Advances in Machine Learning and Artificial Intelligence: Applications to Agriculture

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- PhD Telecommunications Engineering, 2011.
- Researcher at IUMPA – UPV (Pure and Applied Maths Institute): from 2012
- Part-time lecturer: Computer Science Department, University of Valencia. 2015-2021.
- Lecturer: Applied Mathematics Department, Universitat Politècnica de València, from 2021.

- Research interests: artificial intelligence and machine learning, biomedical signal processing, time-frequency analysis and its applications, applied maths.

- Project: *Analysis and prediction of the value of agricultural products and crops in the Valencian Community using artificial intelligence techniques*

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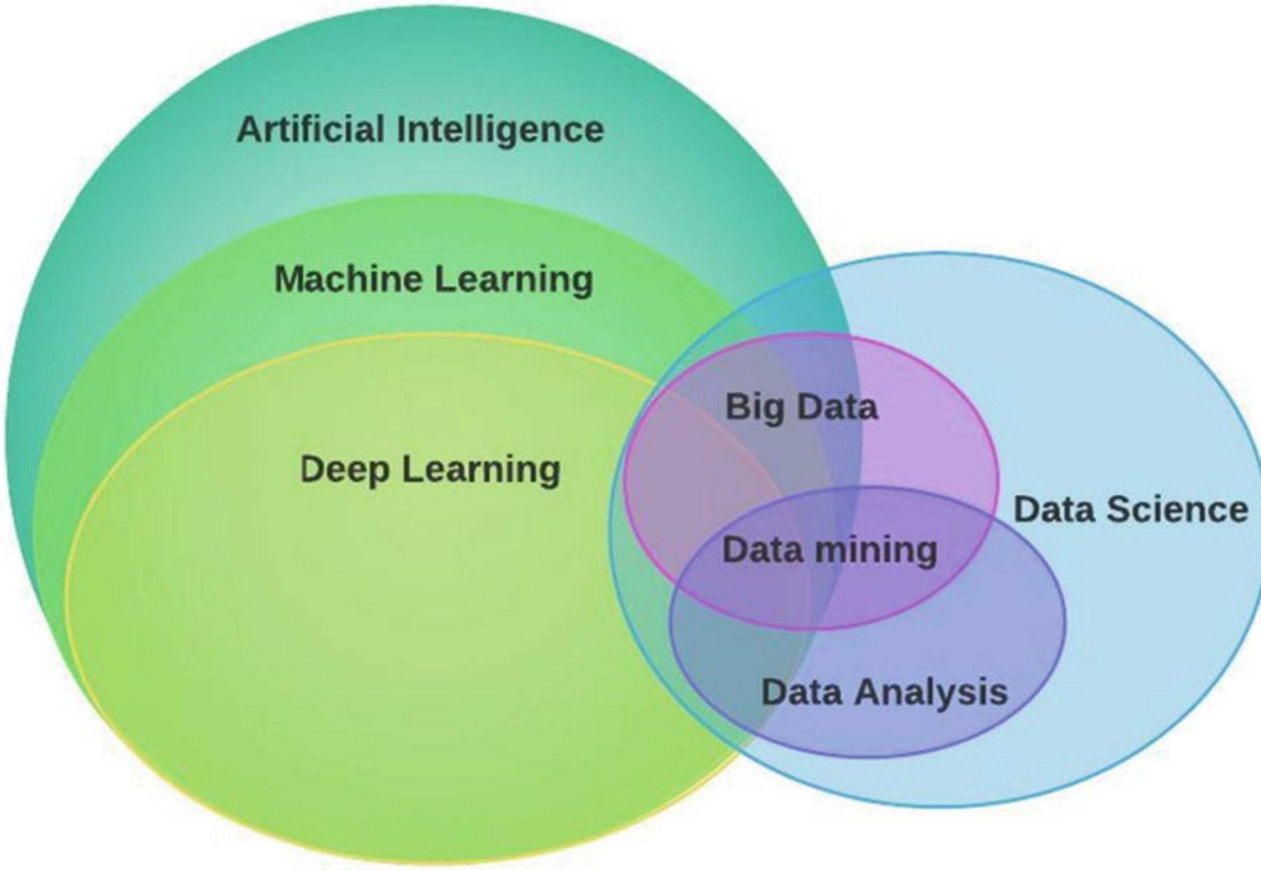
Outline

- Artificial Intelligence – Machine Learning
- What is Machine Learning?
- Machine Learning process
- Types of Machine Learning algorithms
  - Supervised Learning Algorithms
  - Unsupervised Learning Algorithms
  - Reinforcement Learning
- Artificial Intelligence: Generative AI, Limitations and Ethical considerations
- Applications in Agriculture

Artificial Intelligence – Machine Learning

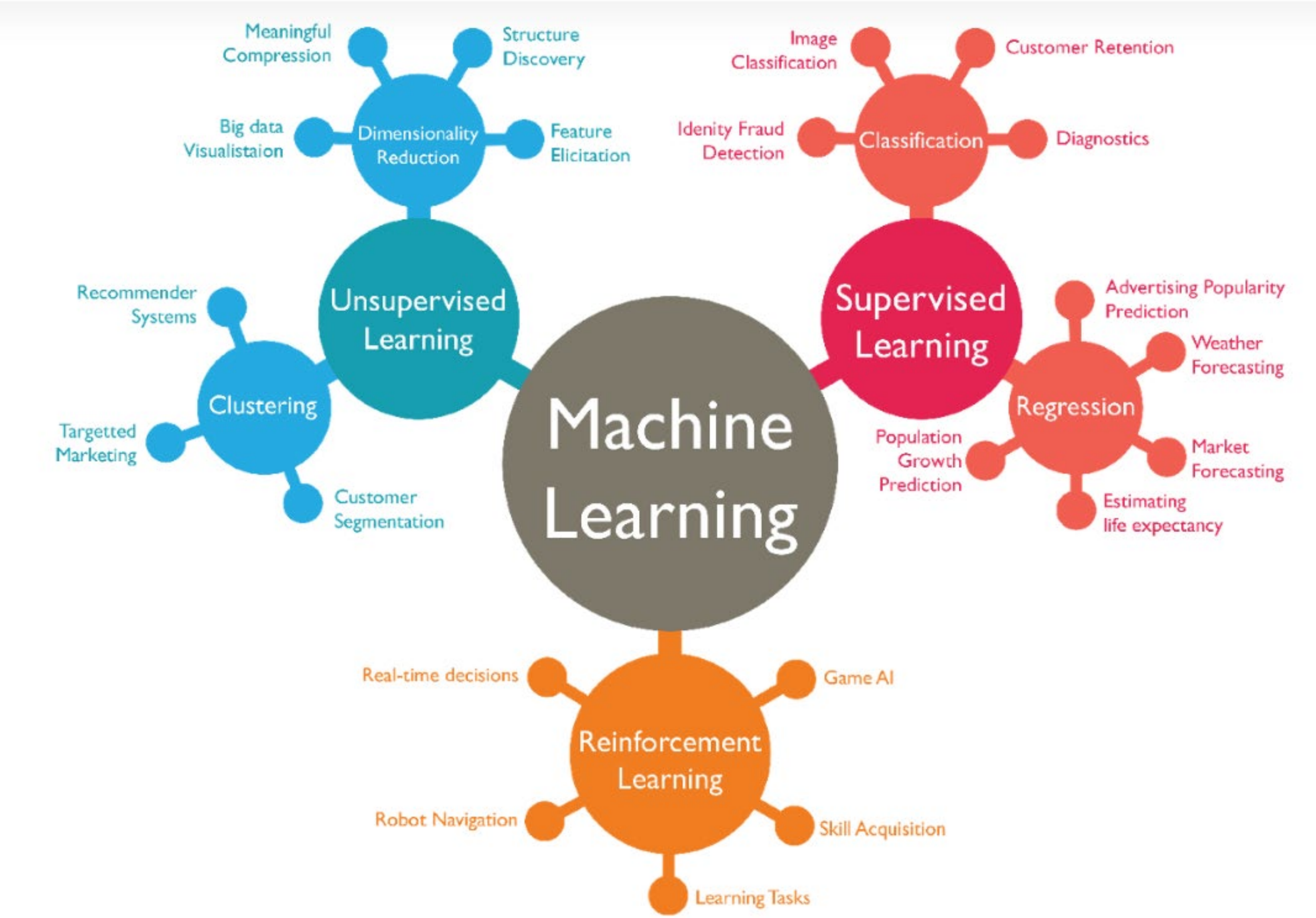
- **Artificial Intelligence** (AI): Programs whose objective is to learn and be able to reason like humans
- **Machine Learning** (ML): Algorithms able to learn and make decisions
- **Deep Learning** (DL): Artificial neural networks which learn from vast amounts of data
- **Data Science** (DS): Combination of maths, statistics, programming, AI and ML to guide decision making and strategic planning



Artificial Intelligence and Industrial Applications, 2023

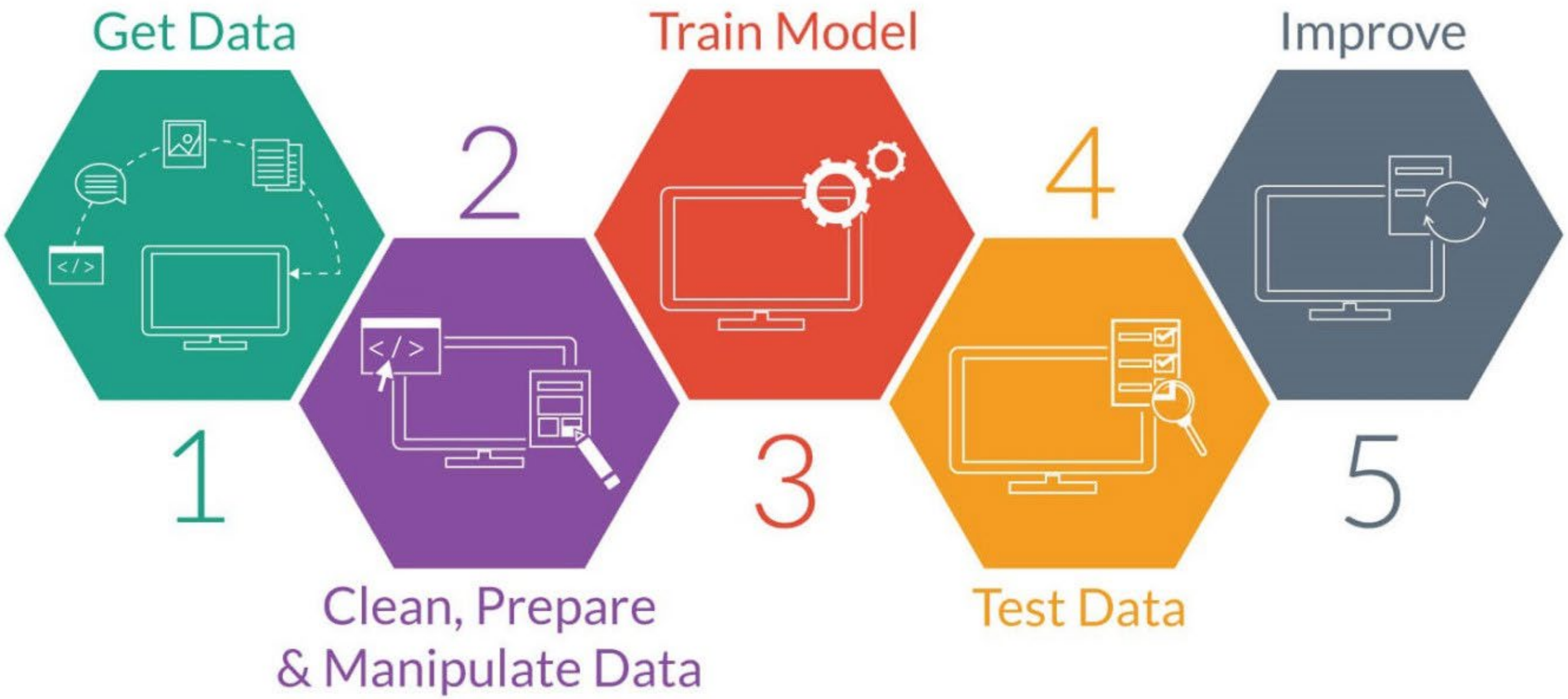
What is Machine Learning?

