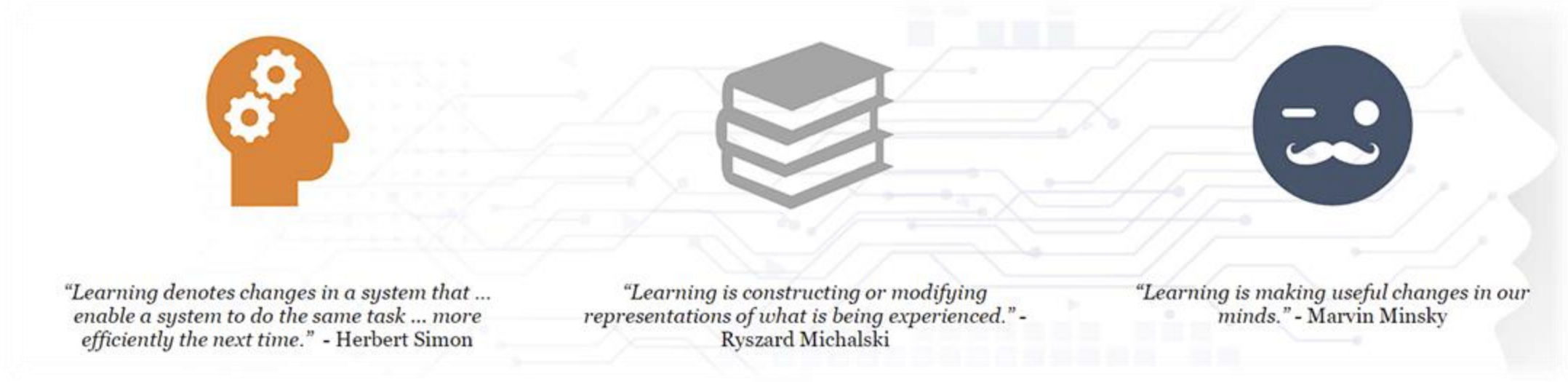
电子科技大学
格拉斯哥学院
Glasgow College, UESTC

Machine Learning (ML)

What is Intelligence?

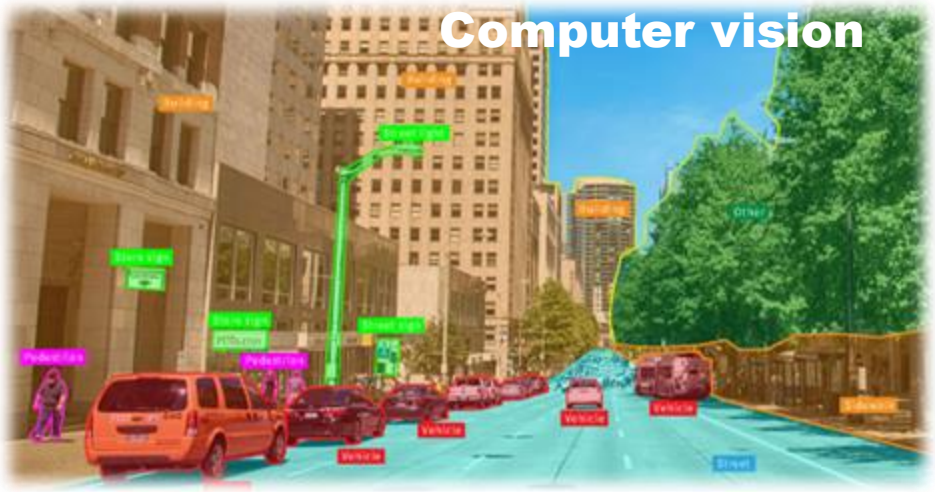
- Intelligence:
  - “the capacity to learn and solve problems”. (Websters dictionary)
  - In particular,
    - *the ability to solve novel problems*
    - *the ability to act rationally*
    - *the ability to act like humans*

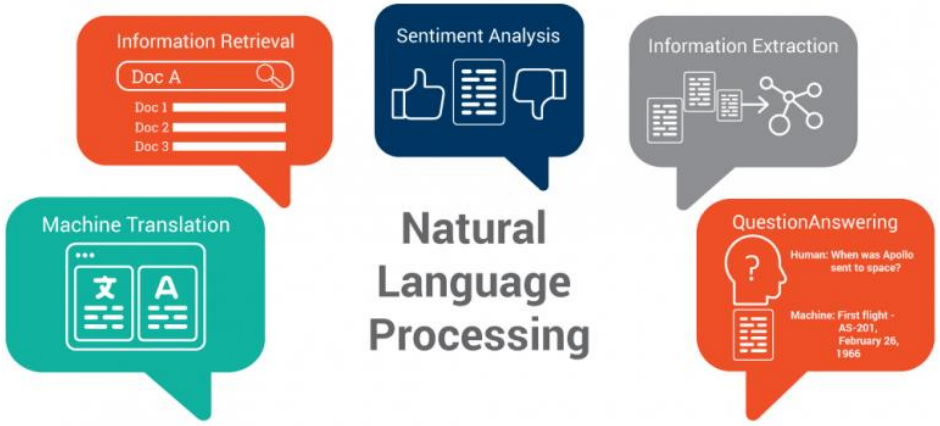
What is Machine Learning?



