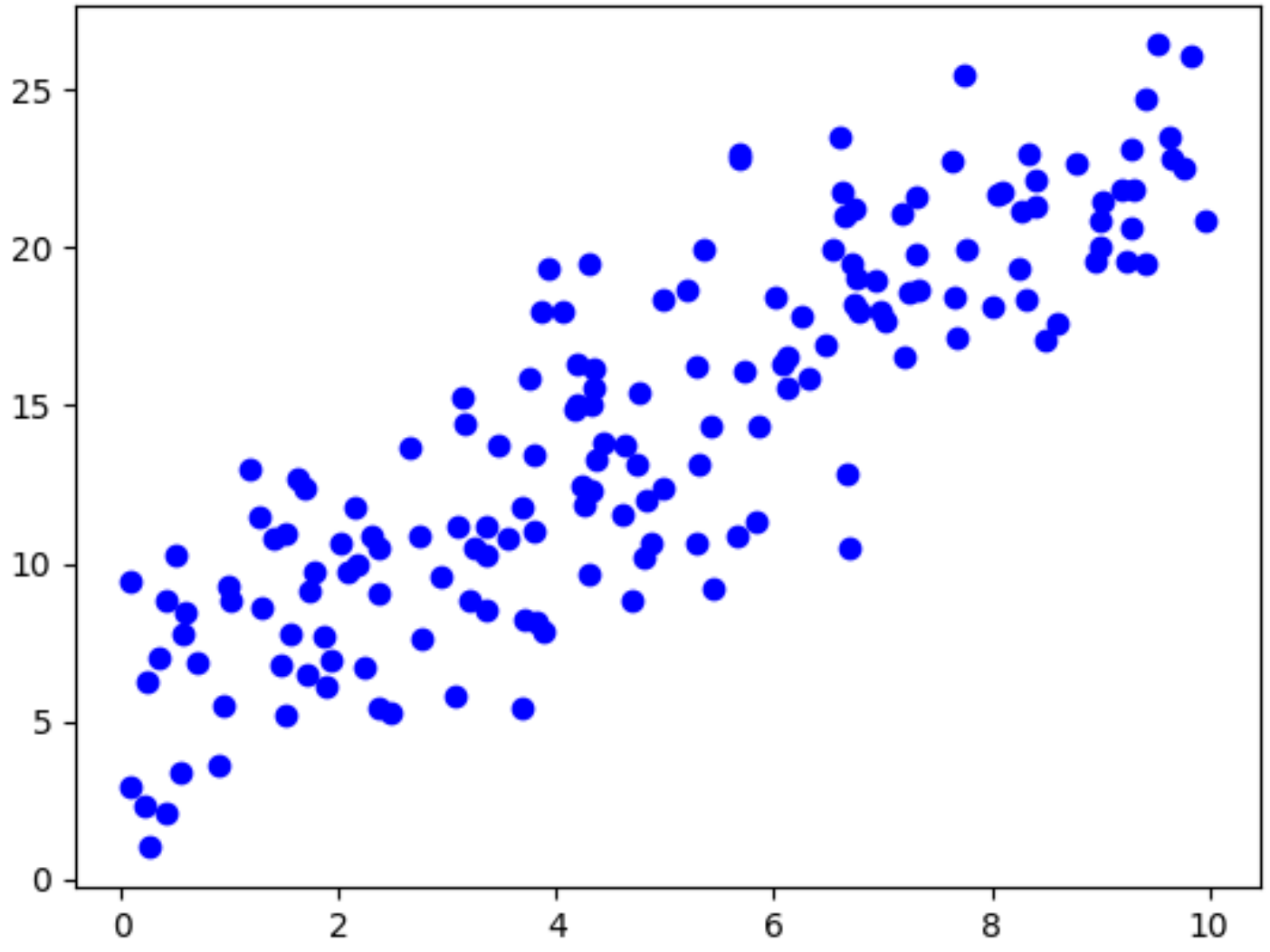
Families of Machine learning



What can we do with that?



What about in this case?