- Type of Artificial Intelligence
- Machine Learning is the science of programming computers so that they can learn from data
- Predict outcomes



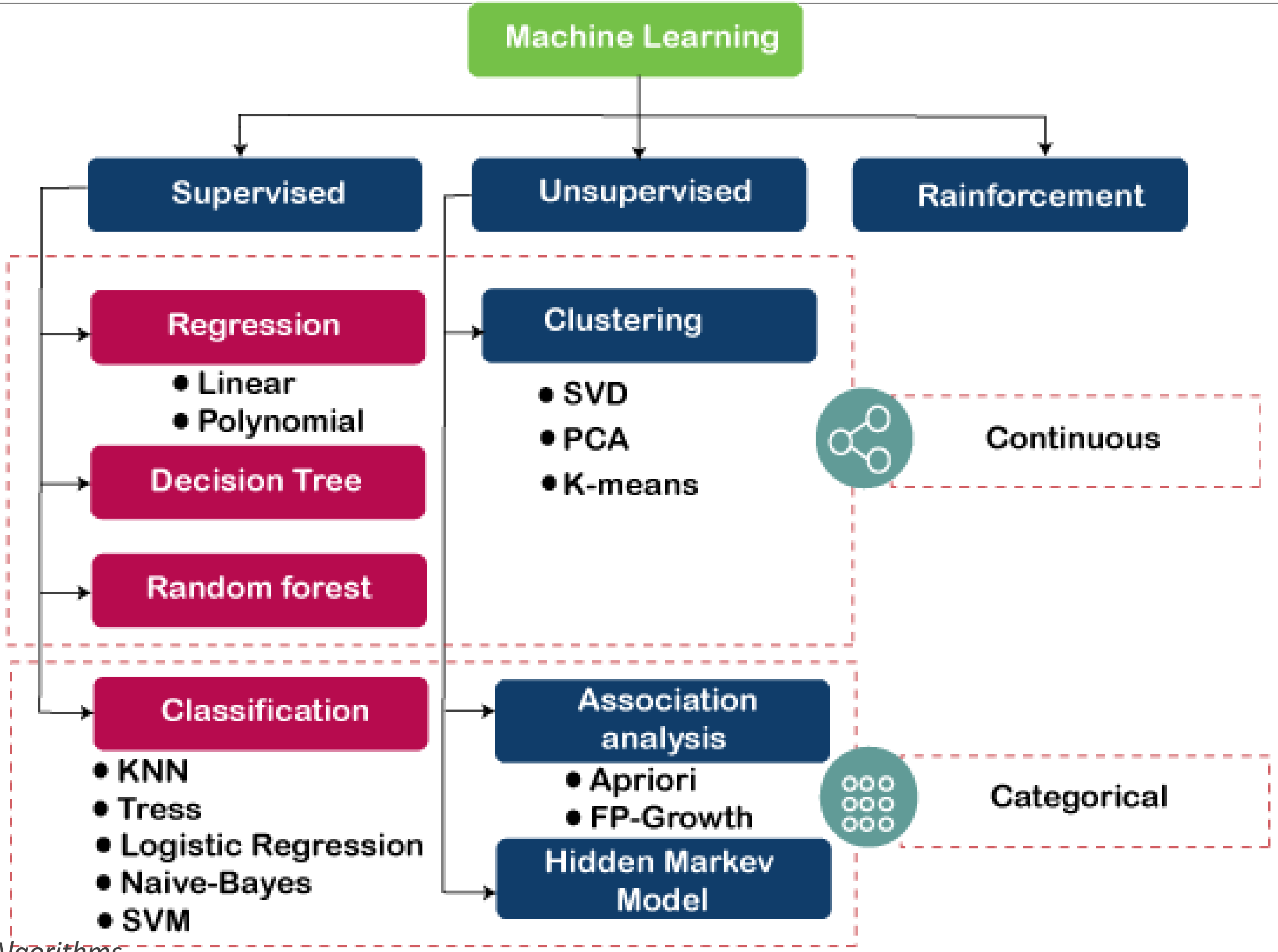
7wData: Types of Machine Learning Algorithms

Machine Learning process



C. Langton: Machine Learning model training over time

Types of Machine Learning algorithms



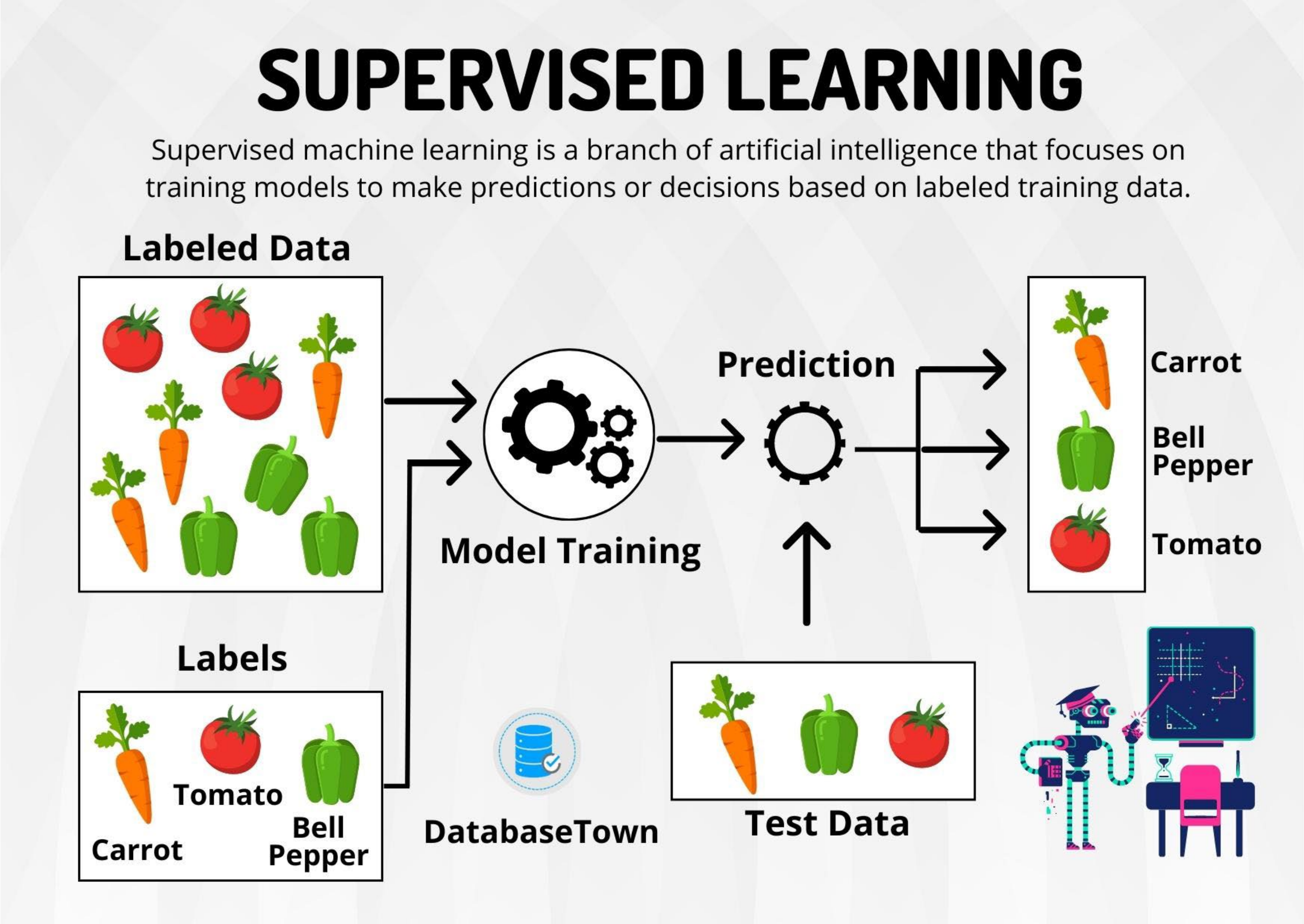
Javatpoint: Machine Learning Algorithms

Types of Machine Learning algorithms

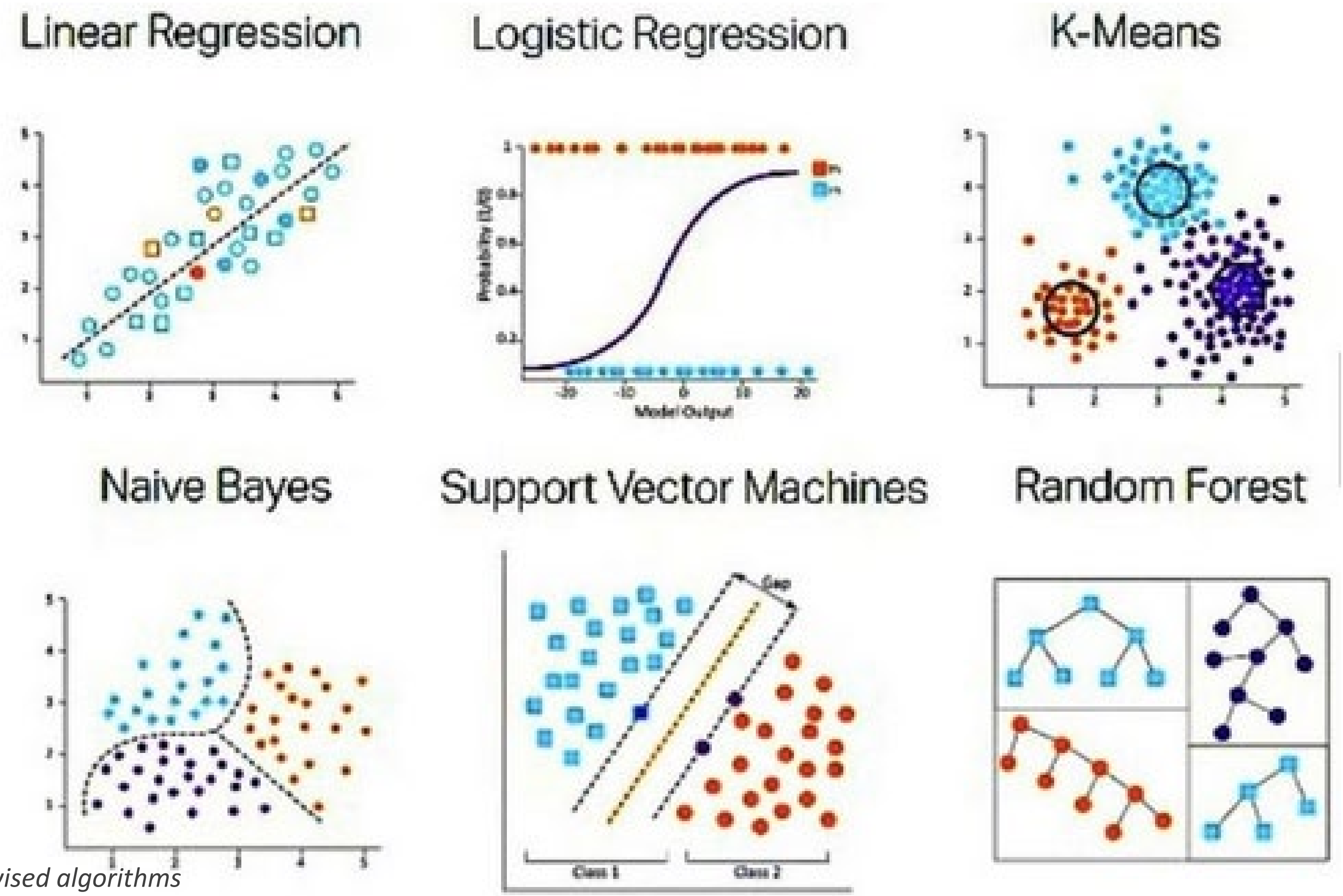
Supervised Learning

- Predict outcomes based on past data
- Requires (for the model to be trained):
  - features (independent variables – predictors)
  - labels (dependent variables – targets)
- Goal: Approximate mapping

Z. Akhtar: Supervised Learning: Algorithms, Examples and How it Works



Supervised Learning Algorithms



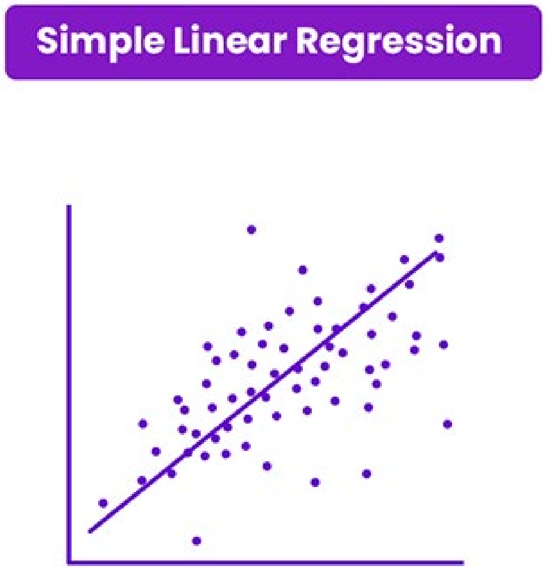
Darkcoding: Types of supervised algorithms

