Machine Learning Overview

Definition of Machine Learning：(Tom m. mitchell in《Machine Learning》)

A computer program is said to learn from experience E with respect to some class of tasks T and performance measure P, if its performance at tasks in T, as measured by P, improves with experience E.

Machine Learning Algorithm Classification

According to different data training methods and machine learning styles, it is mainly divided into supervised learning, unsupervised learning, and reinforcement learning.

Supervised learning	Unsupervised learning	Reinforcement learning
Linear Regression	K-means Clustering	Q-Learning
Logistic Regression	Hierarchical Cluster Analysis (HCA)	Deep Q Network (DQN)
Decision Trees	PCA (Principal Component Analysis)	Policy Gradient Methods
Random Forests	Self-Organizing Map (SOM, Self-Organizing Map)	Actor-Critic Methods
Support Vector Machine (SVM)	Gaussian Mixture Models	Asynchronous Advantage Actor-Critic
Neural Networks		

Supervised Learning

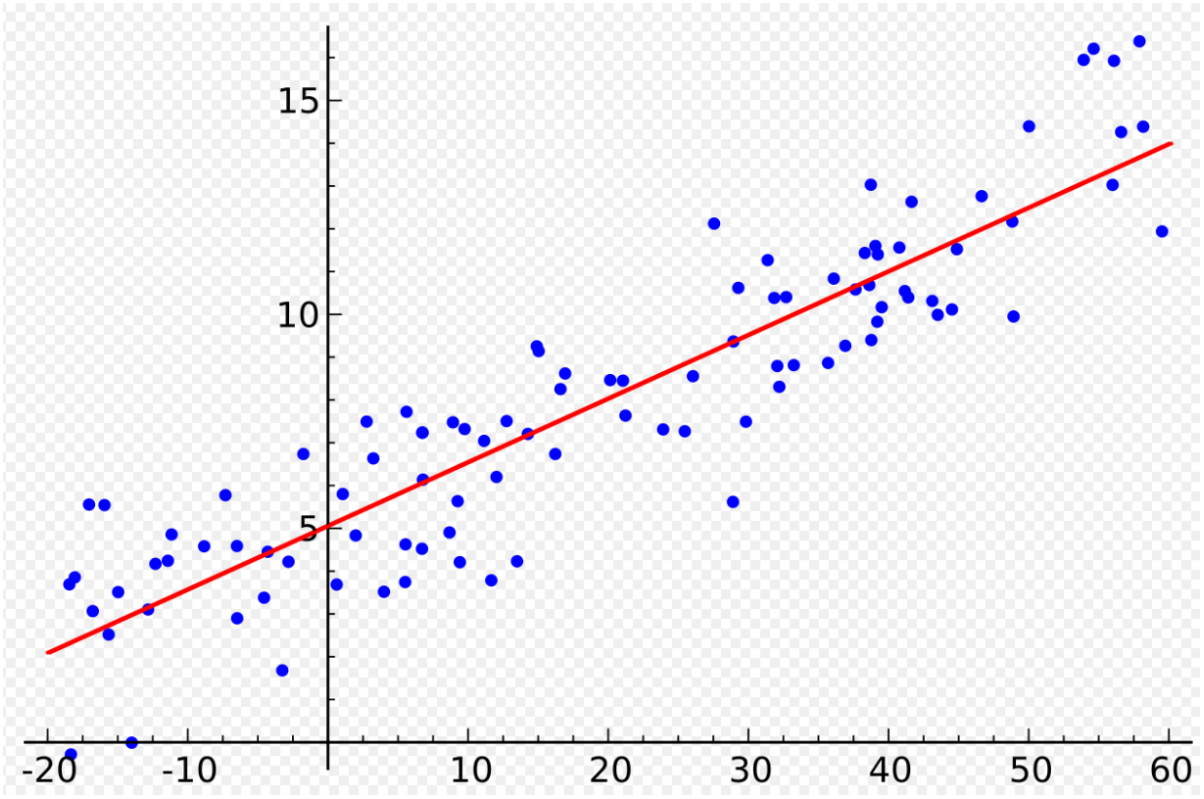
Supervised learning relies on labeled training data, with each training example having an associated output label.