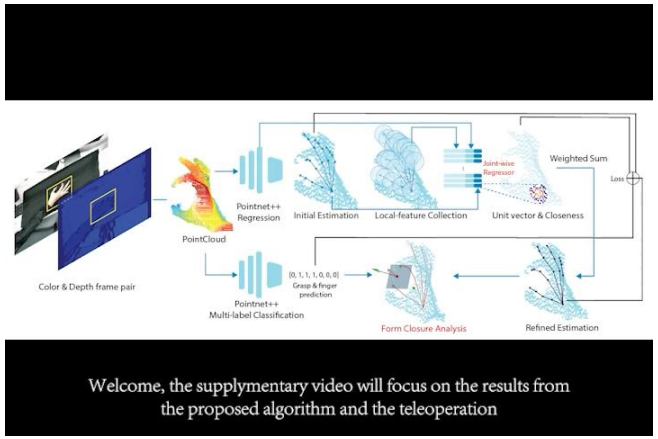
"Machine learning refers to a system capable of the autonomous acquisition and integration of knowledge."

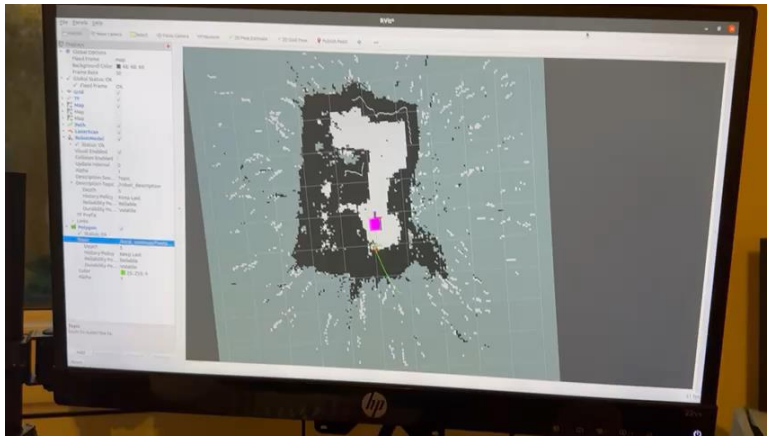
Machine Learning Applications





Applications from My Research Lab at UoG



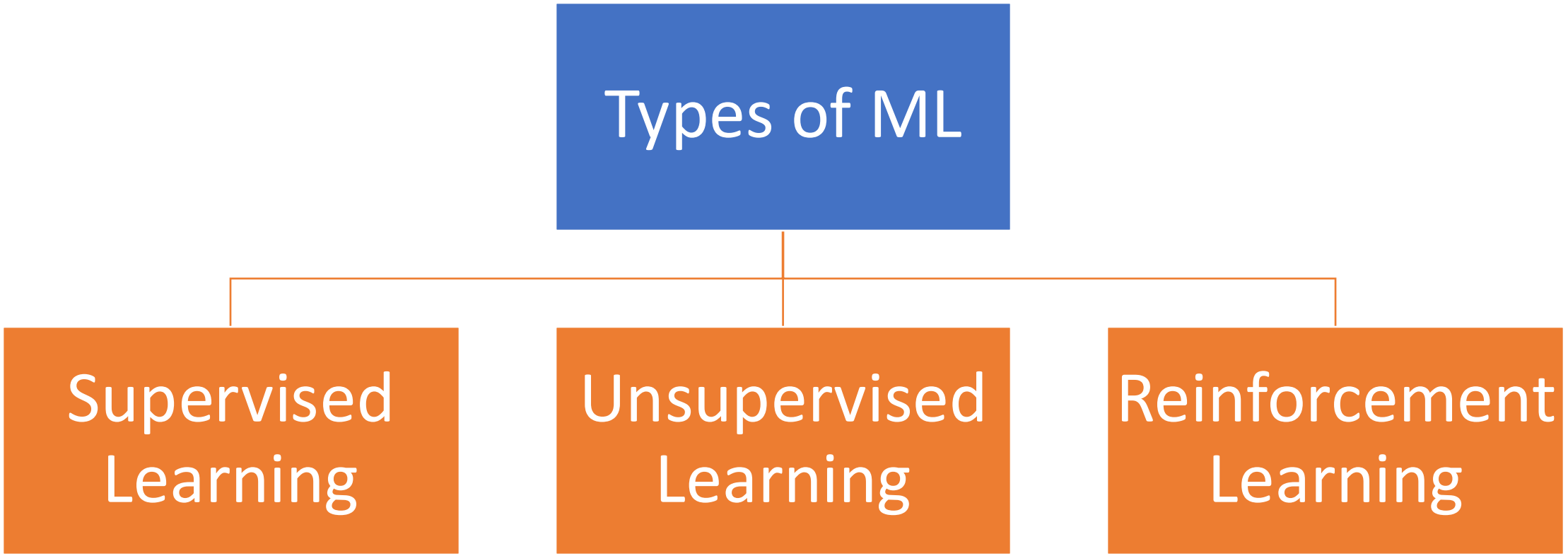


Why Machine Learning?