Python Source code 1

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

def generate_data(n_random_points, noise=16):
    x = np.random.randn(n_random_points) * noise

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

    return x, y

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

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

Python Source code 2

```python
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

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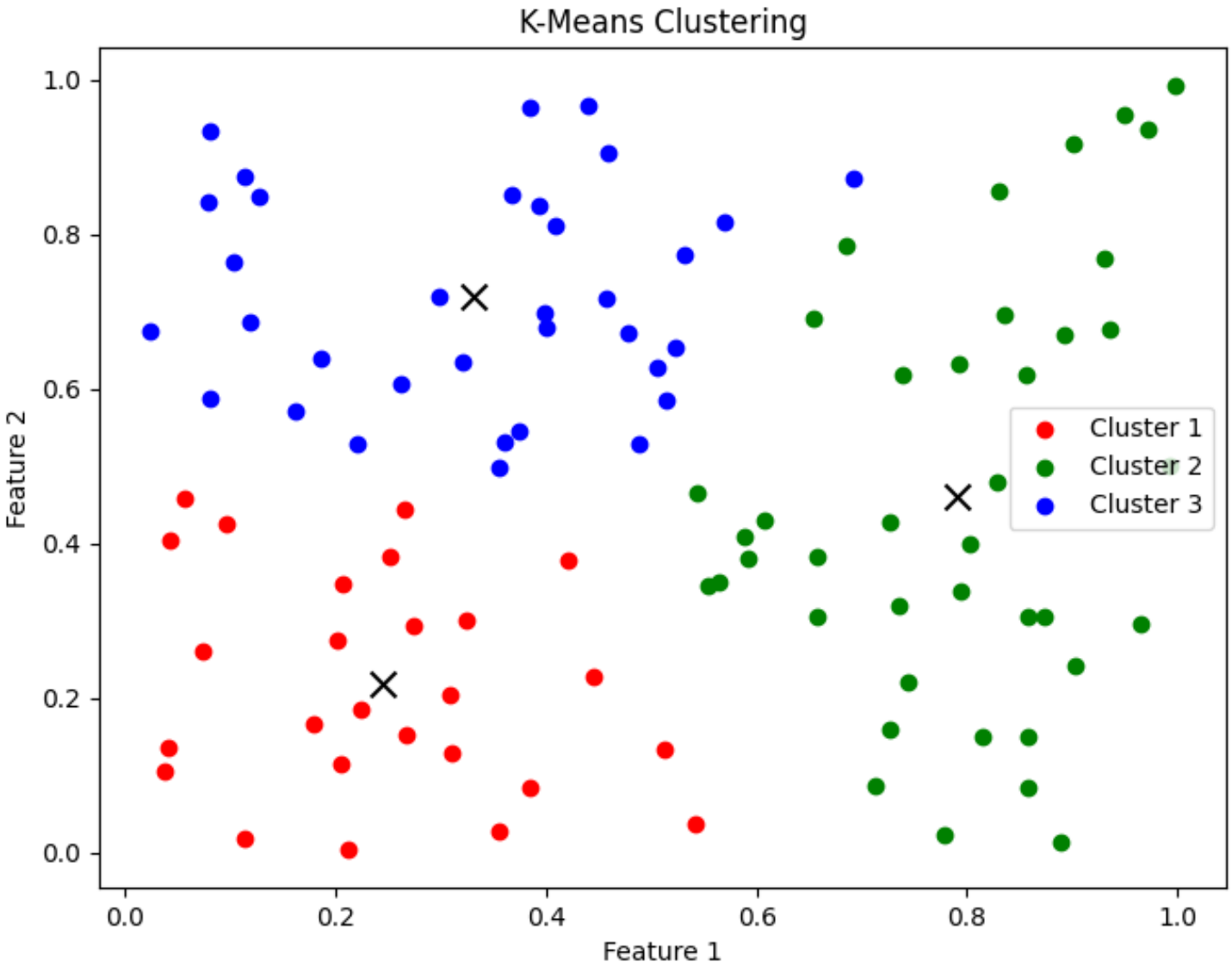
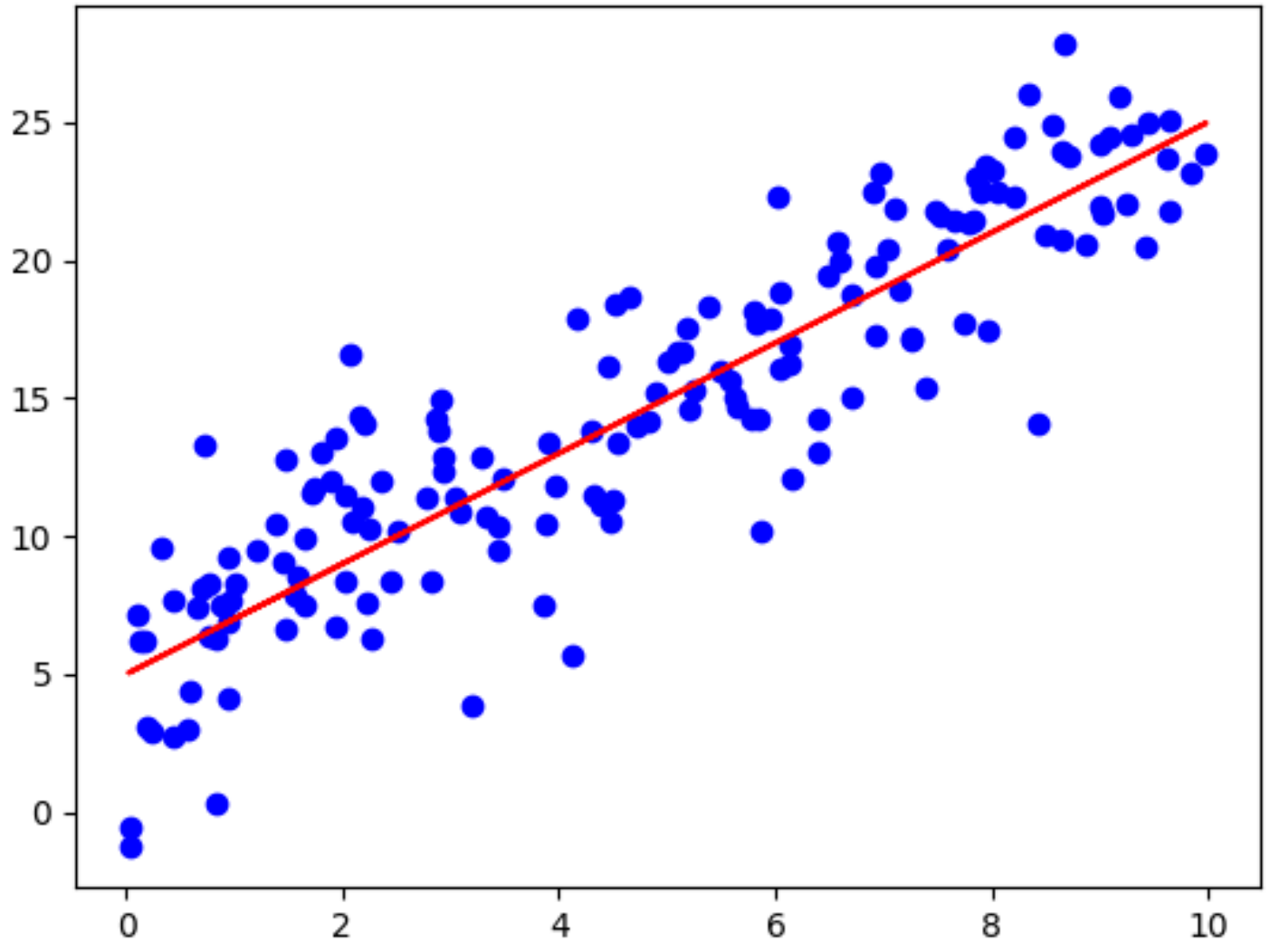


Supervised learning



Is the data to decide?

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.

It is much easier to start from a model (hyphothesis) and collect the data accordingly than the other way around.

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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.