Therefore, the goal of the supervised learning algorithm is to obtain a mapping function that can predict the correct output when the input data has no label.

Common supervised learning algorithms include

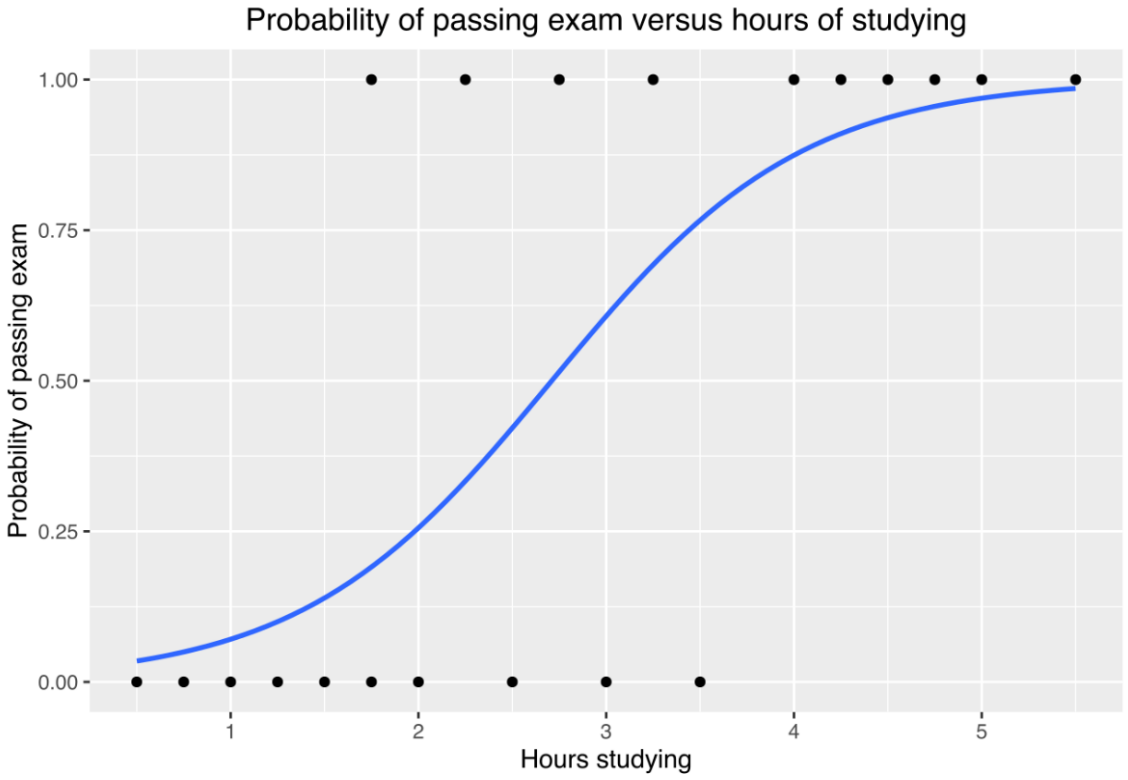
- Linear Regression

$$Y_i = \beta_0 + \beta_1 X_{i1} + \beta_2 X_{i2} + \ldots + \beta_p X_{ip} + \epsilon_i, \quad i = 1, \ldots, n$$



- Logistic Regression

$$P(Y=1|X) = \frac{1}{1+e^{-(\beta_0+\beta_1 X_1+\beta_2 X_2+\ldots+\beta_p X_p)}}$$