- **No human experts**
  - industrial/manufacturing control
  - mass spectrometer analysis, astronomy discovery
- **Black-box human expertise**
  - face/handwriting/speech recognition
  - driving a car, flying a plane
- **Rapidly changing phenomena**
  - credit scoring, financial modeling
  - diagnosis, fraud detection
- **Need for customization/personalization**
  - personalized news reader
  - movie/book recommendation

Only Machines can make sense of the Massive Amount of Data Generated each day

Types of Machine Learning

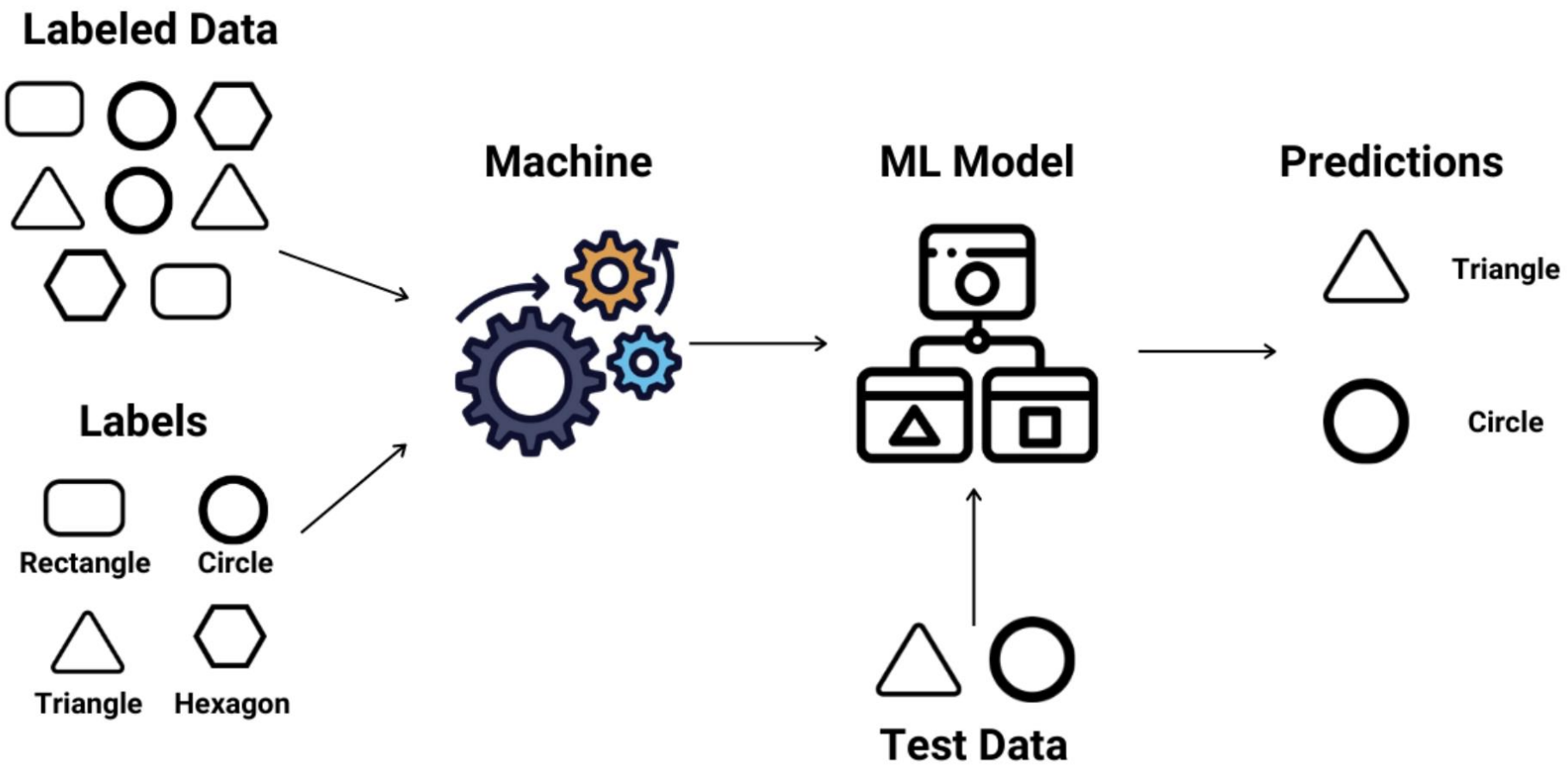


Supervised Learning

Supervised Learning

- In supervised learning, the training data comprises examples of the input vectors along with their corresponding target vectors.
- It is defined by its ability to train algorithms to categorize data and predict outcomes accurately.
- It teaches computer systems to find hidden insights using the available data.
- It also prepares algorithms to perform smart and intelligent tasks without human intervention.

