Unit 1: - Introduction to Machine Learning

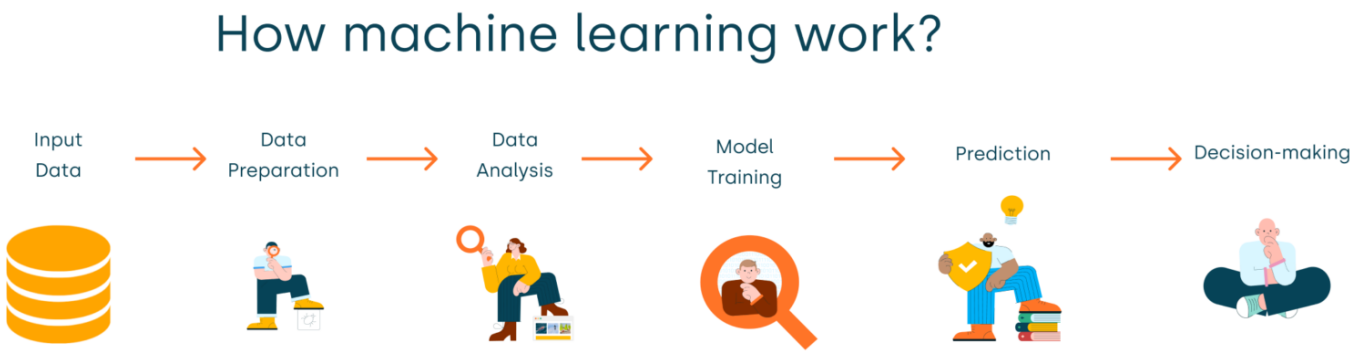
❖ What is Machine learning?

Machine Learning is a branch of artificial intelligence that enables computers to learn from data and improve their performance on a task without being explicitly programmed.
In simple terms, it means giving a computer lots of examples so it can figure out patterns and make decisions on its own.

Example

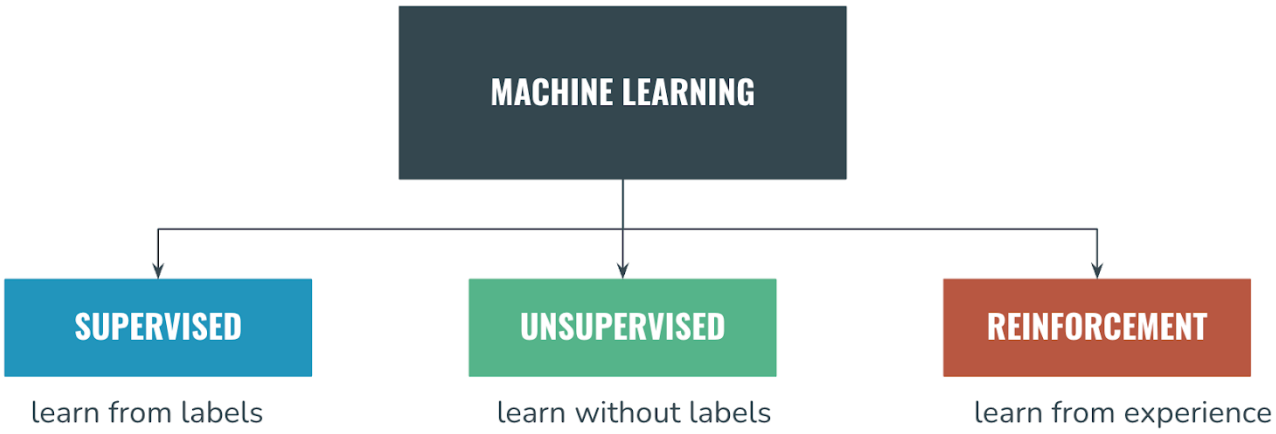
Imagine you want to teach a computer to tell the difference between apples and oranges. Instead of writing rules like "apples are red and oranges are orange," you show the computer lots of pictures of apples and oranges.
The computer looks at the patterns in the pictures (like color, shape, size) and learns how to tell them apart on its own.

❖ How does Machine Learning Work?