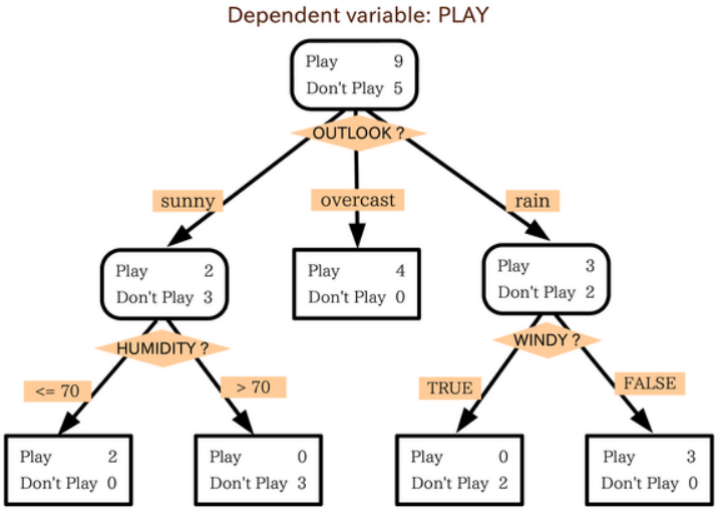


- Decision Trees

$$H(S) = -\sum_{i=1}^{n} p_i \log_2 p_i$$

$$IG(S, A) = H(S) - \sum_{t \in T} p(t) H(t)$$

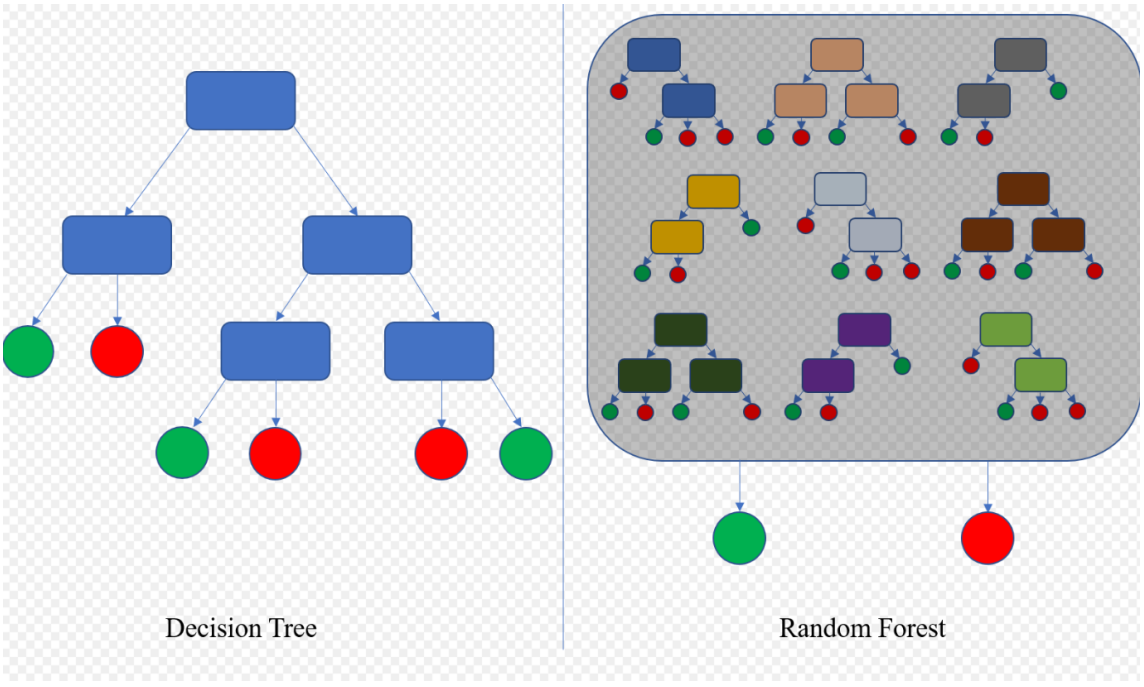
$$Gini(S) = 1 - \sum_{i=1}^{n} p_i^2$$



- Random Forests

$$\text{分类问题：} \hat{Y} = \text{mode}\{Y_1, Y_2, \ldots, Y_t\}$$

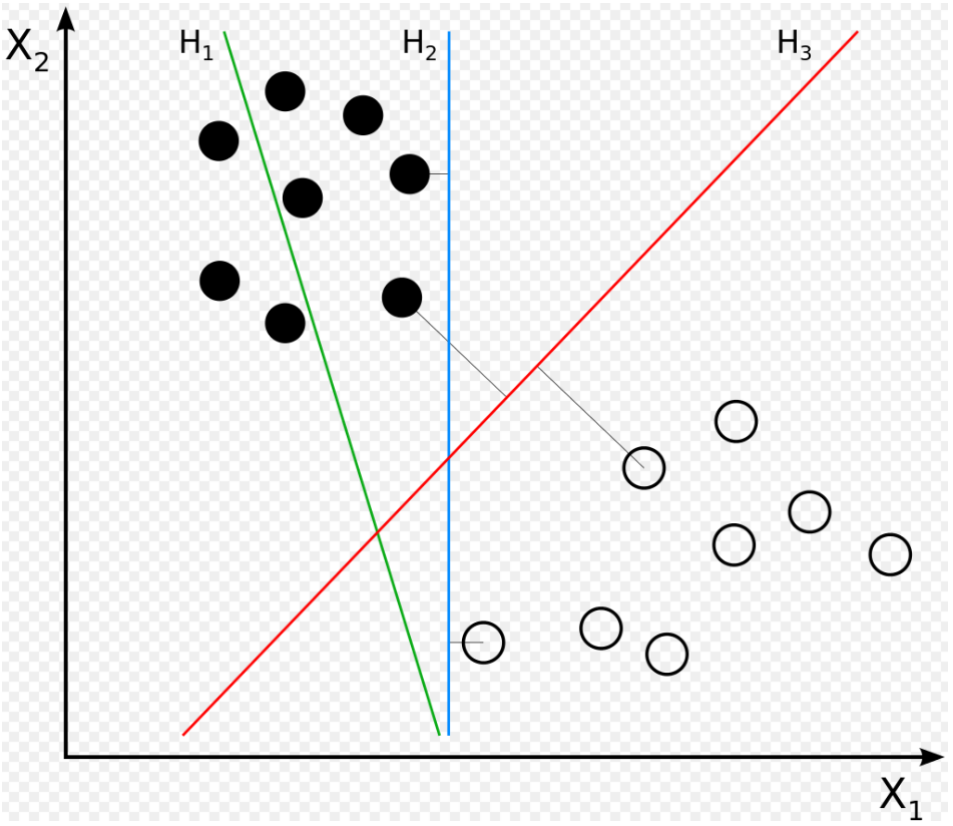
$$\text{回归问题：} \hat{Y} = \frac{1}{t} \sum_{i=1}^{t} Y_i$$



- SVM, Support Vector Machines

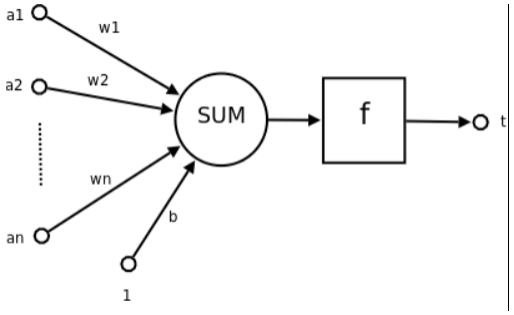
$$\min_{\mathbf{w}, b} \frac{1}{2} \|\mathbf{w}\|^2$$