Supervised Learning



Source: https://medium.com/@metehankozan/supervised-and-unsupervised-learning-an-intuitive-approach-cd8f8f64b644

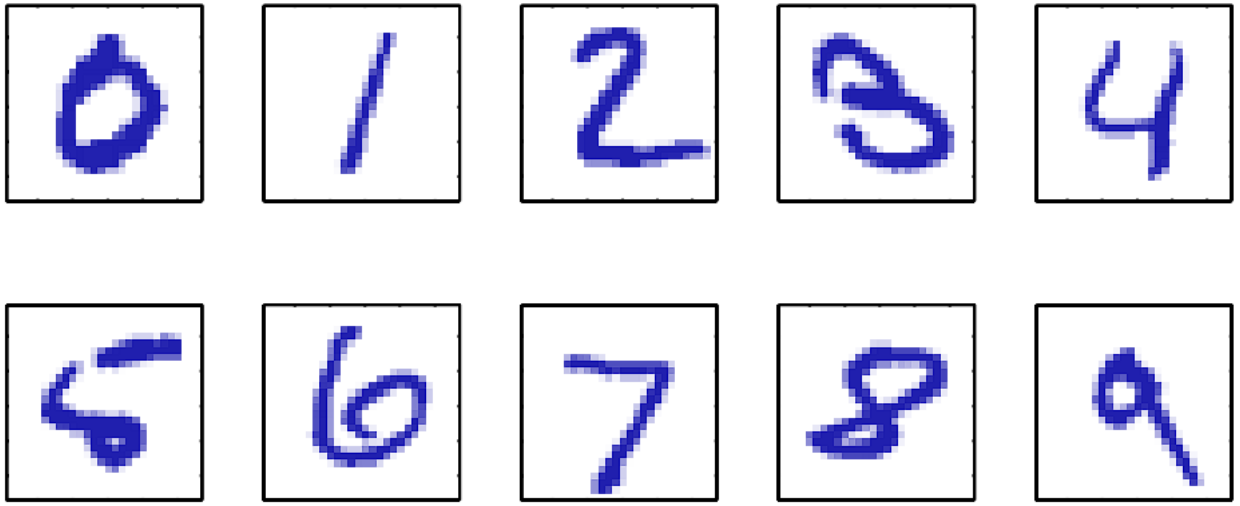
Supervised Learning

- Supervised learning uses a training module to teach algorithms to yield the desired output.
- Supervised learning stands true to data science meaning, which emphasizes using self-reliant and error-free systems and processes to achieve automation and efficiency.
- The training includes using labelled data sets collected through data mining and other processes as inputs to draw the correct output.
- The training module is accommodative and flexible, allowing machines to learn new functions and processes over time.

Supervised Learning

- Various types of algorithms and computation methods are used in the supervised learning process.
  - Regression
  - Naïve Bayes
  - K-Nearest Neighbors (KNN)
  - Support Vector Machines (SVM)
  - Decision Tree
  - Neural Networks (NN)

Example: Hand-writing Recognition



- Each image is 28×28, so it can be represented by a vector x comprising 784 real numbers.
- The goal is to build a machine that will take such a vector x as input and that will produce the identity of the digit 0,..., 9 as the output.

Example: Hand-writing Recognition

- We have a Training set $\{x_1, \ldots, x_N\}$ for tunning the parameters.
- Express the category of a digit using target vector t, Note that there is one such target vector t for each digit image x.
- The result of running the machine learning algorithm can be expressed as a function $y(x)$.
- $y(x)$ is determined during the training phase, also known as the learning phase, on the basis of the training data.
- Once the model is trained, we evaluate it by using new digital images, which called a test set.
- The ability to categorize correctly new examples that differ from those used for training is known as generalization.

Supervised Learning Examples

- Supervised learning models can be used to build and advance a number of business applications, including the following:
- **Image- and object-recognition:** Supervised learning algorithms can be used to locate, isolate, and categorize objects out of videos or images, making them useful when applied to various computer vision techniques and imagery analysis.
- **Predictive analytics:** A widespread use case for supervised learning models is in creating predictive analytics systems to provide deep insights into various business data points. This allows enterprises to anticipate certain results based on a given output variable, helping business leaders justify decisions or pivot for the benefit of the organization.

Supervised Learning Examples

- **Customer sentiment analysis:** Using supervised machine learning algorithms, organizations can extract and classify important pieces of information from large volumes of data—including context, emotion, and intent—with very little human intervention. This can be incredibly useful when gaining a better understanding of customer interactions and can be used to improve brand engagement efforts.
- **Spam detection:** Spam detection is another example of a supervised learning model. Using supervised classification algorithms, organizations can train databases to recognize patterns or anomalies in new data to organize spam and non-spam-related correspondences effectively.

Challenges of Supervised Learning

- Although supervised learning can offer businesses advantages, such as deep data insights and improved automation, there are some challenges when building sustainable supervised learning models. The following are some of these challenges:
  - Supervised learning models can require certain levels of expertise to structure accurately.
  - Training supervised learning models can be very time intensive.
  - Datasets can have a higher likelihood of human error, resulting in algorithms learning incorrectly.
  - Supervised learning cannot cluster or classify data on its own.