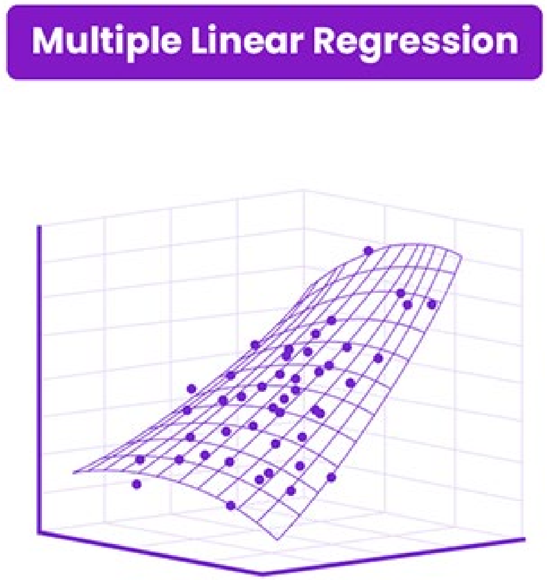
Supervised Learning Algorithms

Linear Regression

- Linear relationship between input features and target variable

- Predict continuous output values



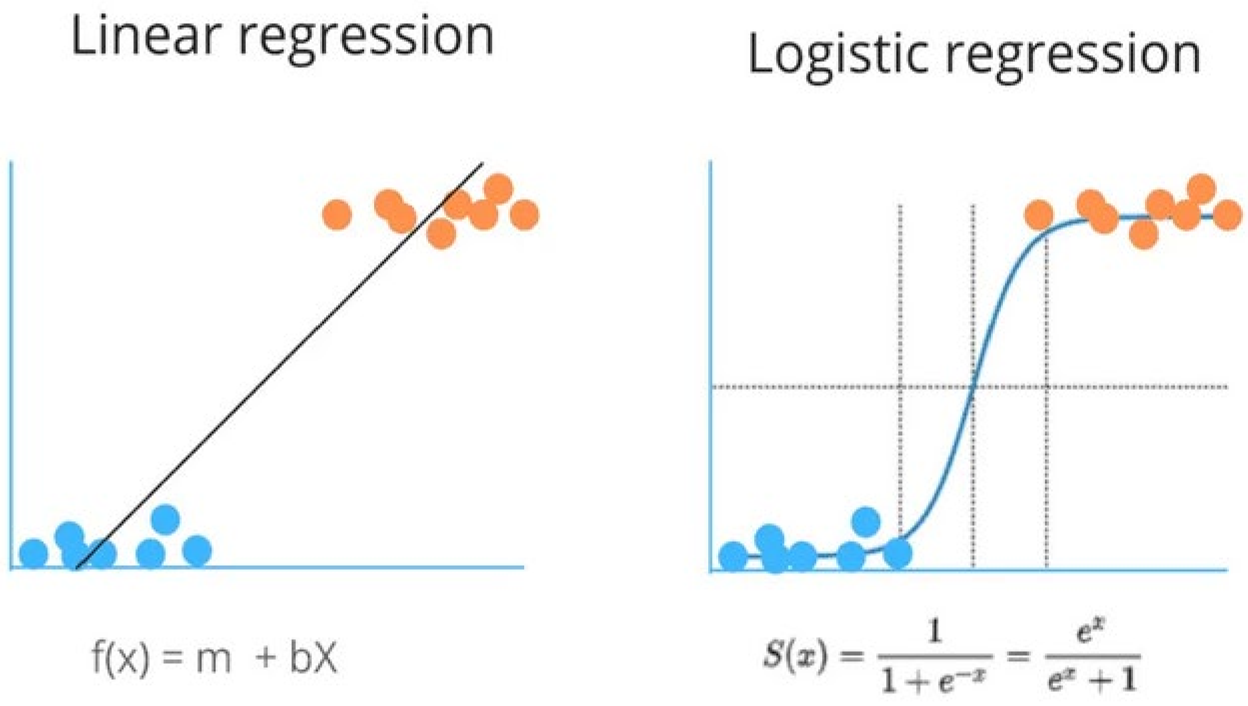


V. Narayan: Machine Learning Algorithms

Supervised Learning Algorithms

Logistic Regression

- Output variable is binary or categorical
- Models the relationship between the input features and the probability of a particular outcome using a logistic function
- Sigmoid function (S-shaped curve)

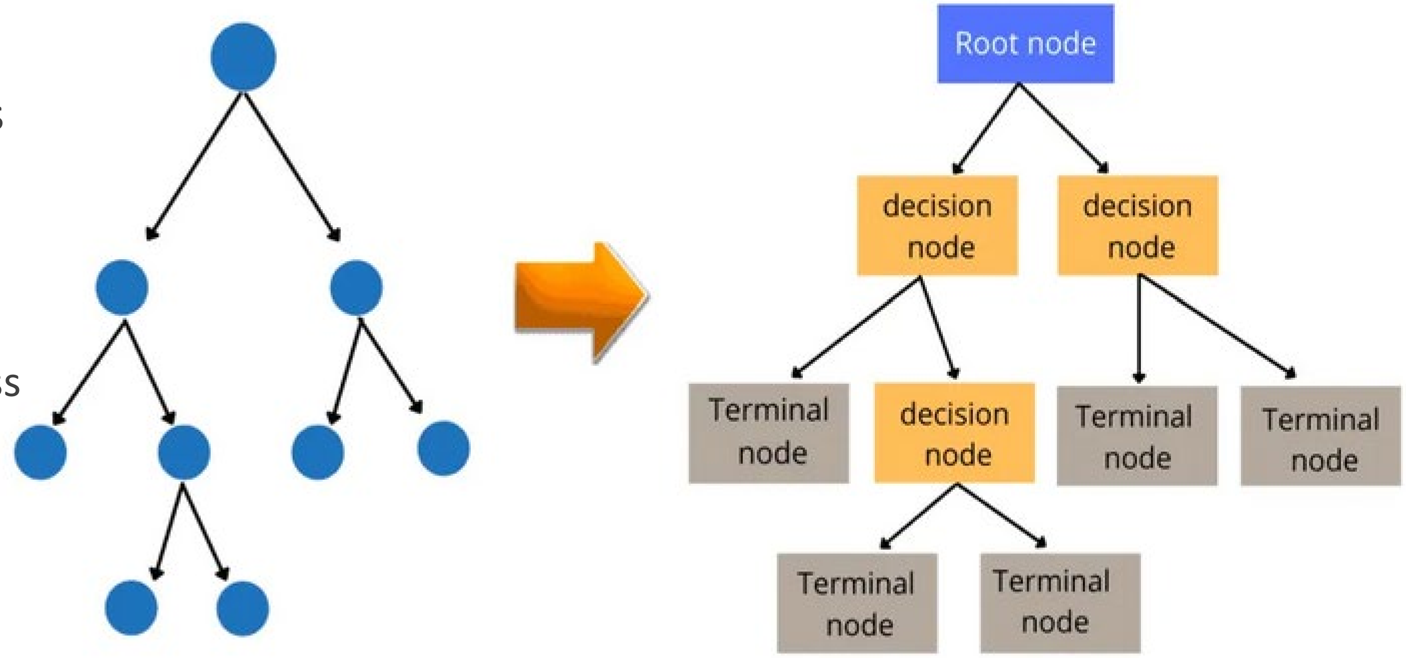


B. Alam: Introduction to Supervised Machine Learning

Supervised Learning Algorithms

Decision Trees

- Hierarchical structure to make decisions
- Split the data based on different features and create a tree-like structure
  - Each internal node represents an attribute test
  - Each branch reflects the test's outcome
  - Each leaf node (terminal node) stores a class label
- Predict the class or value of the target variable by learning simple decision rules inferred from the historical data

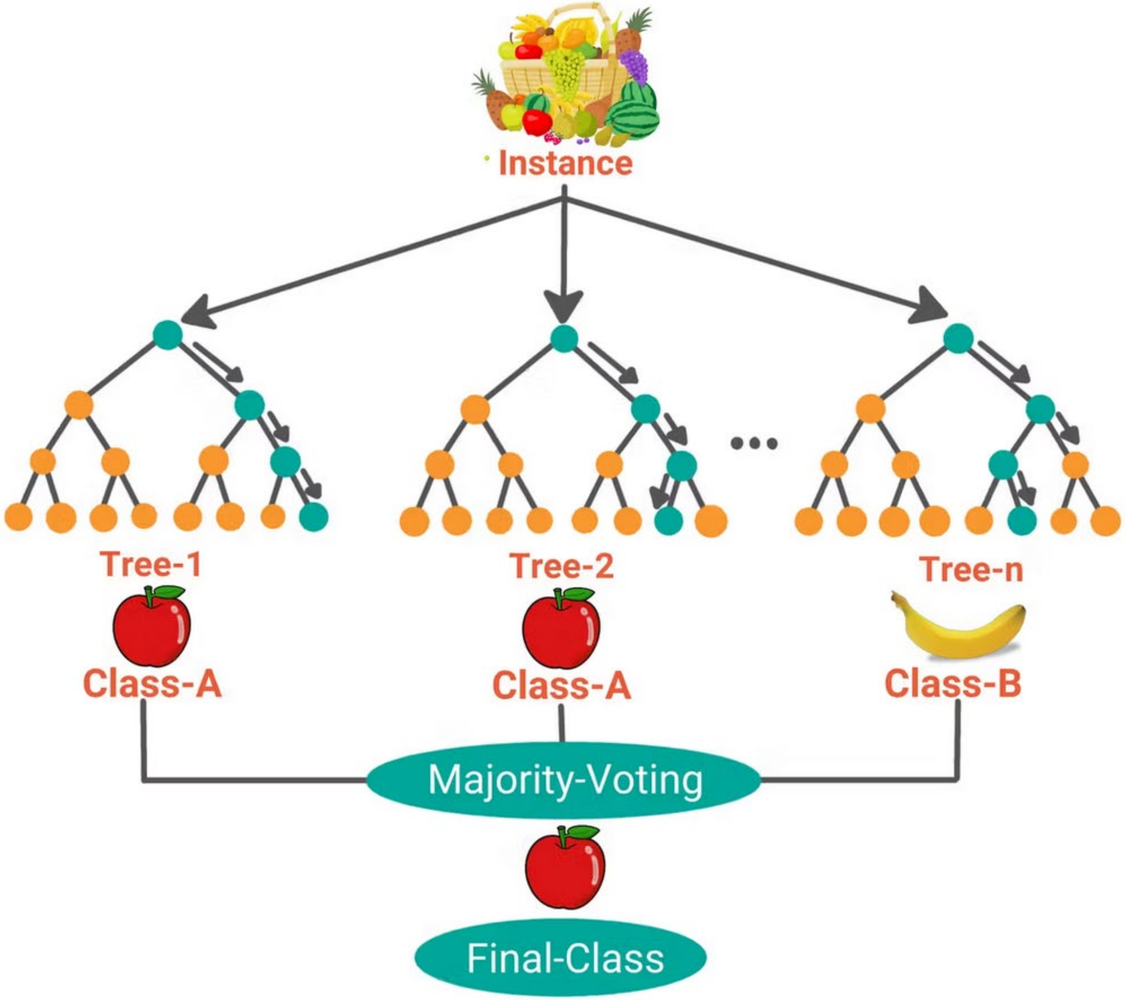


B. Alam: Introduction to Supervised Machine Learning

Supervised Learning Algorithms

Random Forests

- Combine multiple decision trees
- Aggregation predictions from multiple trees
  - Reduces overfitting
  - Increases robustness