- **Collect Data:**
  You gather data relevant to the problem (e.g., images, numbers, text).
- **Prepare the Data:**
  The data is cleaned and organized for training (e.g., remove errors, format properly).
- **Choose a Model:**
  Select a machine learning algorithm (like decision tree, neural network, etc.)
- **Train the Model:**
  The model learns patterns from the training data.
- **Test the Model:**
  Use new (unseen) data to check how well the model performs.
- **Make Predictions:**
  Once trained, the model can make predictions or decisions on new data.

❖ Types of Machine Learning

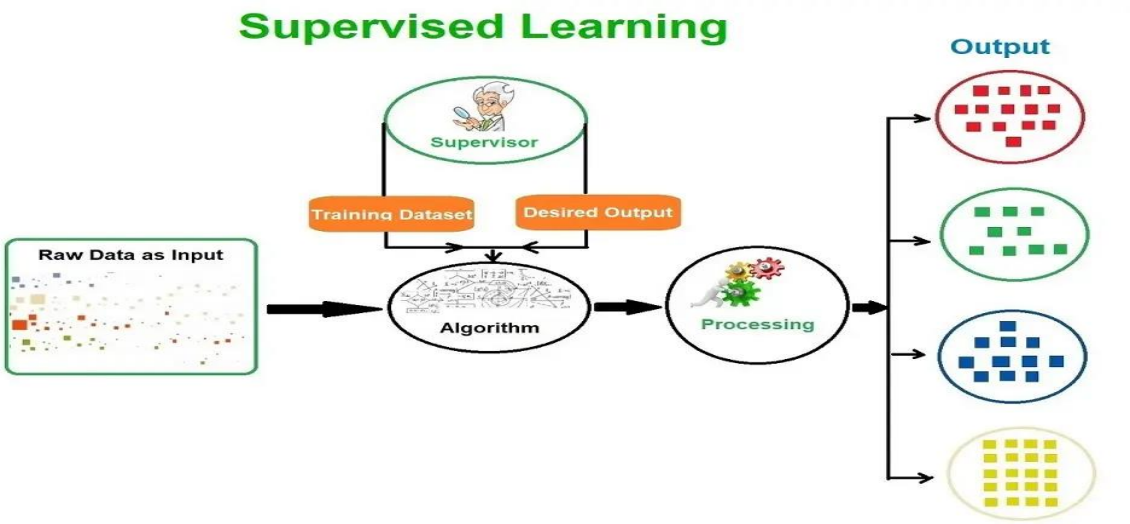


There are three different types of Machine Learning:

1. **Supervised Learning**
2. **Unsupervised Learning**
3. **Reinforcement Learning**

Each type reflects a different approach to learning from data and serves a distinct purpose, tailored to specific problems and scenarios in various fields.

❖ Supervised Machine learning



Supervised Learning is when the algorithm learns on a labeled dataset and analyses the training data. These labeled data sets have inputs and expected outputs. The meaning of the labeled data is the date that is tagged with labels to identify the characteristics, properties, or classifications.

Supervised Learning's algorithm is trained on input data labeled for a specific output. A supervised training model aims to detect the relationships and patterns of the input data and output with the help of the labels. This enables the model to achieve accurate labeling results with inputs it had not seen in the past.

The dataset is labeled. Therefore, we know the correct answers. One way to remember Supervised Learning is by comparing it to the teacher supervising the learning process.

The teacher (supervisor) knows the answers, whereas the student (the algorithm) is still going through the learning process (the labeled data). If the student (algorithm) gets something wrong, the teacher will guide the student to correct the outputs produced. The learning process does not stop until the student (algorithm) achieves a specific level of accurate performance.