Consider the famous ML digits challenge:

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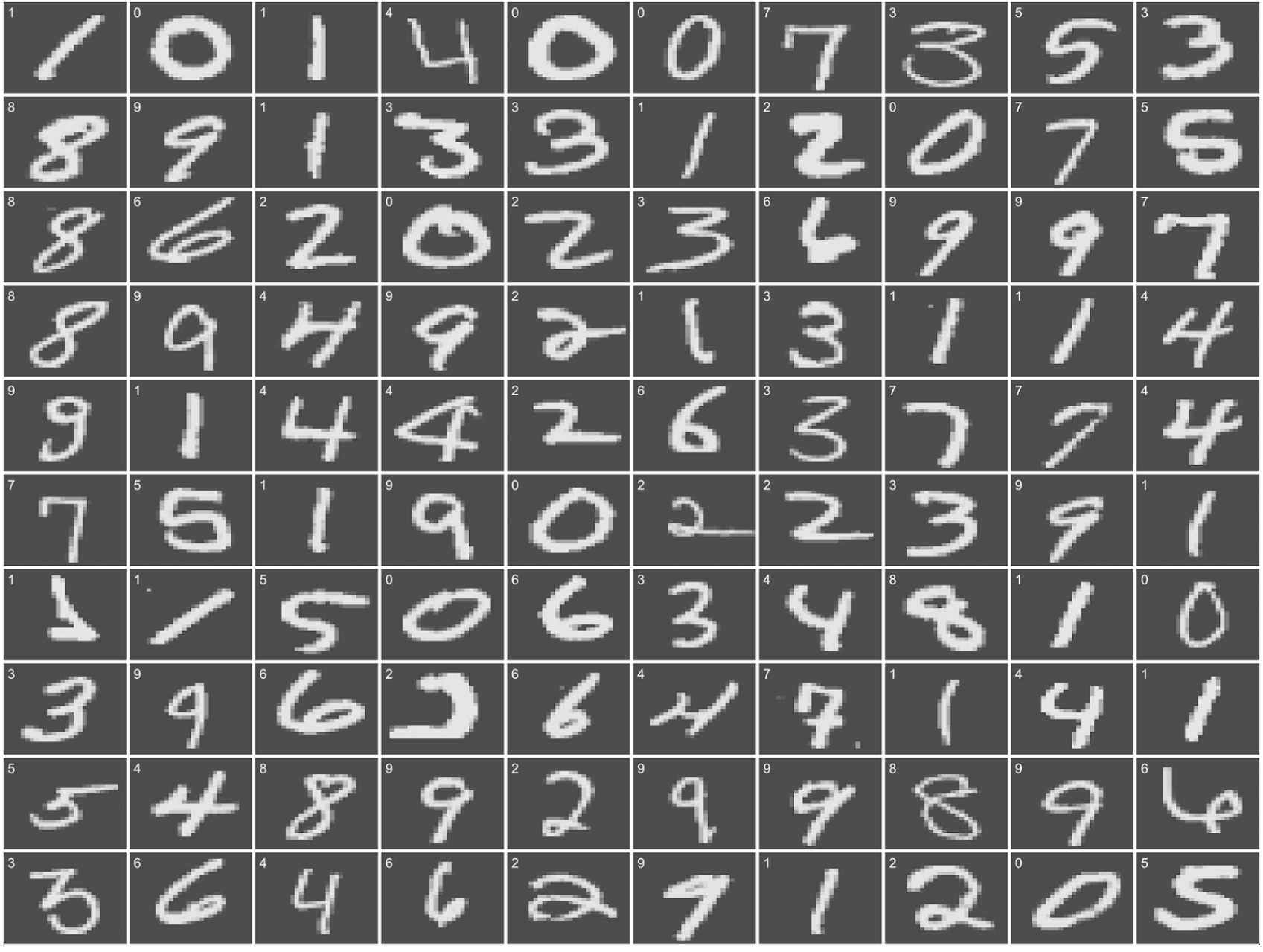

Supervised learning

Supervised learning, a term that implies external intervention (not sure if from a human anymore...), operates on the principle of identifying patterns and structures in datasets with labelled responses.