$$\text{subject to } y_i(\mathbf{w} \cdot \mathbf{x}_i + b) \geq 1, \quad \forall i$$



- Neural Networks, Includes deep learning models

$$t = f\left(\vec{W} \prime \vec{A} + b\right)$$



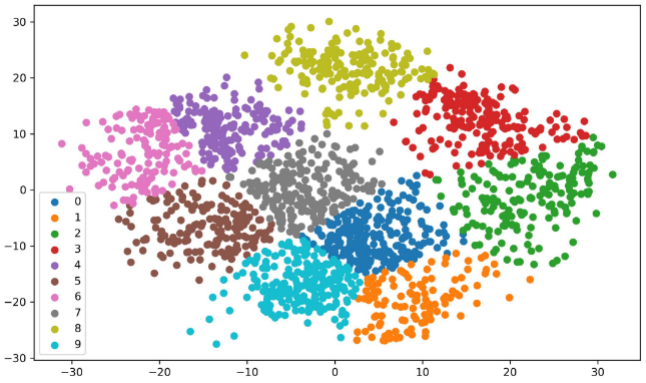
Unsupervised Learning

Unsupervised learning For supervised learning, the training data is unlabeled, and the purpose of the algorithm is to discover the structure in the data. Therefore, this type of algorithm is mostly used in tasks such as clustering, association, and dimensionality reduction.