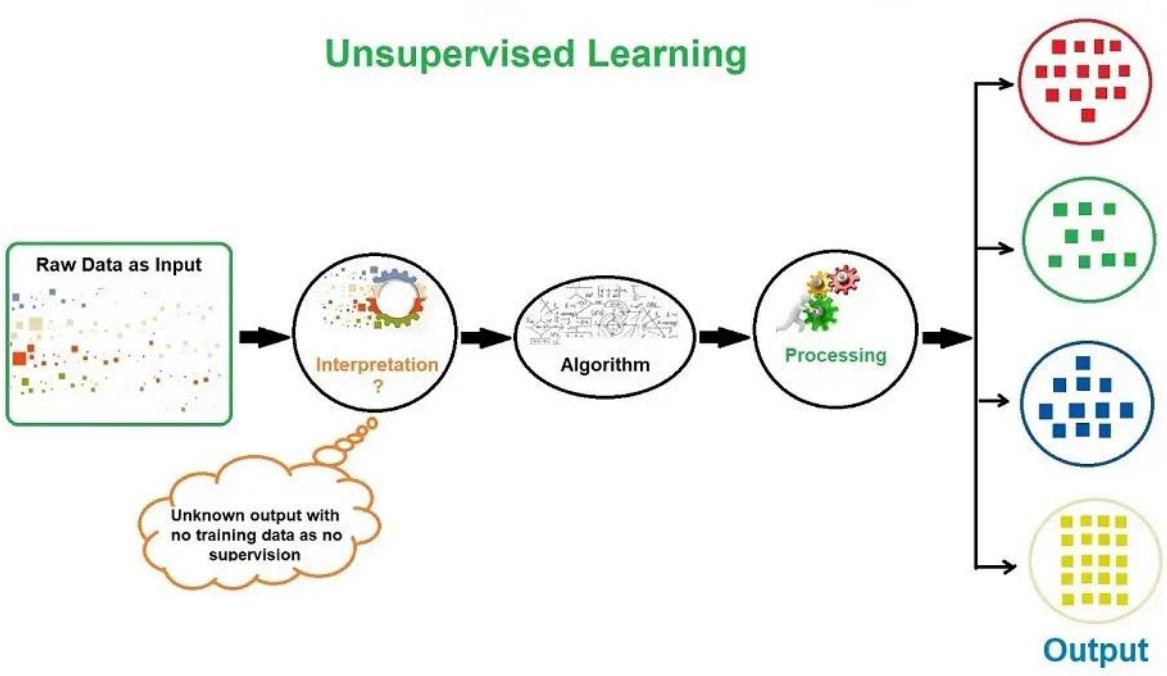
The image below shows input data with different variables and data points. The supervisor (teacher) has the training data set and knows the desired outputs. The algorithms, i.e., the student learns and processes the input data and produces the correct outputs with the help of the supervisor, i.e., the teacher.

Types of Supervised Machine Learning

within supervised learning, there are typically two main categories based on the type of output or prediction the model is making:

1. **Classification**: In classification tasks, the output variable is a category, such as "spam" or "not spam" in email filtering. The model is trained to categorize the input data into discrete labels. Classification can be binary, with only two categories, or multi-class, with more than two categories of outputs. Examples include image recognition (where inputs are images and outputs are labels), disease diagnosis, and sentiment analysis.
2. **Regression**: In regression tasks, the output variable is a continuous value or a real number, such as "house price" or "temperature." The model predicts the quantity given the input data. This could involve predicting prices, forecasting weather, estimating values, etc. Regression analysis is about predicting numerical value based on historical data.

❖ Unsupervised Machine learning



"Unsupervised Learning is an algorithm that learns patterns from untagged data. The hope is that through mimicry, which is an important mode of learning in people, the machine is forced to build a compact internal representation of its world and then generate imaginative content from it."

This is a complex definition. To break it down into Layman's terms, **Unsupervised Learning** learns on unlabeled data, inferring more about hidden structures to produce accurate and reliable outputs.

To help you understand Unsupervised Learning better, I will use the same concept of the teacher and the student. The data has no specific structure, meaning it has no training data, and the outputs are unknown as there is no supervision (teacher).

Therefore, the student (the algorithm) has to identify the structure without any help from the teacher by making its own interpretations. The algorithms (student) learn and process the data through interpretation and produce outputs.