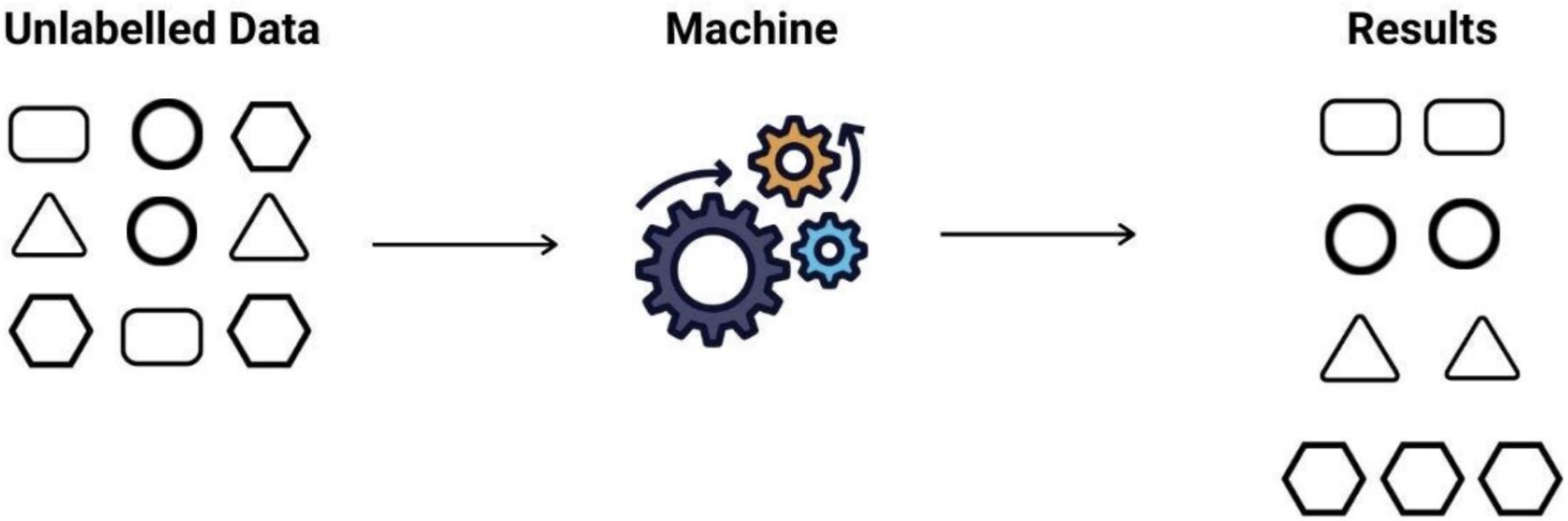
Unsupervised Learning

Unsupervised Learning

- Unsupervised learning uses machine learning algorithms to analyze and cluster unlabelled datasets.
- These algorithms discover hidden patterns or data groupings without the need for human intervention.
- Unsupervised learning algorithms do not require input-to-output mappings to learn a mapping function.
- This is what is meant when we say, *“no teacher is provided to the learning algorithm”*.

Unsupervised Learning

- Since no labels are present, unsupervised learning methods are typically applied to build a concise representation of the data so we can derive imaginative content from it.



Source: https://medium.com/@metehankozan/supervised-and-unsupervised-learning-an-intuitive-approach-cd8f8f64b644

Unsupervised Learning

- The training data consists of a set of input vectors *x* without any corresponding target values, and the goal is
  - to discover groups of similar examples within the data, where it is called clustering, or
  - to determine the distribution of data within the input space, known as density estimation, or
  - to project the data from a high-dimensional space down to two or three dimensions for the purpose of visualization.

Unsupervised Learning

- Unsupervised learning can be broken down into three main tasks:
  - Clustering
    - K-means clustering (exclusive clustering method)
    - Gaussian Mixture Models (Probabilistic clustering)
  - Association rules
    - Apriori algorithms
  - Dimensionality reduction
    - Principal Component Analysis
    - Singular Value Decomposition
    - Autoencoders

Application of Unsupervised Learning

- Some of the most common real-world applications of unsupervised learning are:
- **News Sections:** Google News uses unsupervised learning to categorize articles on the same story from various online news outlets. For example, the results of a presidential election could be categorized under their label for “US” news.

- **Computer vision:** Unsupervised learning algorithms are used for visual perception tasks, such as object recognition.

Application of Unsupervised Learning

- **Medical imaging:** Unsupervised machine learning provides essential features to medical imaging devices, such as image detection, classification and segmentation, used in radiology and pathology to diagnose patients quickly and accurately.

- **Anomaly detection:** Unsupervised learning models can comb through large amounts of data and discover a typical data points within a dataset. These anomalies can raise awareness around faulty equipment, human error, or breaches in security.

Application of Unsupervised Learning

- **Customer personas:** Defining customer personas makes it easier to understand common traits and business clients' purchasing habits. Unsupervised learning allows businesses to build better buyer persona profiles, enabling organizations to align their product messaging more appropriately.
- **Recommendation Engines:** Using past purchase behavior data, unsupervised learning can help to discover data trends that can be used to develop more effective cross-selling strategies. This is used to make relevant add-on recommendations to customers during the checkout process for online retailers.