Common unsupervised learning algorithms are:

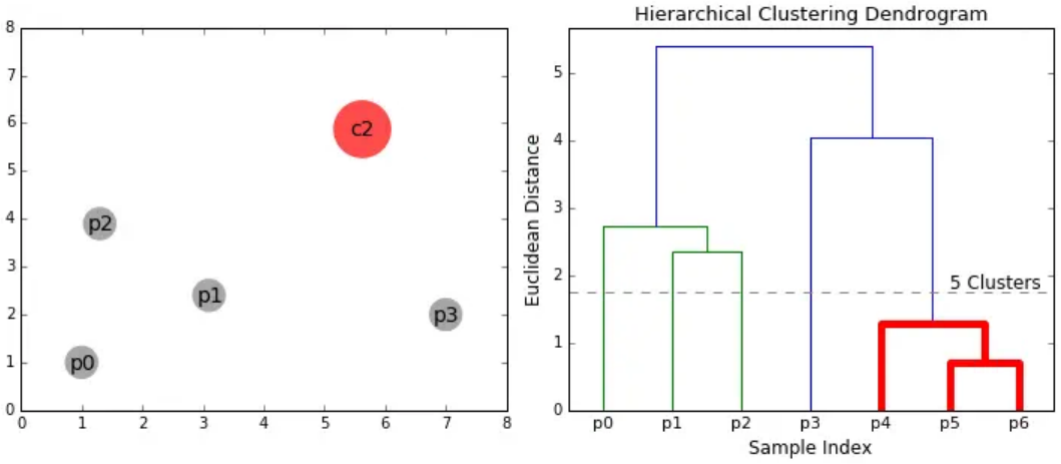
- K-means Clustering

$$J = \sum_{i=1}^{n} \sum_{k=1}^{K} w_{ik} ||x_i - \mu_k||^2$$



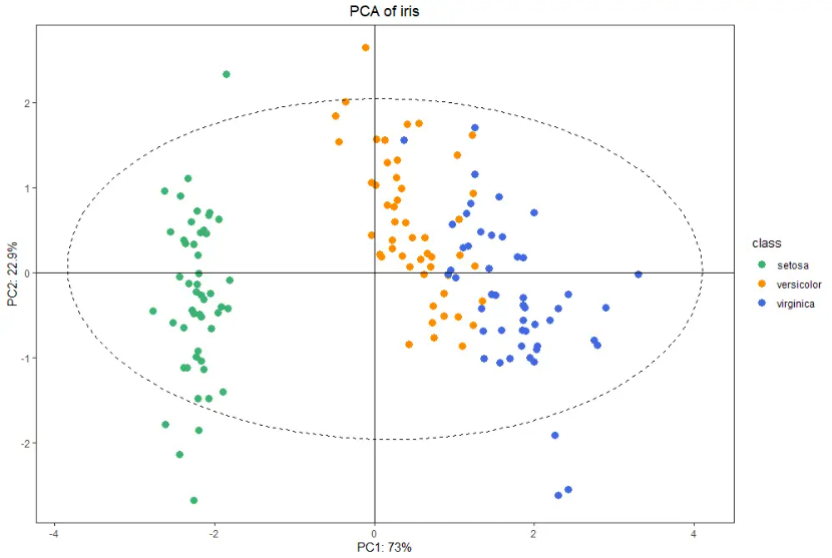
- Hierarchical Cluster Analysis, HCA

$$d(\{X\},\{Y\}) = \min(d(X_i, Y_j)) \quad X_i \in \{X\}, Y_j \in \{Y\}$$



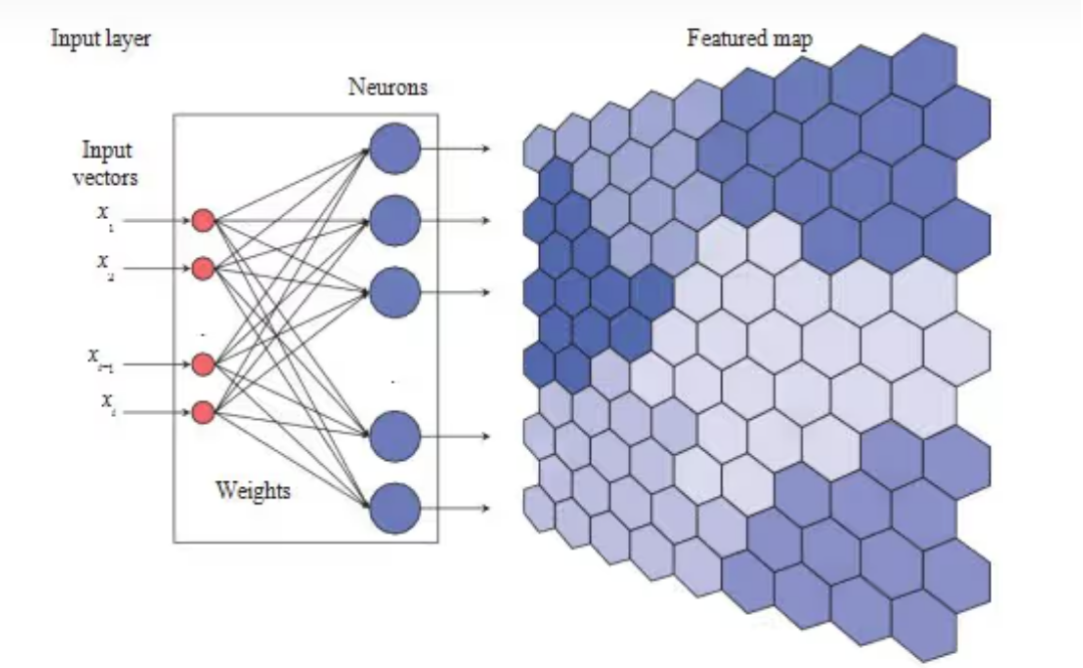
- PCA, Principal Component Analysis