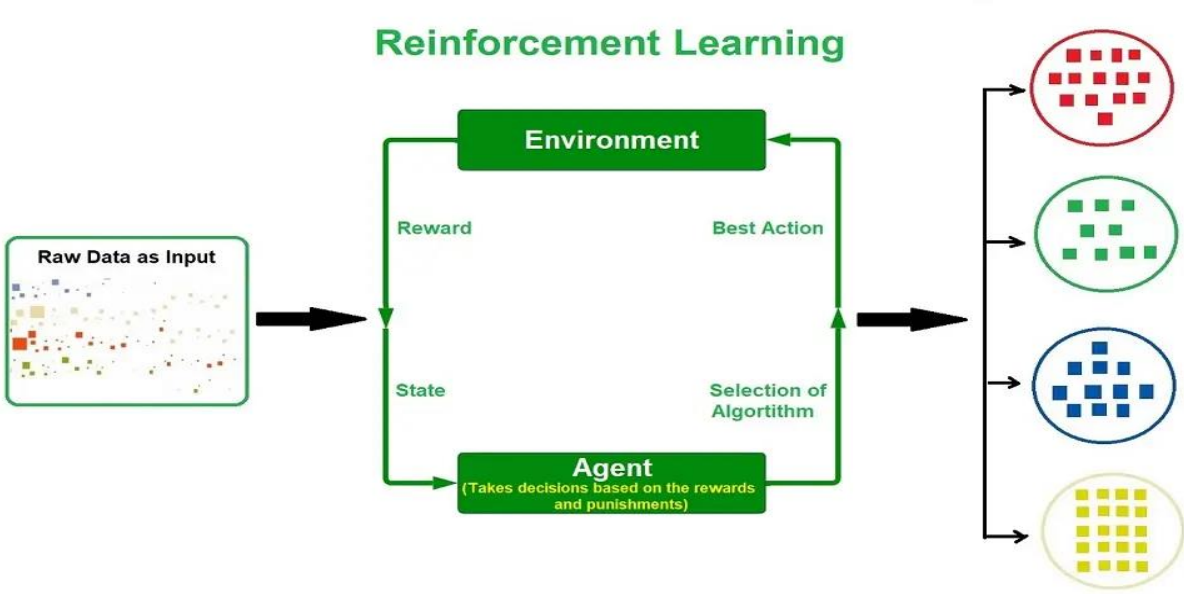
The image below shows the raw input data. However, no supervision (teacher) guides the algorithm (student) with training data or known outputs. Therefore, it makes its interpretations, and the algorithm (student) learns and processes outputs.

Types of Unsupervised Machine Learning

within unsupervised learning, there are several categories based on the task's nature. Here are the primary ones:

1. **Clustering**: This is the task of grouping a set of objects so that objects in the same group (a cluster) are more similar to each other than those in other groups. Common clustering algorithms include:
   - **K-Means**
   - **Hierarchical Clustering**
   - DBSCAN (Density-Based Spatial Clustering of Applications with Noise)
   - Gaussian Mixture Models
   - Mean Shift
2. **Association**: Association rules are used to discover relationships between variables in large databases. It's a rule-based machine learning method for discovering interesting relationships between large databases' variables. An example algorithm is:
   - Apriori
   - Eclat
   - FP-Growth

❖ Reinforcement Machine Learning



Reinforcement Learning is the third type of Machine Learning and is the training of machine learning models to make a sequence of decisions. It concerns how intelligent agents are to act in an environment to maximize cumulative reward.

Reinforcement Learning stems from Machine Learning. It aims to train a model to return an optimum solution. It uses a sequence of solutions and/or decisions created for a specific problem.

To understand reinforcement learning better, let's first walk through the terminologies.

Reinforcement Learning terminology

Below is a list of terminologies that will be important for you to understand the overall concept of Reinforcement Learning.