N. Rosidi: Machine Learning Algorithms You Should Know for Data Science

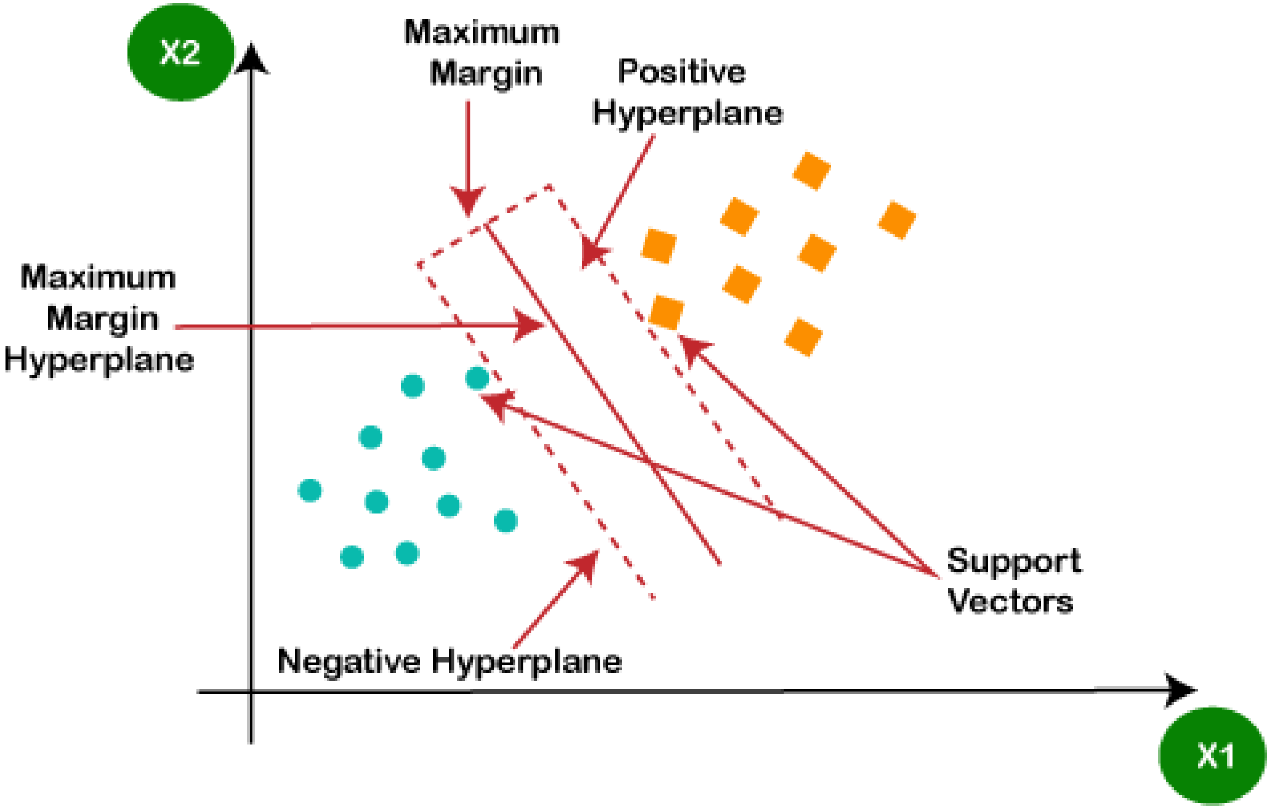
Supervised Learning Algorithms

Support Vector Machines (SVM)

- Effective for both classification and regression tasks

- Hyperplanes or decision boundaries that maximize the margin between different classes

- Data points that help to define the hyperplane are known as support vectors

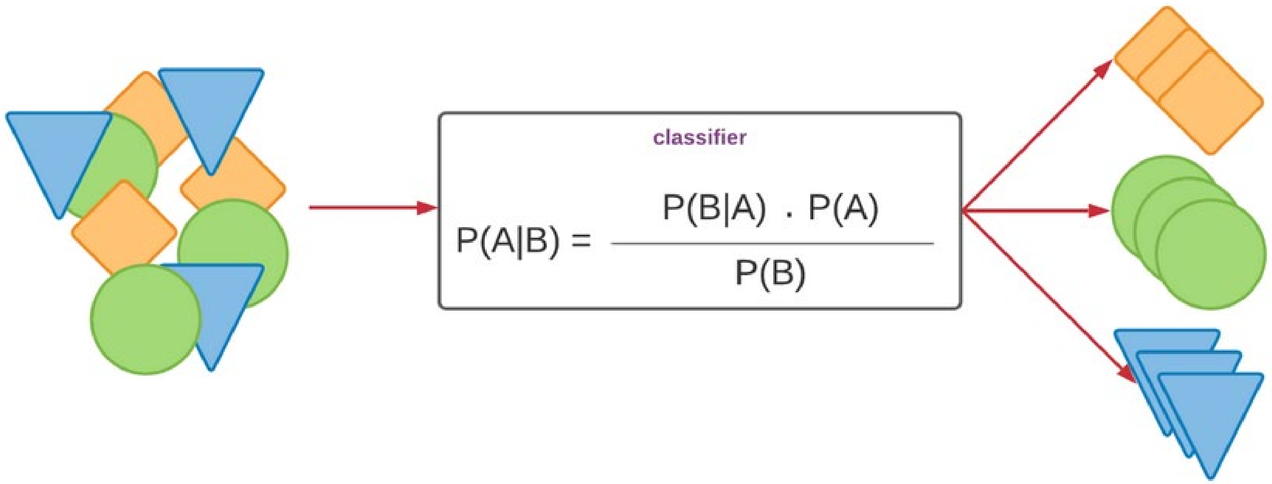


Javatpoint: Machine Learning Algorithms

Supervised Learning Algorithms

Naïve Bayes

- Based on Bayes' theorem
  - make predictions based on the probability of the object
  - follows the *naïve* assumption that says' variables are independent of each other
  1. Convert the given dataset into frequency tables.
  2. Generate Likelihood table by finding the probabilities of given features.
  3. Now, use Bayes theorem to calculate the posterior probability.
- One of the best classifiers that provide a good result for a given problem
- Commonly used for classification tasks
  - Text

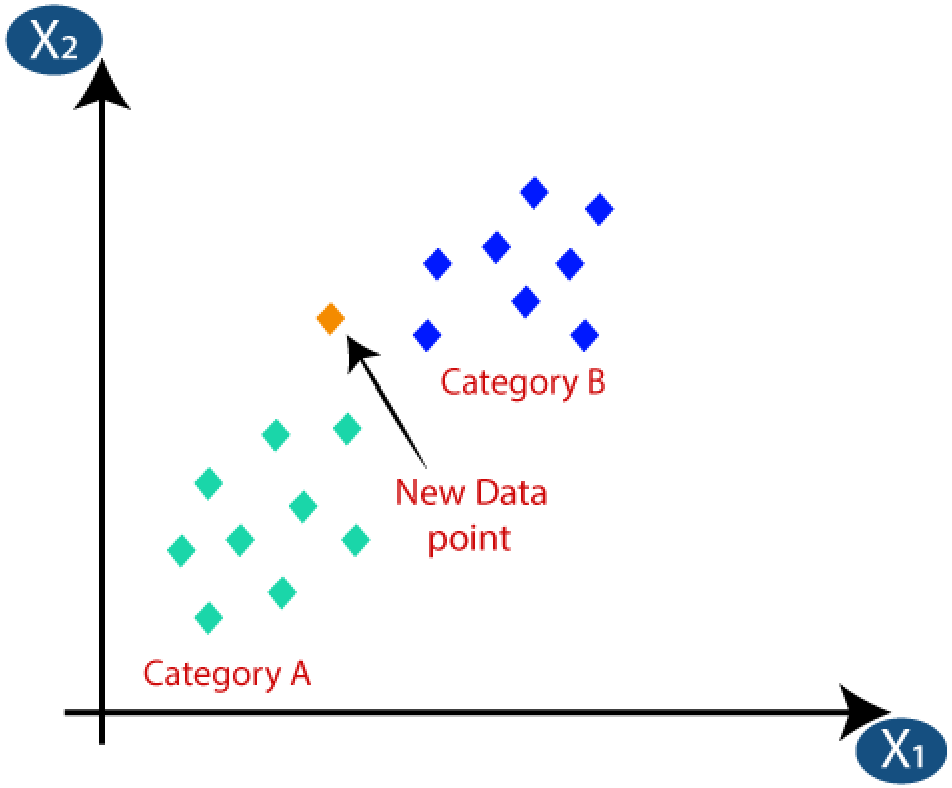


A. Saleem: data science for everyone

Supervised Learning Algorithms

K-Nearest Neighbours (KNN)

- non-parametric algorithm
- classification and regression problems
- classifies new instances based on their proximity to the labelled instances in the training data
- a class label based on the majority vote of its k nearest neighbours

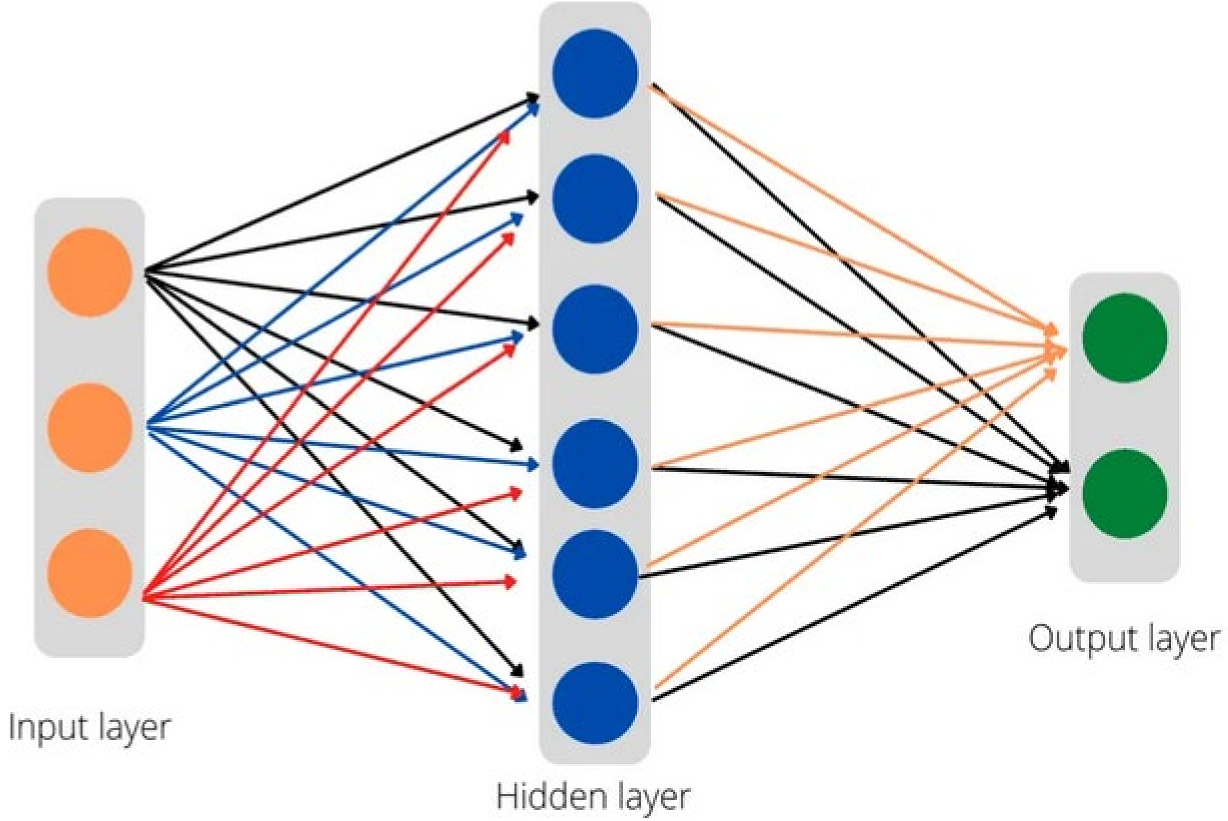


A. Saleem: data science for everyone

Supervised Learning Algorithms

Neural Networks

- interconnected nodes (neurons) organized in layers
- learn complex patterns and relationships
- Each node, or artificial neuron, is connected to the others and has a weight and threshold
- different activation functions are applied on the hidden and output layers
  - sigmoid function: on the output layer in the case of a binary classification problem
  - softmax function: multi-class classification problem.