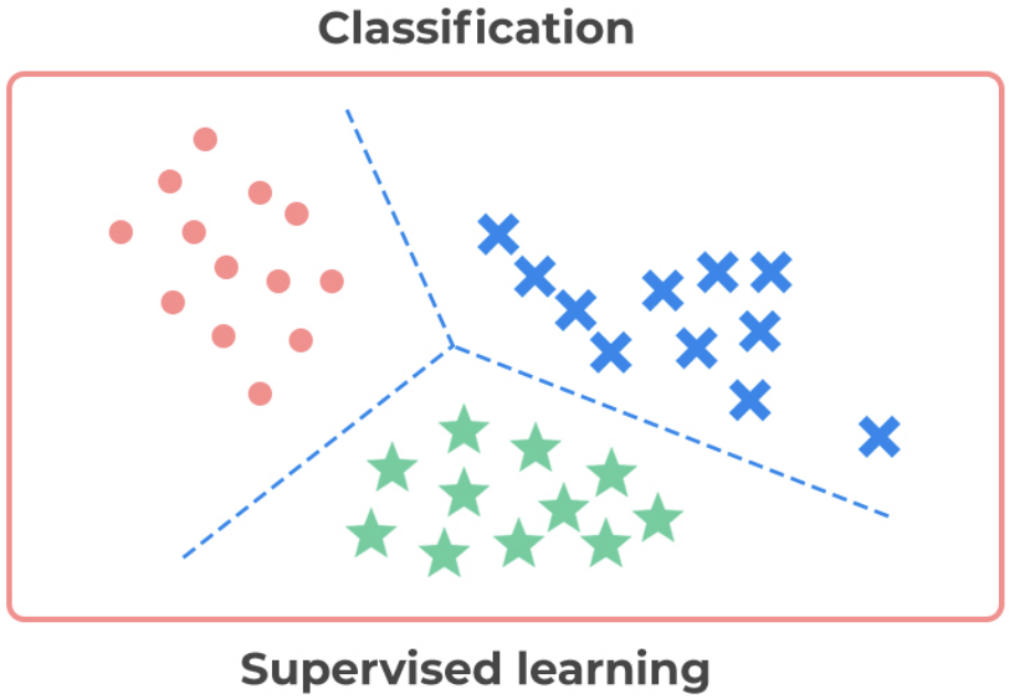
Challenges Unsupervised Learning

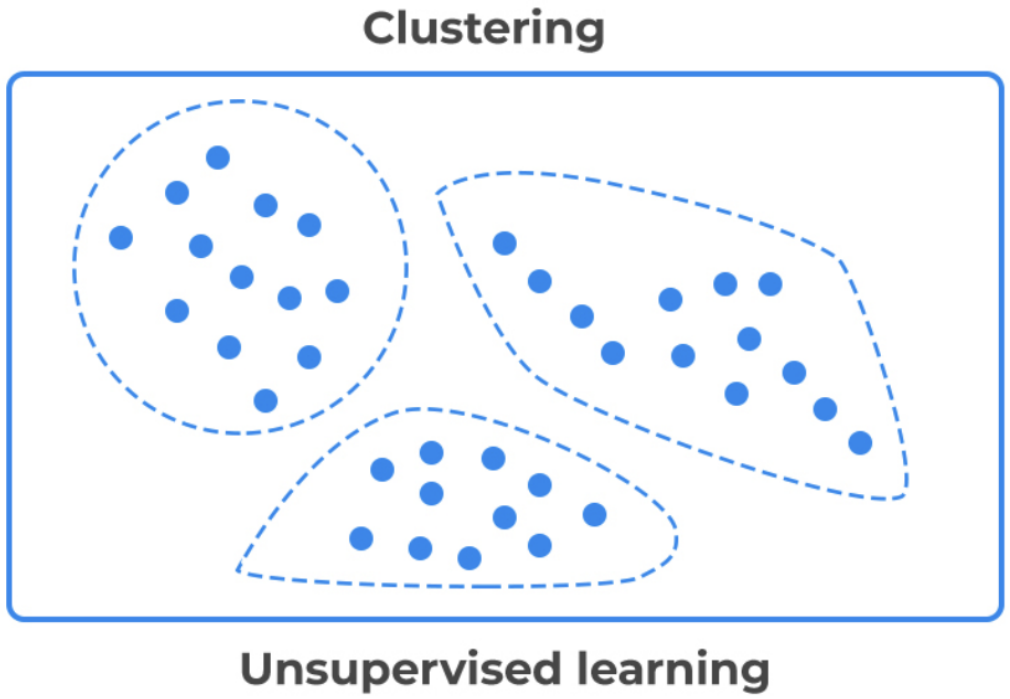
- While unsupervised learning has many benefits, some challenges can occur when it allows machine learning models to execute without any human intervention. Some of these challenges can include:
  - Computational complexity due to a high volume of training data
  - Longer training times
  - Higher risk of inaccurate results
  - Human intervention to validate output variables
  - Lack of transparency into the basis on which data was clustered

Supervised vs Unsupervised Learning

	Supervised Learning	Unsupervised learning
Objective	To approximate a function that maps inputs to outputs based out example input-output pairs.	To build a concise representation of the data and generate imaginative content from it.
Accuracy	Highly accurate and reliable.	Less accurate and reliable.
Complexity	Simpler method.	Computationally complex.
Classes	Number of classes is *known.*	Number of classes is *unknown.*
Output	A desired output value (also called the supervisory signal).	No corresponding output values.