- **Actions:** Actions are all the possible steps the model can take to yield a reward from the Environment. They are based on policy.
- **Agent:** This is the learning phase of Reinforcement Learning. The agent's aim is to maximize the rewards the Environment gives it.
- **Environment:** In layman's terms, this is the Agent's home where it lives and interacts. The Agent performs actions within the Environment but cannot influence the dynamics of the Environment due to these actions.
- **Episode:** This is each of the repeated attempts by the Agent to help it learn the Environment. All the states come in between an initial state and a terminal state.
- **Policy:** This determines how an agent behaves and acts as a mapping method between the Agent's present state and actions.
- **Return:** This is the sum of all the rewards the Agent expects to receive. The Agent does this following the policy from the state to the end of the episode.
- **Reward:** This numerical value comes from the Environment and is sent to the Agent. It is a response to the Agent's actions in the Environment. There are three types of rewards: positive (desired action), negative (undesired action), and zero (no action).
- **State:** This is the current configuration of the Environment in which the Agent chooses to take action

❖ Issues in Machine learning

1. Data Quality and Quantity
Problem: Poor quality or insufficient data leads to inaccurate models.
Examples: Missing values, noisy data, unbalanced datasets.

2. Overfitting and Underfitting
Overfitting: The model learns the training data too well, including noise, and performs poorly on new data.
Underfitting: The model is too simple and fails to capture important patterns in the data.

3. Bias in Data
Problem: If the training data is biased, the model will also be biased.
Impact: This can lead to unfair or unethical decisions (e.g., in hiring, lending, or law enforcement).

4. Interpretability
Problem: Some machine learning models (like deep neural networks) are like "black boxes"—hard to understand how they make decisions.
Impact: Lack of trust in the system, especially in critical applications like healthcare or finance.

5. Computational Resources
Problem: Training large models requires significant computing power and time.
Impact: High costs and energy usage, especially in deep learning.

6. Model Deployment and Maintenance
Problem: Deploying a model into a real-world system can be complex.
Impact: The model may degrade over time if not updated with new data (called model drift).

7. Security and Privacy
Problem: Models can be attacked (e.g., through adversarial examples) or leak sensitive information.
Impact: Threats to user privacy and system safety.

8. Ethical Concerns
Problem: How decisions are made, who is affected, and whether they are fair.
Impact: Ethical use of AI is a growing concern in society.

❖ Application in Machine learning

1.Face Recognition

Used to unlock phones and tag people in photos.

2.Voice Assistants

Like Siri, Alexa, and Google Assistant that understand and respond to your voice.

3.Spam Email Detection

Filters out unwanted or harmful emails automatically.

4.Product Recommendations

Suggests products you may like on websites like Amazon or Flipkart.

5.Online Movie Suggestions

Apps like Netflix recommend movies based on what you watch.

6.Self-Driving Cars

Cars that learn to drive by recognizing roads, signs, and people.

7.Medical Diagnosis

Helps doctors detect diseases from X-rays or reports.

8.Language Translation

Tools like Google Translate convert one language to another.

9.Fraud Detection

Banks use it to detect fake or unusual transactions.

10.Chatbots

Websites use chatbots to talk to customers and answer questions.

❖ Global Development of Machine Learning

ML has grown rapidly around the world and is being used in almost every industry.

- **Early Stage:** ML began as part of artificial intelligence research in the 1950s–1980s.
- **2000s:** With more data and better computers, ML started solving real-world problems.
- **Today:** ML is used globally in healthcare, finance, education, transport, and more.
- **Big Tech:** Companies like Google, Amazon, Microsoft, and Apple lead ML research and development.
- **Education & Research:** Many universities and institutes now offer ML courses and are doing advanced research.

- **Future:** ML is expected to drive innovation in smart cities, automation, robotics, and climate change solutions.

❖ Difference between Supervised and Unsupervised Learning

Aspect	Supervised Learning	Unsupervised Learning
Input Data	Uses labeled data (input features + corresponding outputs).	Uses unlabeled data (only input features, no outputs).
Goal	Predicts outcomes or classifies data based on known labels.	Discovers hidden patterns, structures, or groupings in data.
Computational Complexity	Less complex, as the model learns from labeled data with clear guidance.	More complex, as the model must find patterns without any guidance.
Types	Two types : **Classification** (for discrete outputs) or **regression** (for continuous outputs).	C**lustering** and **association**
Testing the Model	Model can be tested and evaluated using labeled test data.	Cannot be tested in the traditional sense, as there are no labels.