B. Alam: Introduction to Supervised Machine Learning

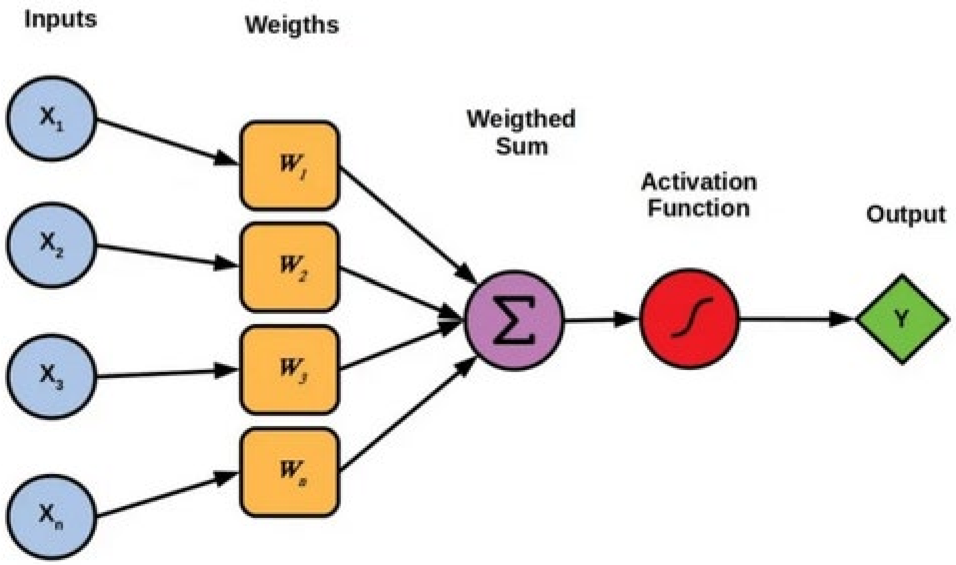
Supervised Learning Algorithms

Neural Networks: types

❖ **Perceptron**

- shallow neural network with the simplest model consisting of just one hidden layer
- The perceptron separates the input space into two categories by a hyperplane, determined by its weight and bias

- Applications:
  - Binary classifiers
  - Simple Image Recognition:
    - Distinguishing between handwritten digits (0-9) where the data is often somewhat linearly separable.
  - Spam Filtering



Just one hidden layer, linearly separable problems only

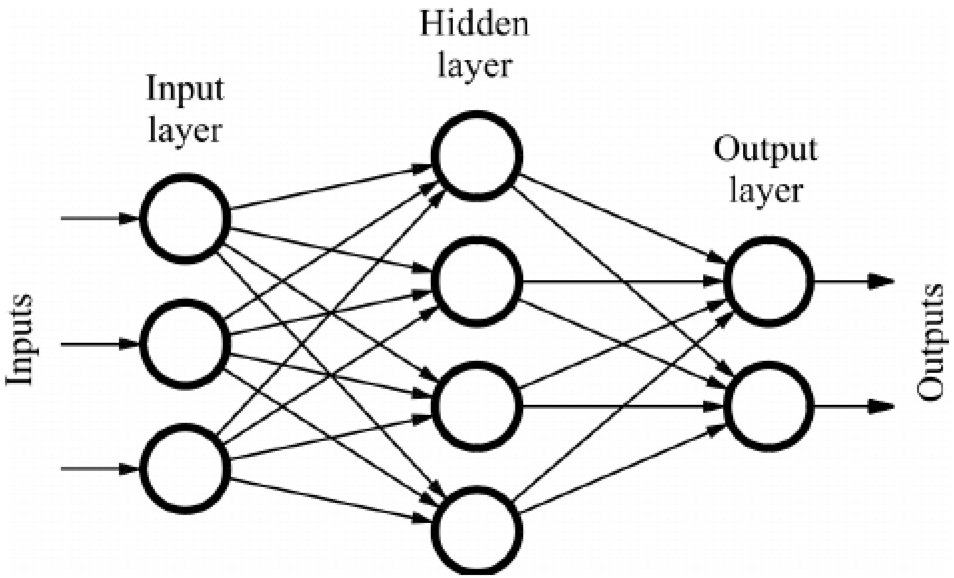
H. Mahmood: Types of neural networks and their applications

Supervised Learning Algorithms

Neural Networks: types

Feed Forward Neural Networks

- shallow neural network where connections between the nodes do not form a cycle
- information moves in only one direction
- Subtype: **Radial basis functions networks** (no computations on input layer: faster)
- Subtype: **Multilayer perceptrons** (non-linear kind of activation function, ideal for non linearly separable data)
- Applications:
  - Facial Recognition
  - Natural Language Processing (NLP): speech recognition and text classification
  - Computer Vision: image classification and object detection, automation of visual understanding tasks.



- Primary limitation: Lack of Feedback Connections
- Difficulty in Capturing Temporal Sequence Information: time series data, or any data where the sequence order is important
- Risk of Overfitting

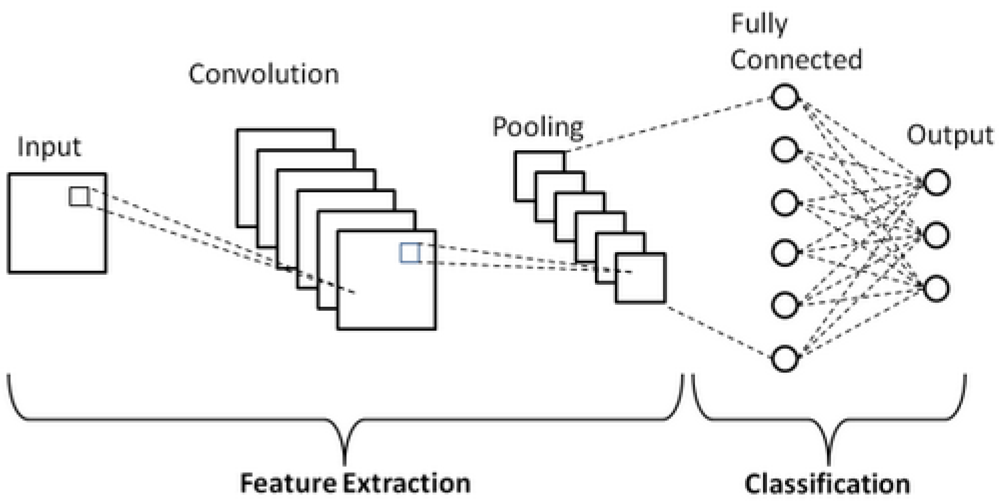
H. Mahmood: Types of neural networks and their applications

Supervised Learning Algorithms

Neural Networks: types

❖ Convolutional neural networks

- used for processing data that has a grid-like topology, such as images
- can recognize patterns with extreme variability (as hand-written characters)
- Applications:
  - Automated Driving
  - Facial Recognition
  - **Agriculture** (crop and soil monitoring, disease detection, and automated harvesting systems)
  - Medical Image Analysis



Three main layers:

1. convolutional layer: where most of the computation occurs
2. pooling layer: where the number of parameters in the input is reduced
3. the fully connected layer: classifies the features extracted from the previous layers

H. Mahmood: Types of neural networks and their applications

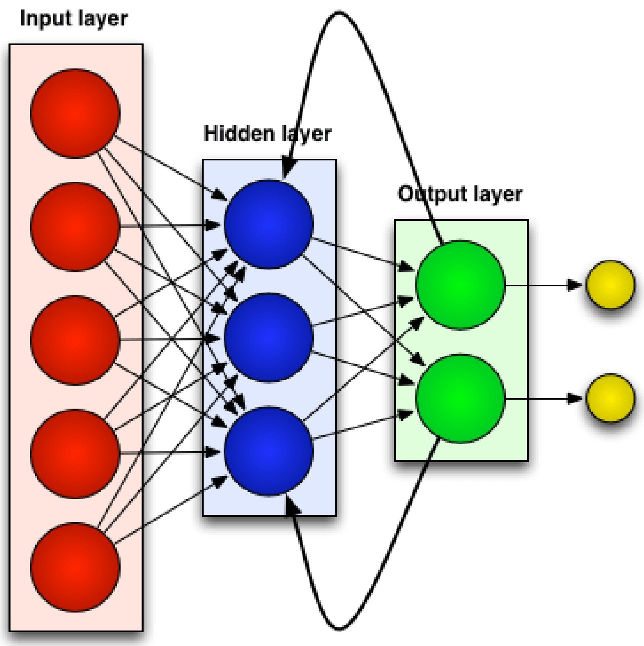
Supervised Learning Algorithms

Neural Networks: types

❖ Recurrent neural networks

- deep neural networks
- Feedback loops in the structure allow information to be stored
- **Long short-term memory networks** (improved RNN with memory cell to learn long-term dependencies)

- Applications:
  - Time-series prediction
  - translate language
  - speech recognition
  - smart home technologies
  - voice command features on mobile phones
  - natural language processing
  - image captioning



- FNNs with hidden layers
- The hidden layer output loops back into itself, creating a memory of past inputs that informs how the network processes new information

H. Mahmood: Types of neural networks and their applications

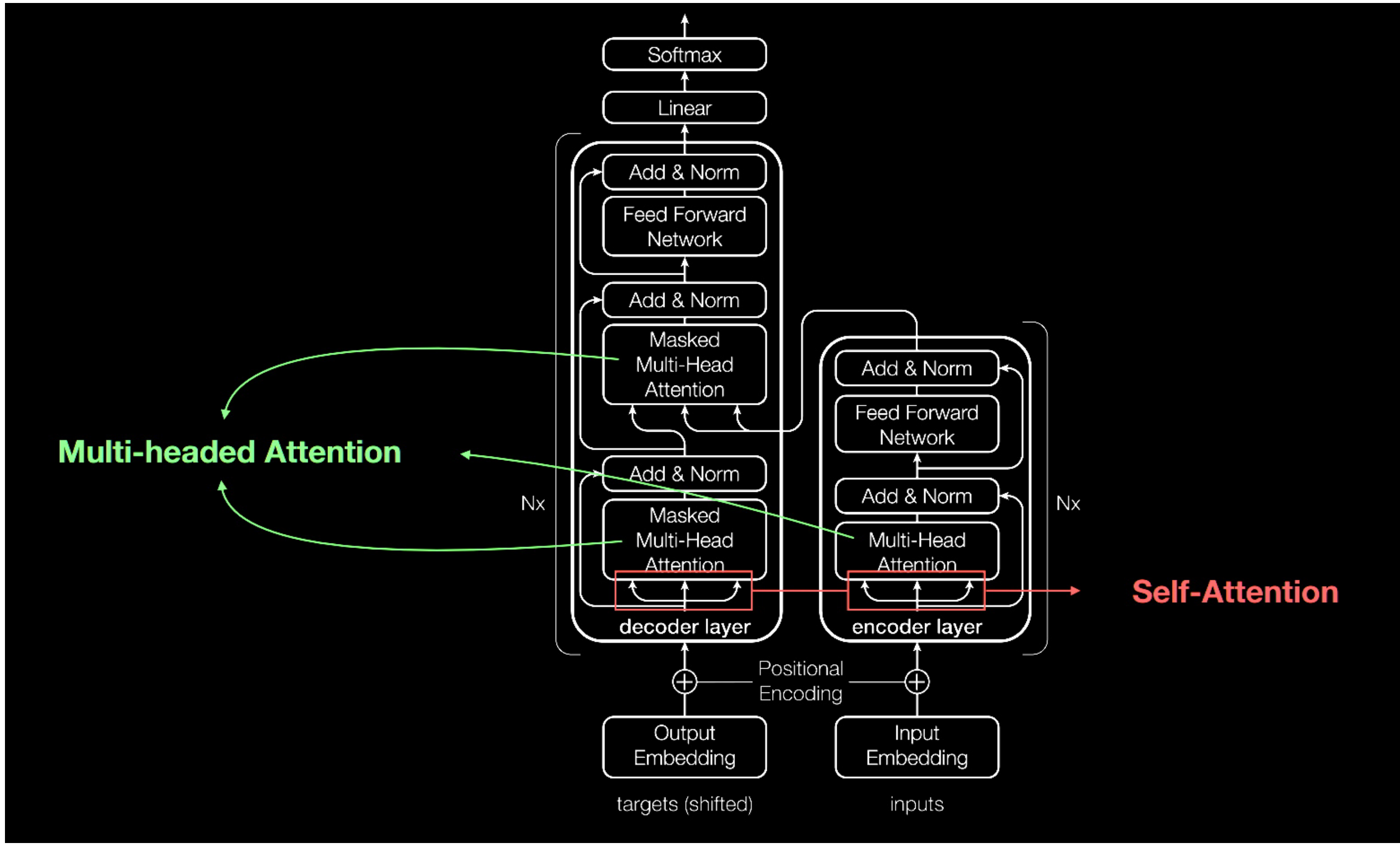
Supervised Learning Algorithms

Neural Networks: types

❖Transformers

- learns context (tracking relationships) in sequential data
- self-supervised learning
- use positional encoders to tag data elements coming in and out of the network
- Attention units follow these tags, calculating a kind of algebraic map of how each element relates to the others
- Transformers are replacing CNNs and RNNs (original paper 2017, Google)
- Able to handle long sequences more efficiently and parallelize data processing

- Applications:
  - Natural Language Processing (NLP) problems
  - detect trends and anomalies to prevent fraud
  - streamline manufacturing
  - make online recommendations



R. Merritt: What Is a Transformer Model?

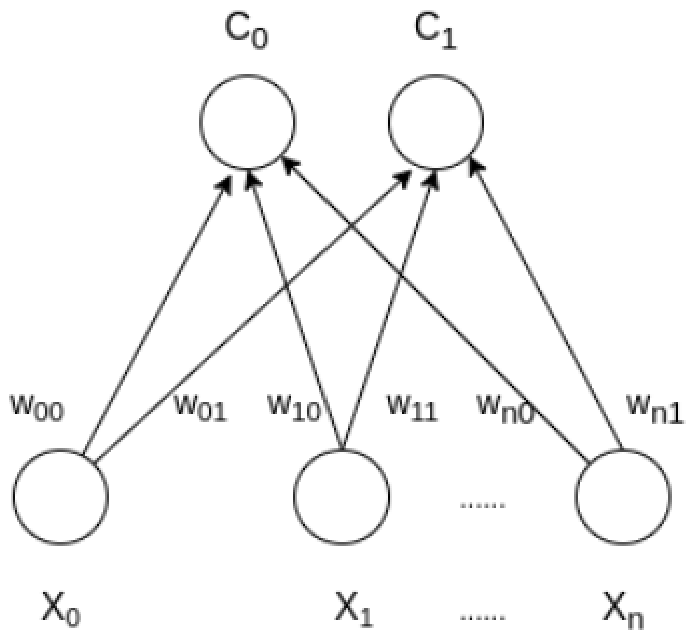
Unsupervised Learning Algorithms

Neural Networks: types

❖ Self-organising maps – Kohonen Maps

- Unsupervised learning approach
- transform extensive complex data sets into understandable two-dimensional maps
  - geometric relationships can be visualised
- neurons must compete to be represented in the output
- apply competitive learning as opposed to error-correction learning

- Applications:
  - displaying voting trends for analysis
  - organising complex data collected to be interpreted.