Supervised vs Unsupervised Learning





Source: https://analystprep.com/study-notes/cfa-level-2/quantitative-method/supervised-machine-learning-unsupervised-machine-learning-deep-learning/

Reinforcement Learning

Reinforcement Learning

- Reinforcement learning (RL) is a subset of machine learning that allows an AI-driven system (sometimes referred to as an agent) to learn through trial and error using feedback from its actions.
- This feedback is either negative or positive, signalled as punishment or reward with, of course, the aim of maximising the reward function.
- RL learns from its mistakes and offers artificial intelligence that mimics natural intelligence as closely as it is currently possible.

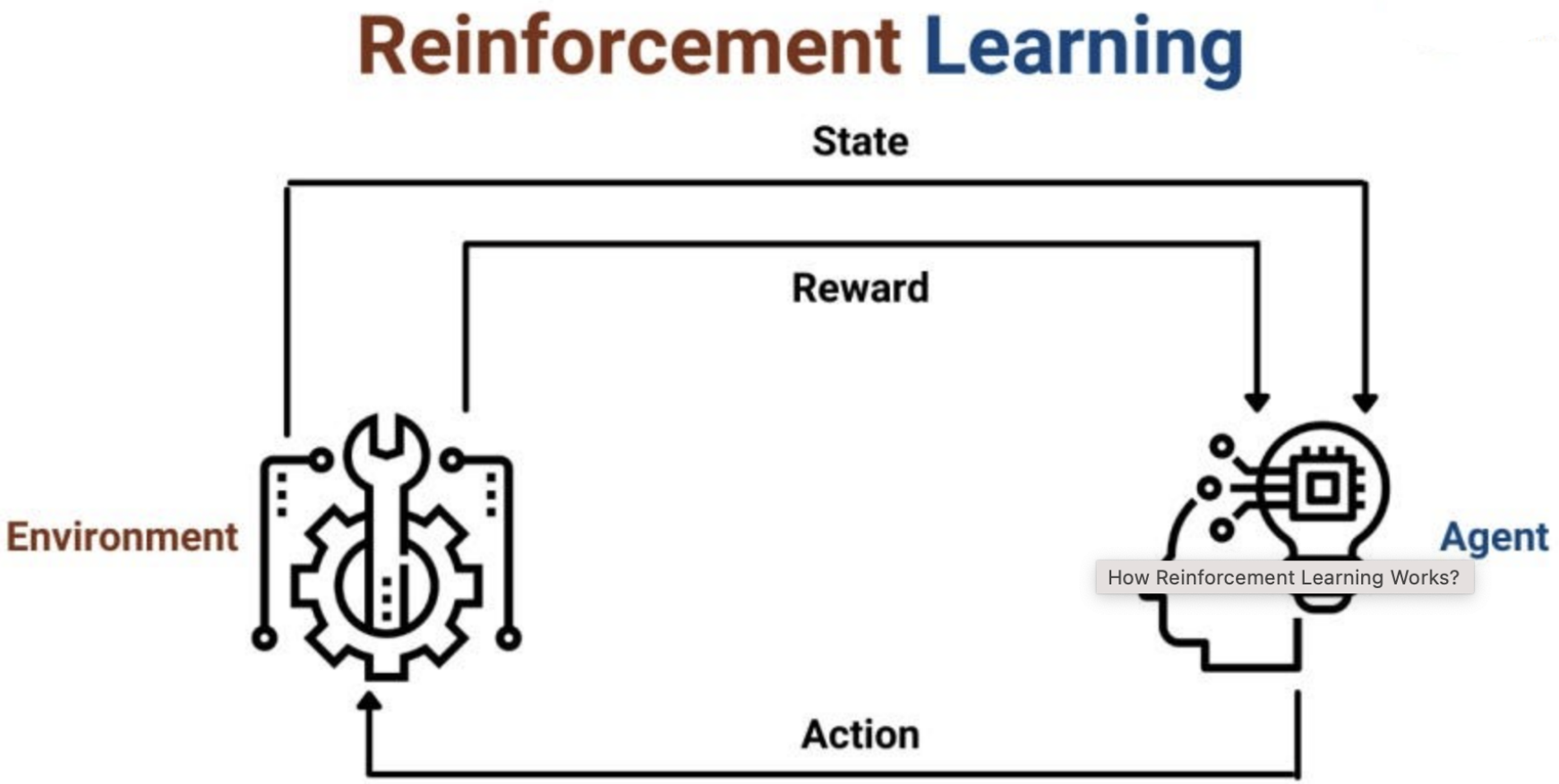
Reinforcement Learning vs Supervised Learning

- In terms of learning methods, RL is similar to supervised learning only in that it uses mapping between input and output, but that is the only thing they have in common.
- Whereas in supervised learning, the feedback contains the correct set of actions for the agent to follow. In RL there is no such answer key.
- The agent decides what to do itself to perform the task correctly.

Reinforcement Learning vs Unsupervised Learning

- Compared with unsupervised learning, RL has different goals.
- The goal of unsupervised learning is to find similarities or differences between data points, but RL's goal is to find the most suitable action model to maximise total cumulative reward for the RL agent.
- With no training dataset, the RL problem is solved by the agent's own actions with input from the environment.