Data and labels

In a data matrix, one or more coloums are selected as labels (or target, or dependent variables)

The task is to either operate a **regression** or a **classification**

Most common approaches

- *Linear Regression*
- *Logistic Regression*
- *Support Vector Machines (SVM)*
- *Neural Networks*

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 learing

Multiple instances are needed to learn (quite clear name)

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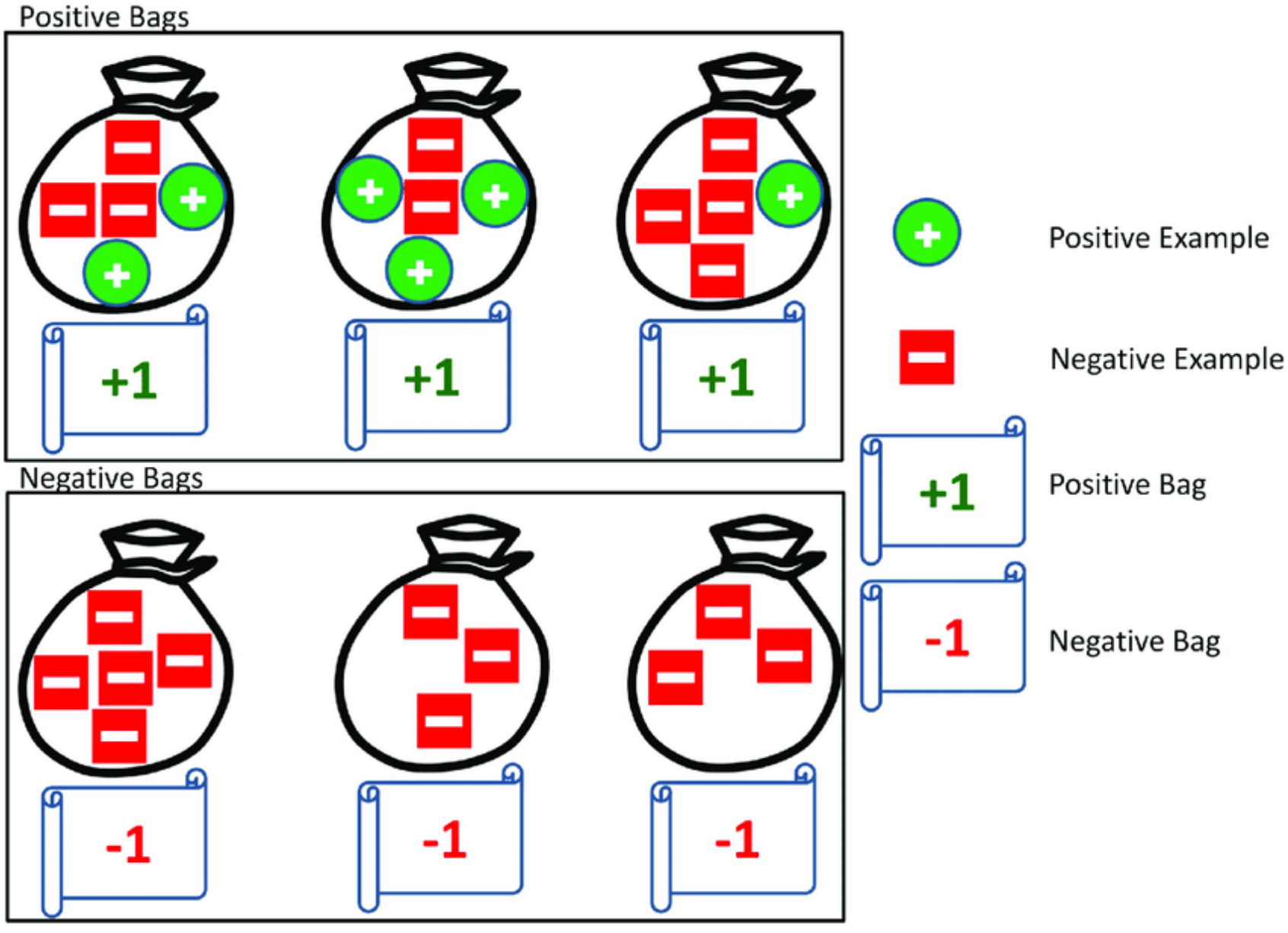

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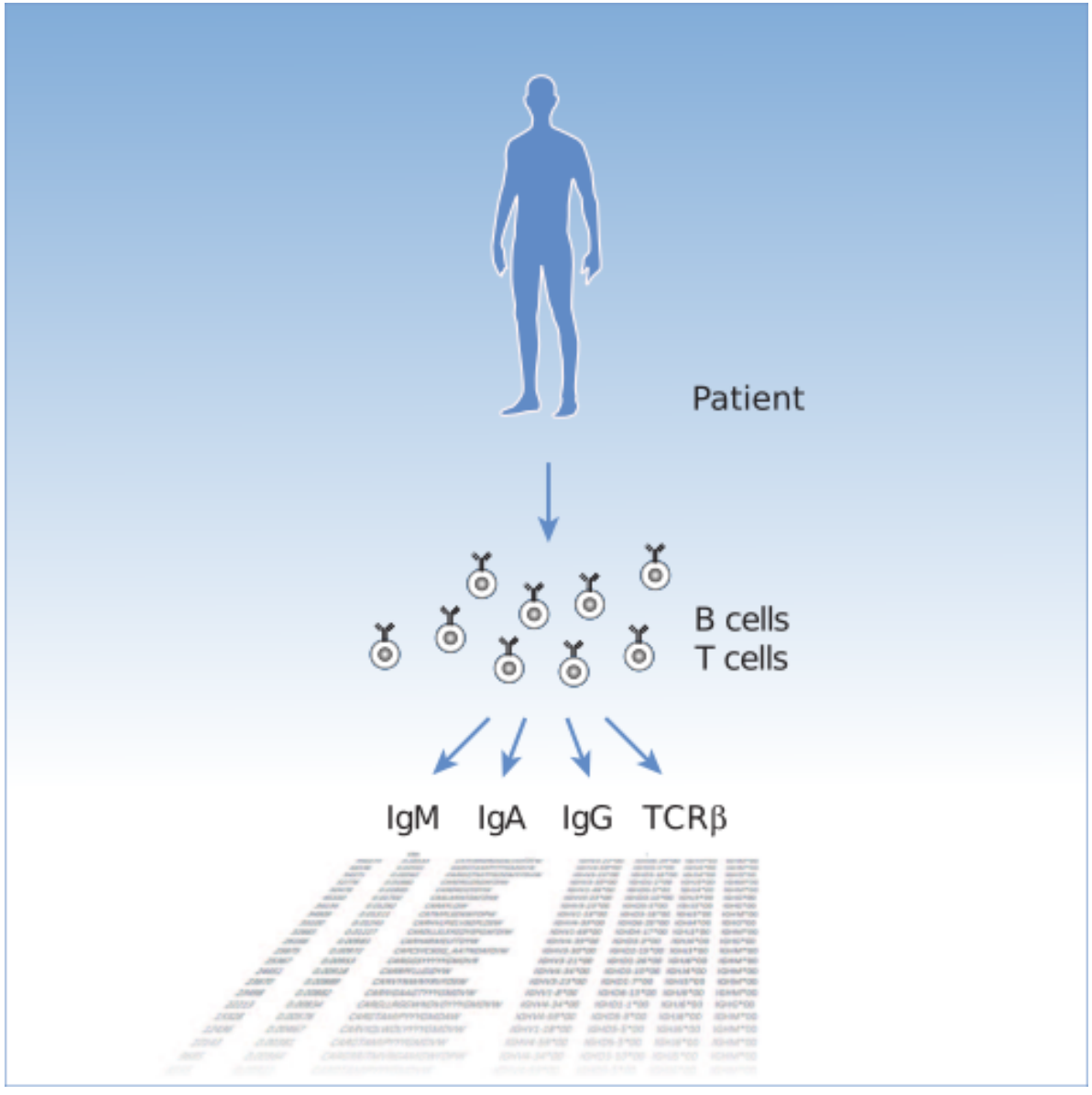

Reinforcement learning

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.

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As discussed, Machine learning can be used in a large set of fields. In particular, in geo-applications one can:

1. Handle (too) large dataset
2. Automate long repetitive and low value tasks
3. Support decision making
4. Implement expert assesment
5. Provide visualization and analysis
6. Correct models with data (e.g. geosteering)

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Application examples

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Is data fit for the task?

1. Prompt anamolous operation conditions (safe drilling).

Frequency? Resolution? Interpretability? Variable types?

1. Feature detection/guided interpretation.

Significance? Labeling strategy? Correlated data? Statistical interactions?

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Use with CAUTION!

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