$$\mathrm{Cov}(X) \cdot v = \lambda v$$



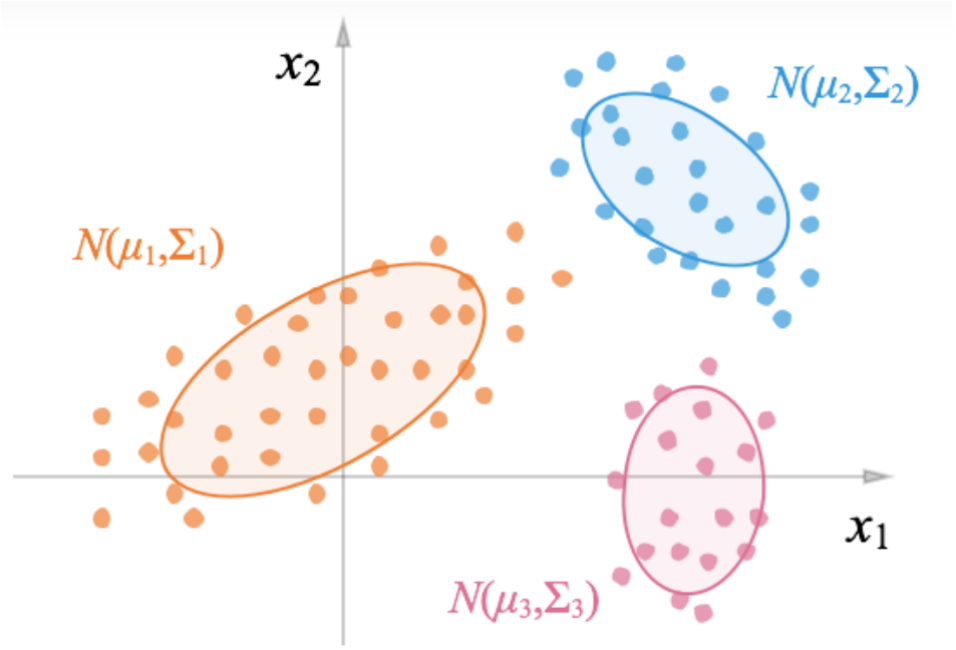
- SOM, Self-Organizing Map

$$w(t+1) = w(t) + \theta(t)\alpha(t)(v(t) - w(t))$$



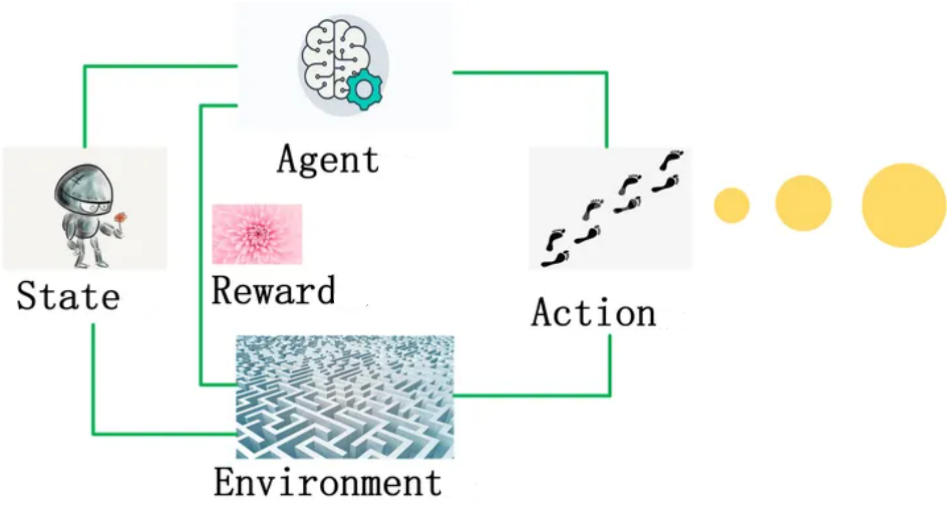
- Gaussian Mixture Models

$$p(x) = \sum_{k=1}^{K} \pi_k \mathcal{N}(x|\mu_k, \Sigma_k)$$



Reinforcement Learning

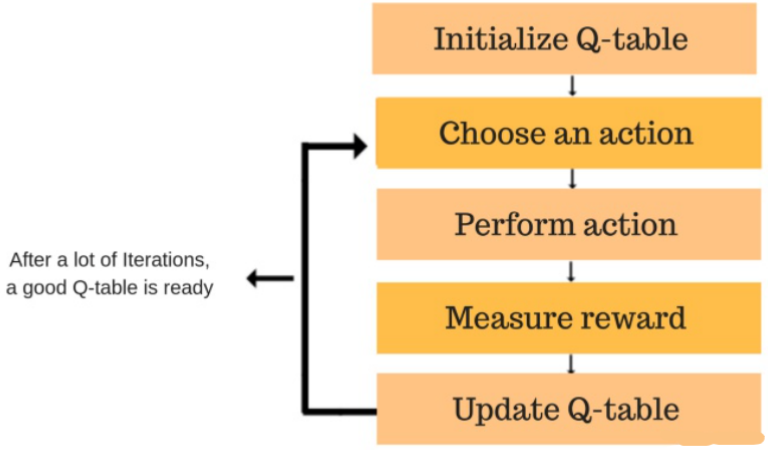
Reinforcement learning is different from the paradigms of supervised learning and unsupervised learning. It mainly allows the agent to continuously explore and exploit the environment (Environment) and perform experiential learning based on feedback rewards (Reward). Agent is the object to be learned, Environment is an external constraint on Agent, and Reward is the most direct feedback from the environment to the agent.