Reinforcement Learning

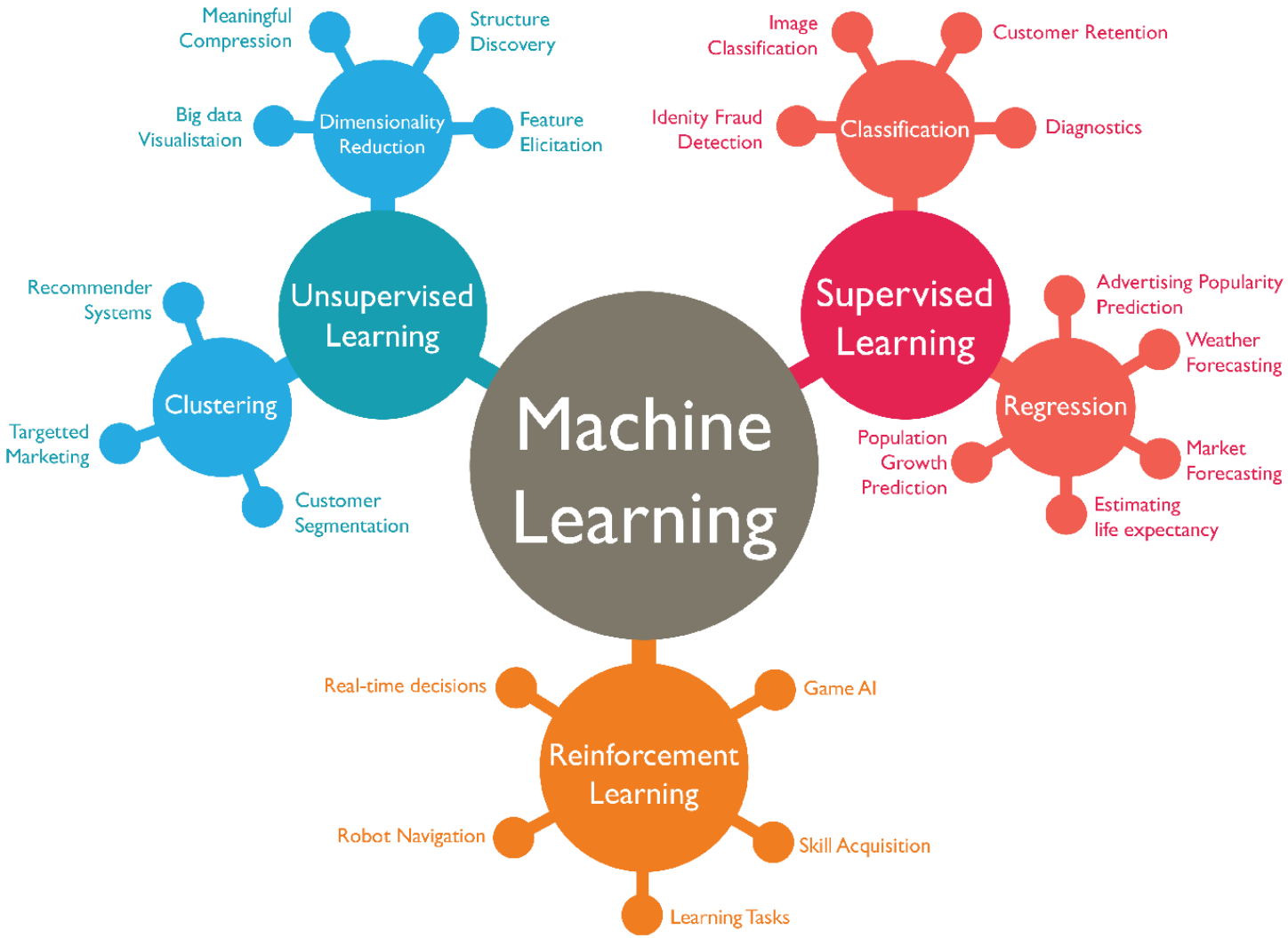


Reinforcement Learning

- Example Algorithms:
  - Q-learning; Deep Q Network; Markov Decision Process; Deep Deterministic Policy Gradient

- There are three types of RL implementations:
  - Policy-based RL uses a policy or deterministic strategy that maximises cumulative reward
  - Value-based RL tries to maximise an arbitrary value function
  - Model-based RL creates a virtual model for a certain environment and the agent learns to perform within those constraint

ML Summary


Machine Learning
Unsupervised Learning
Dimensionality Reduction
Meaningful Compression
Structure Discovery
Big data Visualistaion
Feature Elicitation
Clustering
Recommender Systems
Targetted Marketing
Customer Segmentation
Supervised Learning
Classification
Image Classification
Customer Retention
Idenity Fraud Detection
Diagnostics
Regression
Advertising Popularity Prediction
Weather Forecasting
Population Growth Prediction
Market Forecasting
Estimating life expectancy
Reinforcement Learning
Real-time decisions
Game AI
Robot Navigation
Skill Acquisition
Learning Tasks