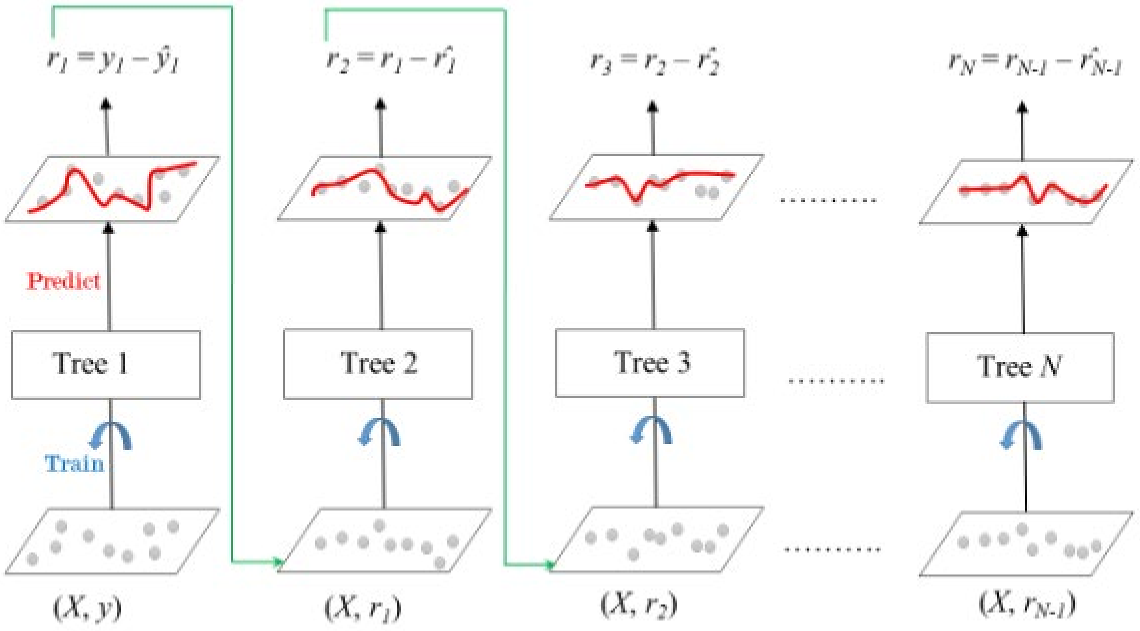
- two layers: Input layer and Output layer

H. Mahmood: Types of neural networks and their applications

Supervised Learning Algorithms

Gradient Boosting Algorithms

- ensemble methods that sequentially build models
- each focusing on the errors of the previous models
- effective for classification and regression tasks: high predictive accuracy
  - Gradient Boosted Trees
  - XGBoost



Gradient Boosted Trees for Regression

Supervised Learning Algorithms

Benefits

- Accurate predictions
  - when trained on a diverse and representative dataset.
- Versatility
  - wide range of problem domains
- Interpretable results
  - understand the reasoning behind predictions.

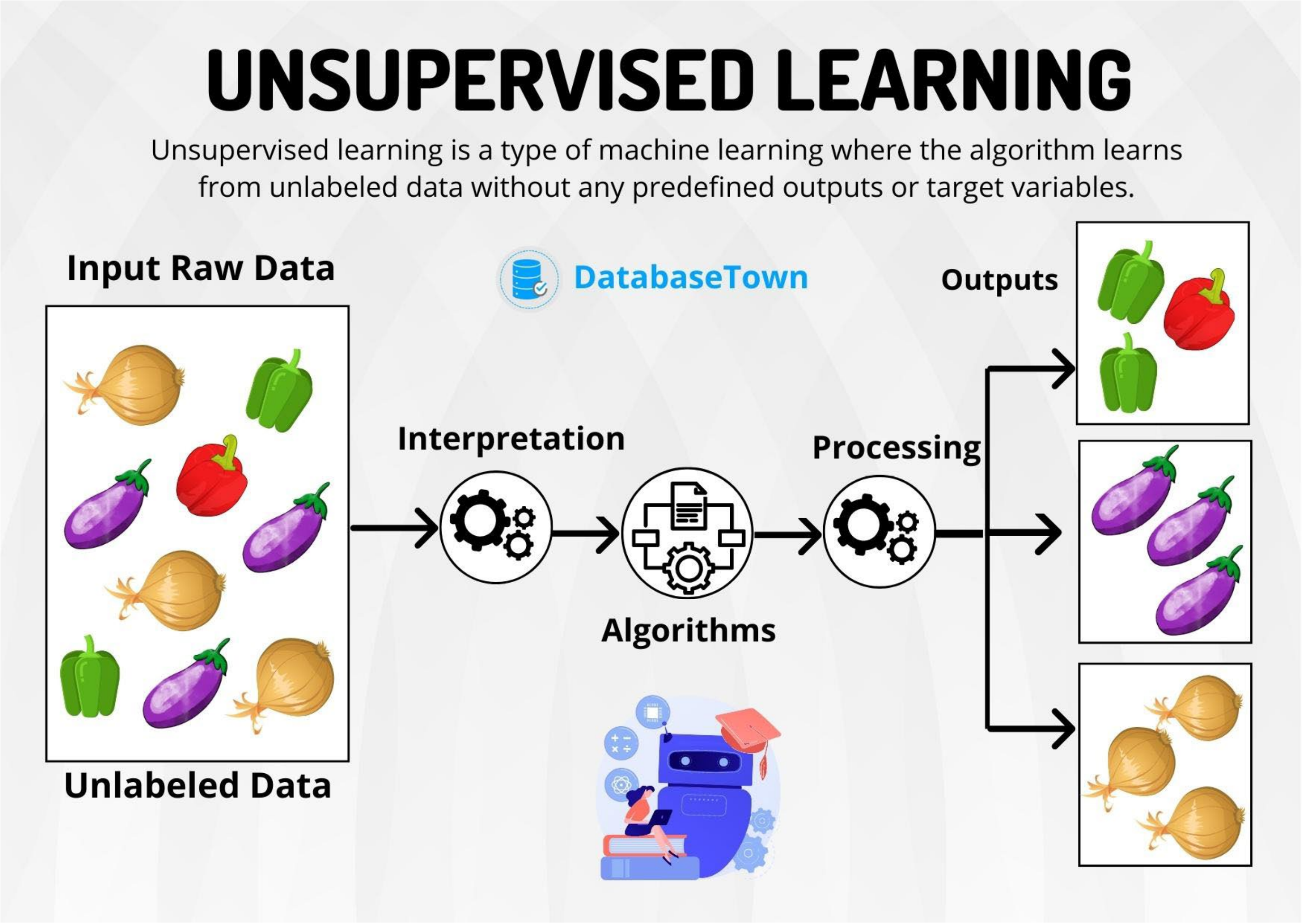
Limitations

- Dependency on labelled data
  - labelled data is expensive and time-consuming to collect.
- Limited generalization
  - struggle to generalize well to new or unseen data that differ significantly from the training data distribution.
- Overfitting
  - If trained on limited data, poor performance on unseen data.

Types of Machine Learning

Unsupervised Learning

- Identify hidden patterns from input data that lacks pre-existing labels or annotations
- discover inherent structures or clusters within the data
- useful when dealing with large datasets where manual labelling would be impractical or costly

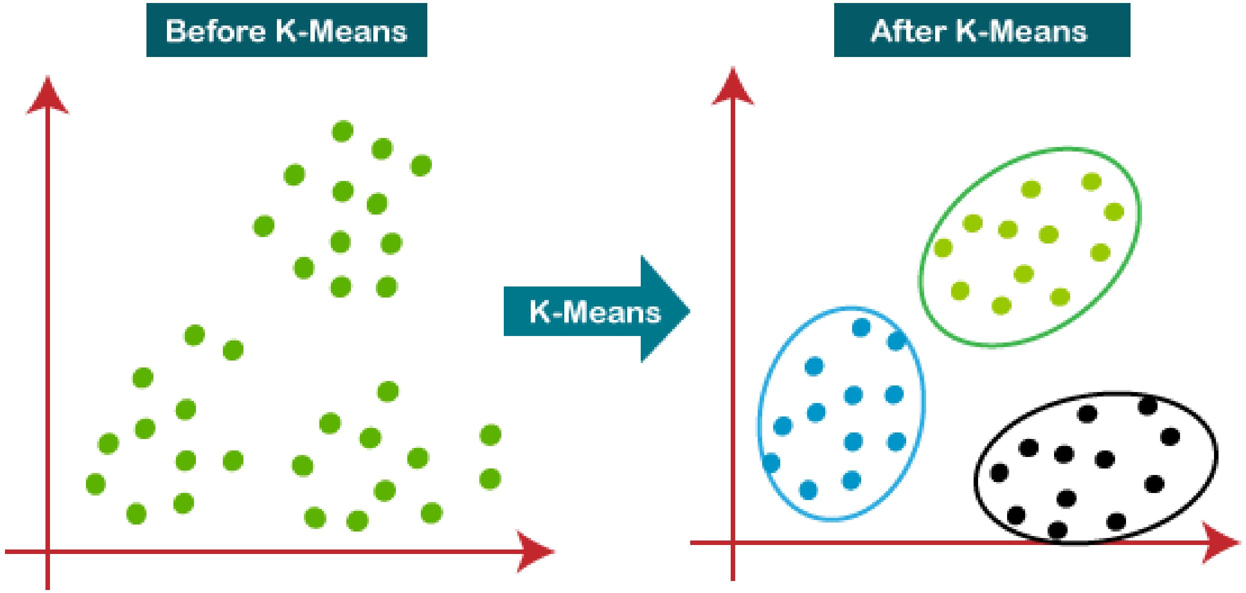


Z. Akhtar: Unsupervised Learning: Types, Applications & Advantages

Unsupervised Learning Algorithms

Clustering Algorithms

- **K-means**
  - data is divided into a specific number of clusters
  - Minimize the total squared distances between the data points and the centres of each cluster.
  - Advantages
    - very simple to implement
    - scalable to a huge data set, faster to large datasets
    - adapts the new examples
    - generalization of clusters for different shapes and sizes
  - Disadvantages
    - sensitive to outliers
    - Shape Assumption: This tends to hold the distances by treating the clusters as spherical objects of equal sizes, which is not always true
    - As the number of dimensions increases its scalability decreases

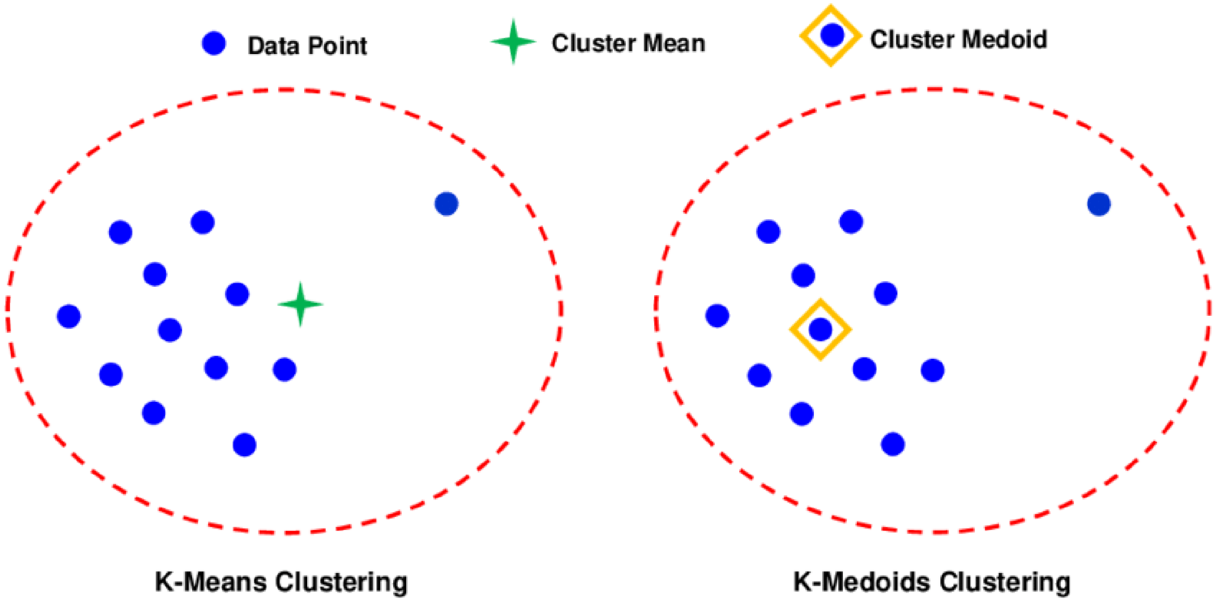


Javatpoint: Machine Learning Algorithms

Unsupervised Learning Algorithms

Clustering Algorithms

- **K-medoids,** Partitioning Around Medoids (PAM)
  - similar to the K-Means
  - requires the use of medians for the formation of subgroups
  - Uses actual data points as medoids, making it more interpretable
  - Advantages
    - Robustness to outliers vs centroids.
    - Flexibility in Distance Metrics: can use any distance measurement, not limited to the Euclidean distance measurement, making it general for all data types.
  - Disadvantages
    - Computationally Intensive: relatively slower than K-Means due to its higher complexity when working with larger databases.
    - Complexity: more difficult to implement