Common reinforcement learning algorithms are:

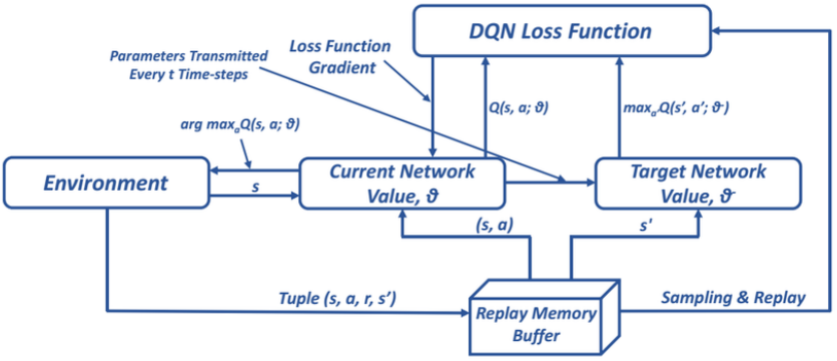
- Q-Learning algorithm based on tables without neural network involvement

$$Q^{new}(s_t, a_t) \leftarrow Q(s_t, a_t) + \alpha[r_{t+1} + \gamma \max_a Q(s_{t+1}, a) - Q(s_t, a_t)]$$



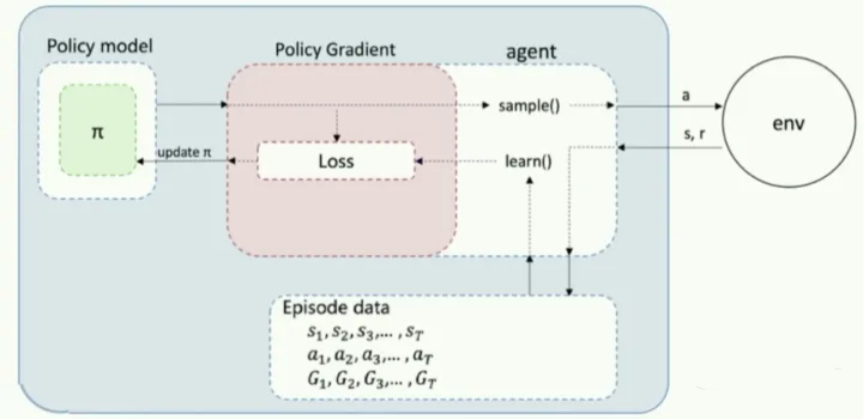
- Value-Based Deep Q Network (DQN) algorithm

$$L(\theta) = \mathbb{E}\left[\left(r + \gamma \max_{a'} Q(s', a'; \theta^-) - Q(s, a; \theta)\right)^2\right]$$



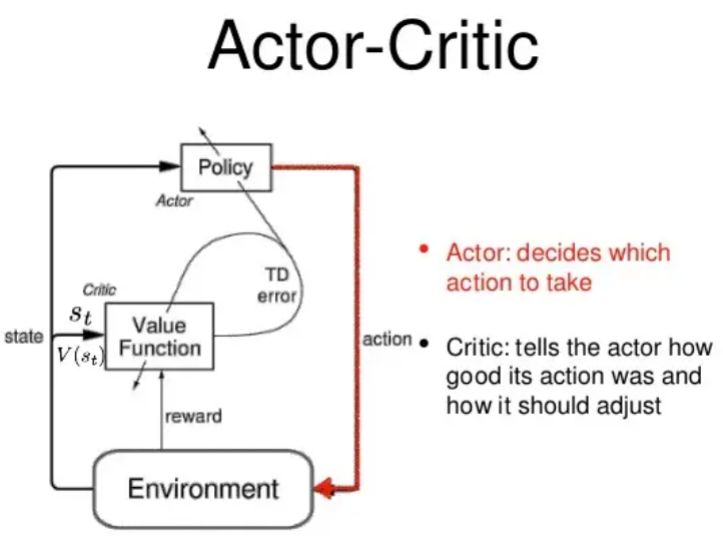
- Policy-Based Policy Gradient (PG) algorithm

$$\theta_{t+1} = \theta_t + \alpha \nabla_\theta \log \pi_\theta(s_t, a_t) G_t$$



- Actor Critic algorithm that combines Value-Based and Policy-Based.

$$\nabla_\theta J(\theta) = \mathbb{E}\left[\nabla_\theta \log \pi_\theta(s,a) A^{\pi_\theta}(s,a)\right]$$



General process of machine learning

Data collection, input data, data preprocessing, model training and testing, model evaluation