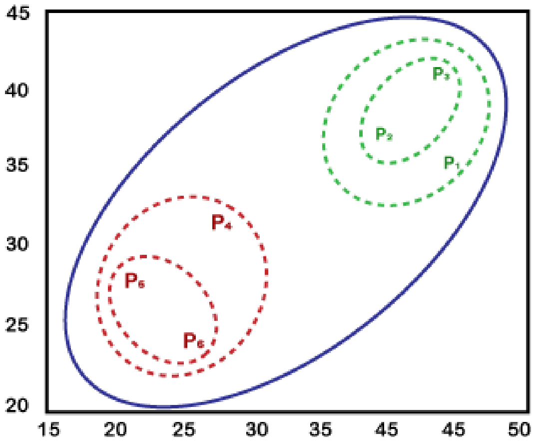
A. Entezami: graphical representation of the difference between the k-means and k-medoids clustering methods (An innovative hybrid strategy for structural health monitoring by modal flexibility and clustering methods)

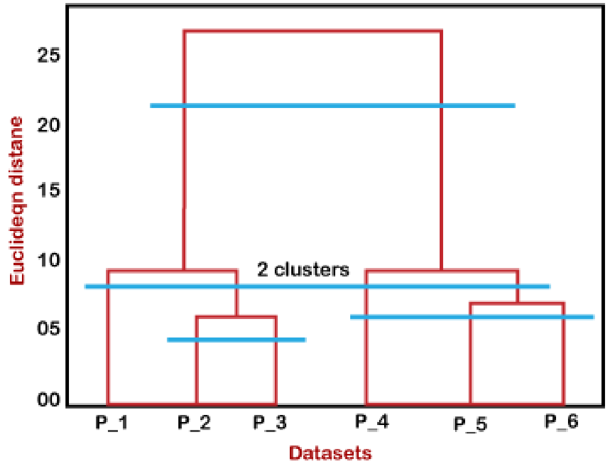
Unsupervised Learning Algorithms

Clustering Algorithms

- **Hierarchical Clustering**
  - develops a hierarchy of clusters by merging or splitting them depending on their similarity
  - two approaches:

1. Agglomerative
   - bottom-up approach
   - the algorithm starts with taking all data points as single clusters and merging them until one cluster is left
2. Divisive
   - reverse of the agglomerative algorithm as it is a top-down approach.



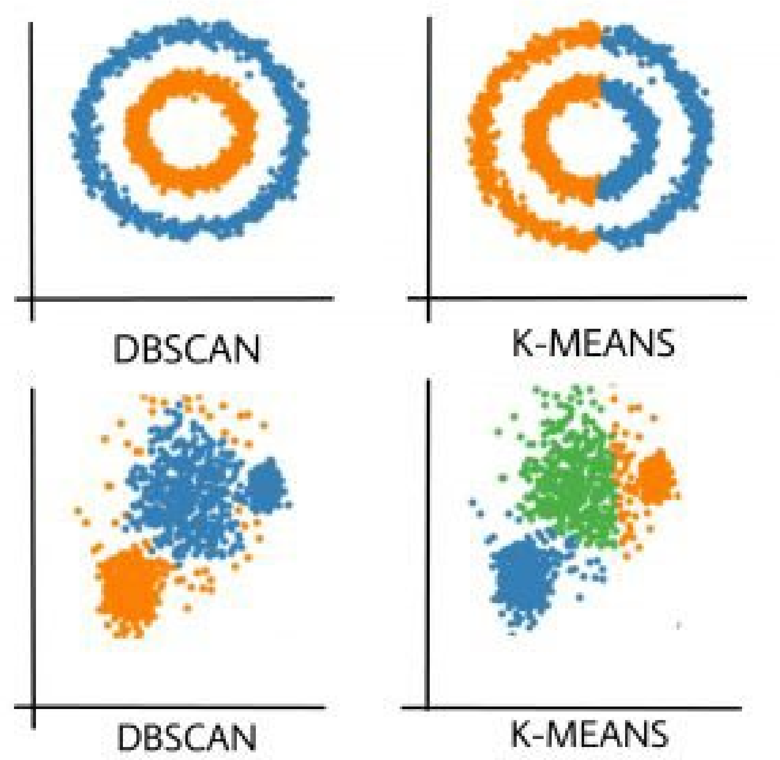


Javatpoint: Machine Learning Algorithms

Unsupervised Learning Algorithms

Clustering Algorithms

- **DBSCAN (Density-Based Spatial Clustering of Applications with Noise)**
  - Clusters are dense regions in the data space, separated by regions of the lower density of points
  - for each point of a cluster, the neighbourhood of a given radius has to contain at least a minimum number of points
  - Partitioning methods (k-means, PAM clustering) are suitable only for compact and well-separated clusters
  - DBSCAN for data set containing non-convex shape clusters and outliers

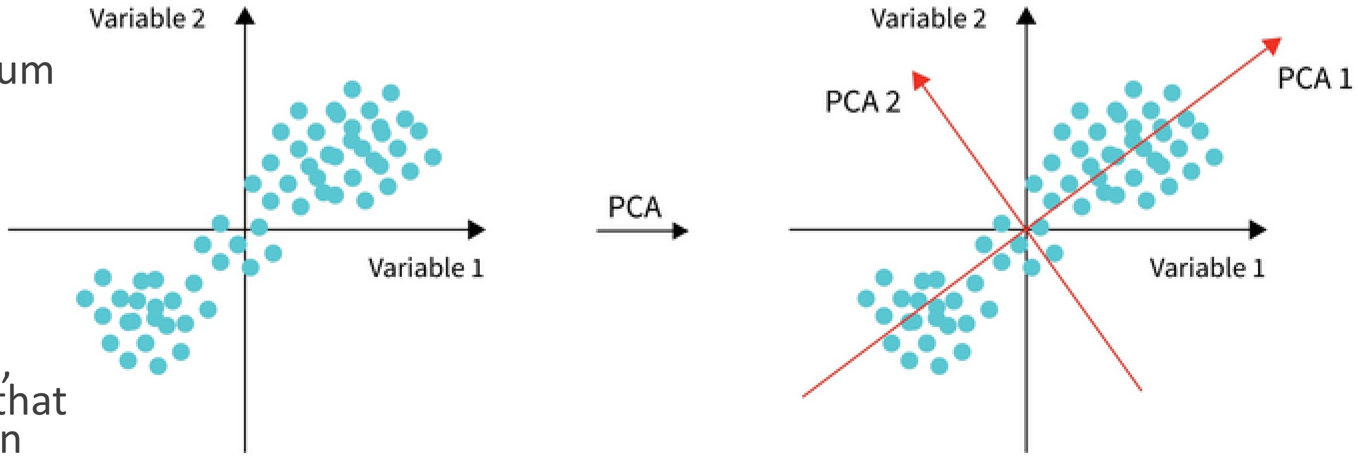


DBSCAN Clustering in ML

Unsupervised Learning Algorithms

Dimensionality Reduction Algorithms

- **Principal Component Analysis (PCA)**
  - transforms the original features into a lower-dimensional space while preserving the maximum amount of information
  - considers the variance of each attribute
  - transforms the original data to a new set of variables called the principal components (PCs), which are uncorrelated and can be ordered so that the first few PCs can retain most of the variation present in all of the original variables of the dataset.



S. Madala: Principal Component Analysis

Unsupervised Learning Algorithms

Benefits

- Use of unlabelled Data
- Scalability
  - handle large-scale datasets without manual labelling Interpretable results
- Anomaly Detection
  - effectively detect anomalies or outliers in data
- Data Pre-processing
  - dimensionality reduction can help pre-process data by reducing noise, removing irrelevant features, and improving efficiency

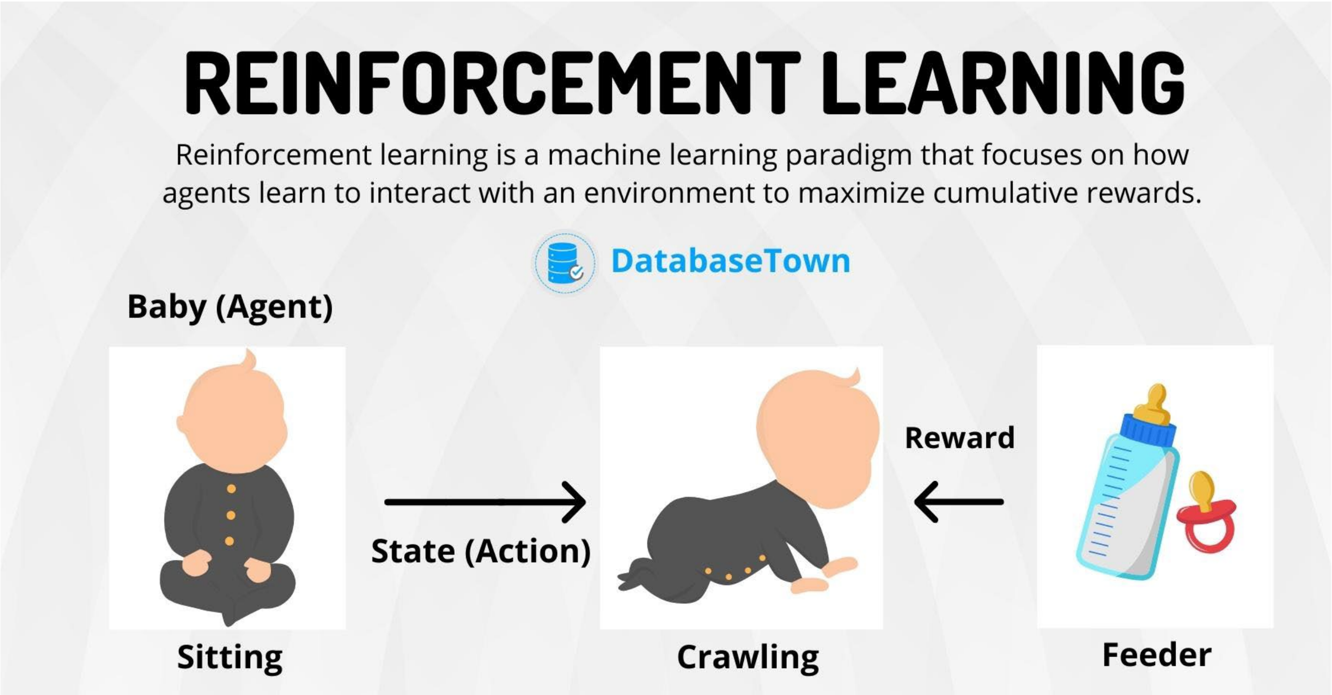
Limitations

- Lack of groundtruth
  - no definitive measure of correctness or accuracy
  - Evaluation and interpretation of results become subjective and rely heavily on domain expertise
- Interpretability
  - Interpreting and understanding the meaning of these clusters can be challenging and subjective
- Overfitting and Model Selection
  - susceptible to overfitting
- Limited guidance
  - lacks explicit guidance, which can result in discovering irrelevant or noisy patterns

Types of Machine Learning

Reinforcement Learning

- learn to interact with an environment to maximize cumulative rewards
- trial and error learning through interactions with the environment
- 3 components:
  - Agent: represents the intelligent entity that interacts with the environment, receives rewards or punishments based on its actions
  - Environment: external system with which the agent interacts
  - Action: decisions taken by the agent to transition between states in the environment.
- Markov decision processes: model decision-making problems in which the outcomes depend on the current state and the chosen action



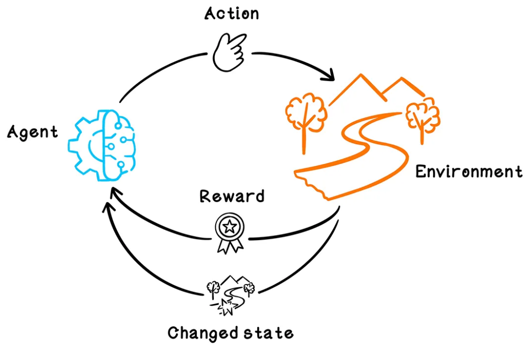
Z. Akhtar: Basics of Reinforcement Learning

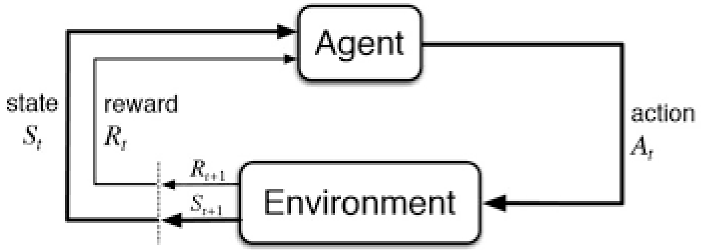
Reinforcement Learning

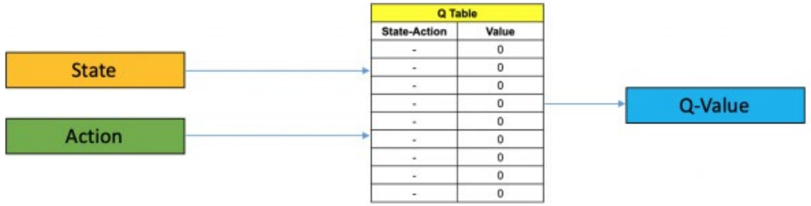
Algorithms and Approaches

- Q-learning
  - model-free method: does not require explicit knowledge of the environment’s dynamics
  - estimates the value of state-action pairs and iteratively updates the Q-values based on the observed rewards

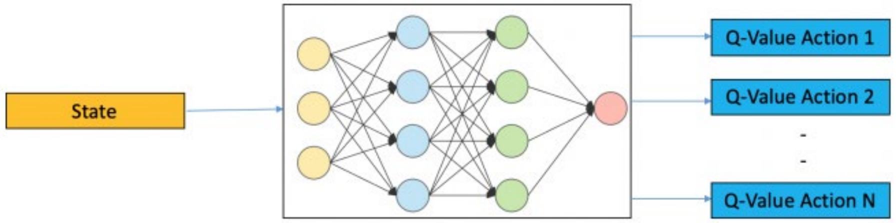
- Deep Q-networks
  - combine reinforcement learning with deep neural networks
  - use the power of deep learning architectures to approximate the Q-values for large state-action spaces
  - can handle complex environments and learn high-dimensional representations







Q Learning



Deep Q Learning

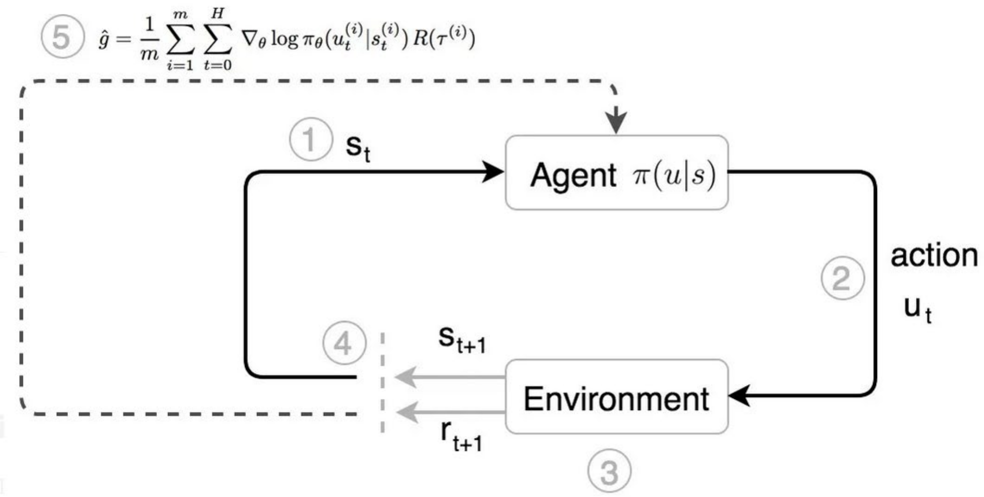
R. Hurbans: Reinforcement learning with Q-learning

P. Foy: Deep Reinforcement Learning

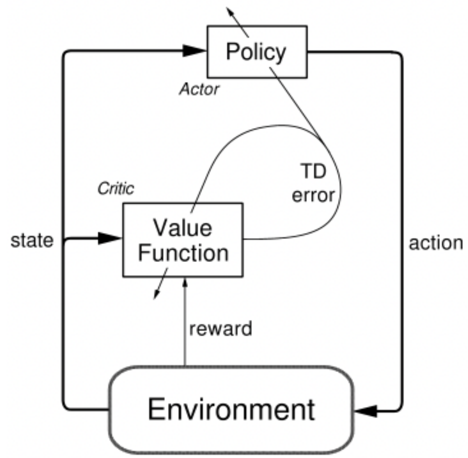
Reinforcement Learning

Algorithms and Approaches

- Policy Gradients
  - directly optimize the policy by estimating the gradients of the expected rewards with respect to the policy parameters.
  - By iteratively updating the policy in the direction of higher rewards, these methods can learn complex and continuous action policies



- Proximal Policy Optimization (PPO)
  - optimization algorithm
  - maintains a balance between stability and sample efficiency
  - uses a surrogate objective function to update the policy parameters and ensure small policy updates to maintain stability



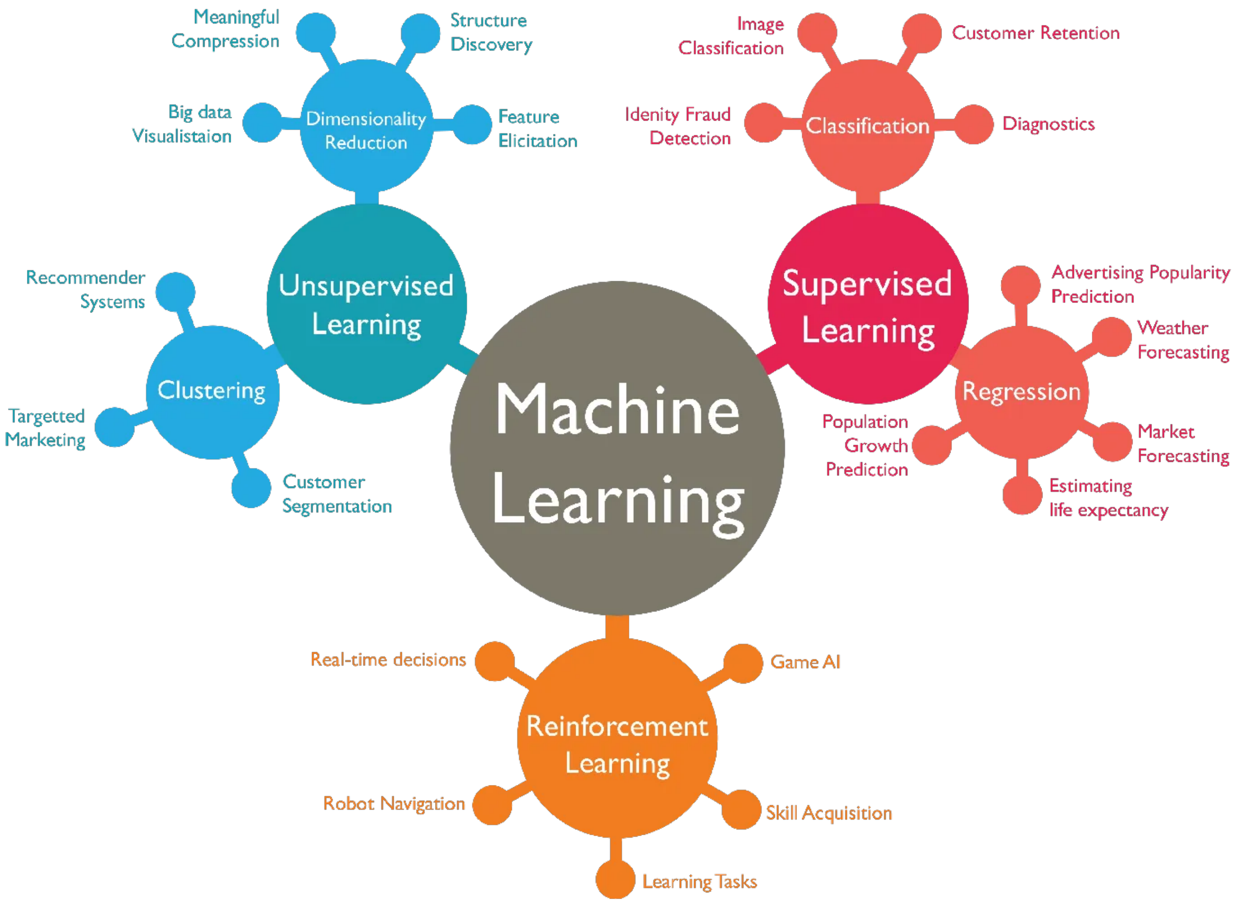
J. Hui: RL — Policy Gradient Explained

R. Khandelwal: Proximal Policy Optimization (PPO): Exploring the Algorithm Behind ChatGPT's Powerful Reinforcement Learning Capabilities

Conclusions of Machine Learning

- ➢ No algorithm better for all problems
  - ➢ Depends on pattern, type of data, experience of the analyst

- ➢ Wide scope of applications

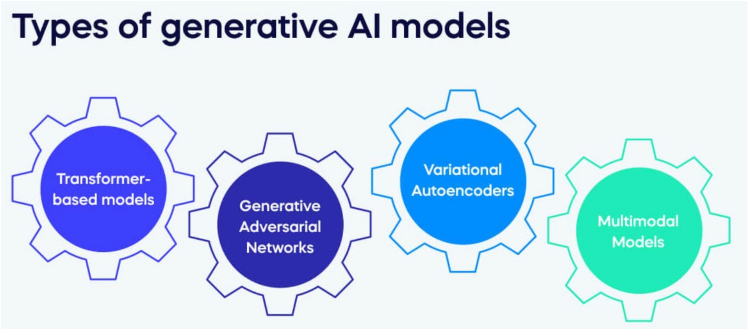


A. Loberferd: Towards data science

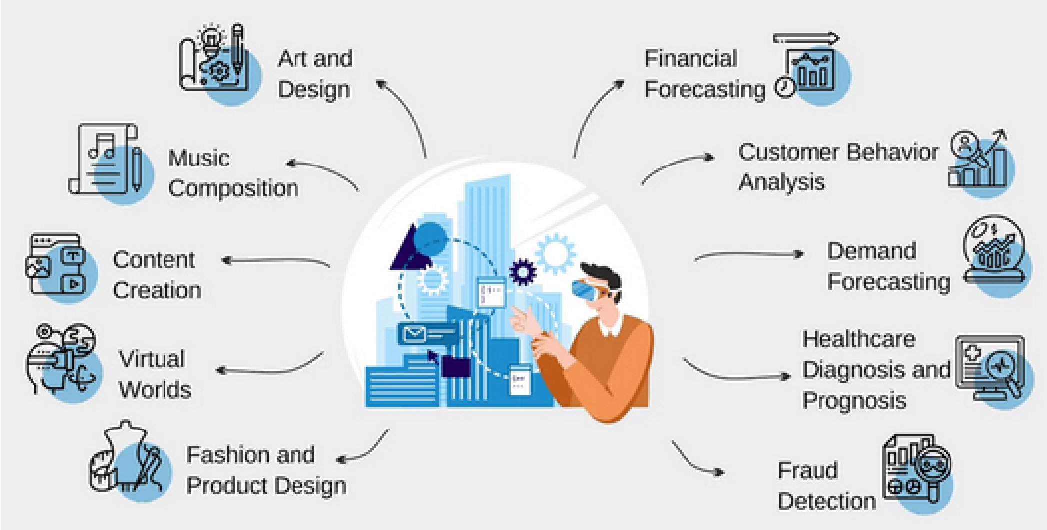
Artificial Intelligence

Generative AI

- AI algorithms and models designed to generate new and original data or content
- Generative AI can produce unique outputs



- Most popular examples:
  - ChatGPT
  - Bard (Google)
  - DALL.E
  - Midjourney

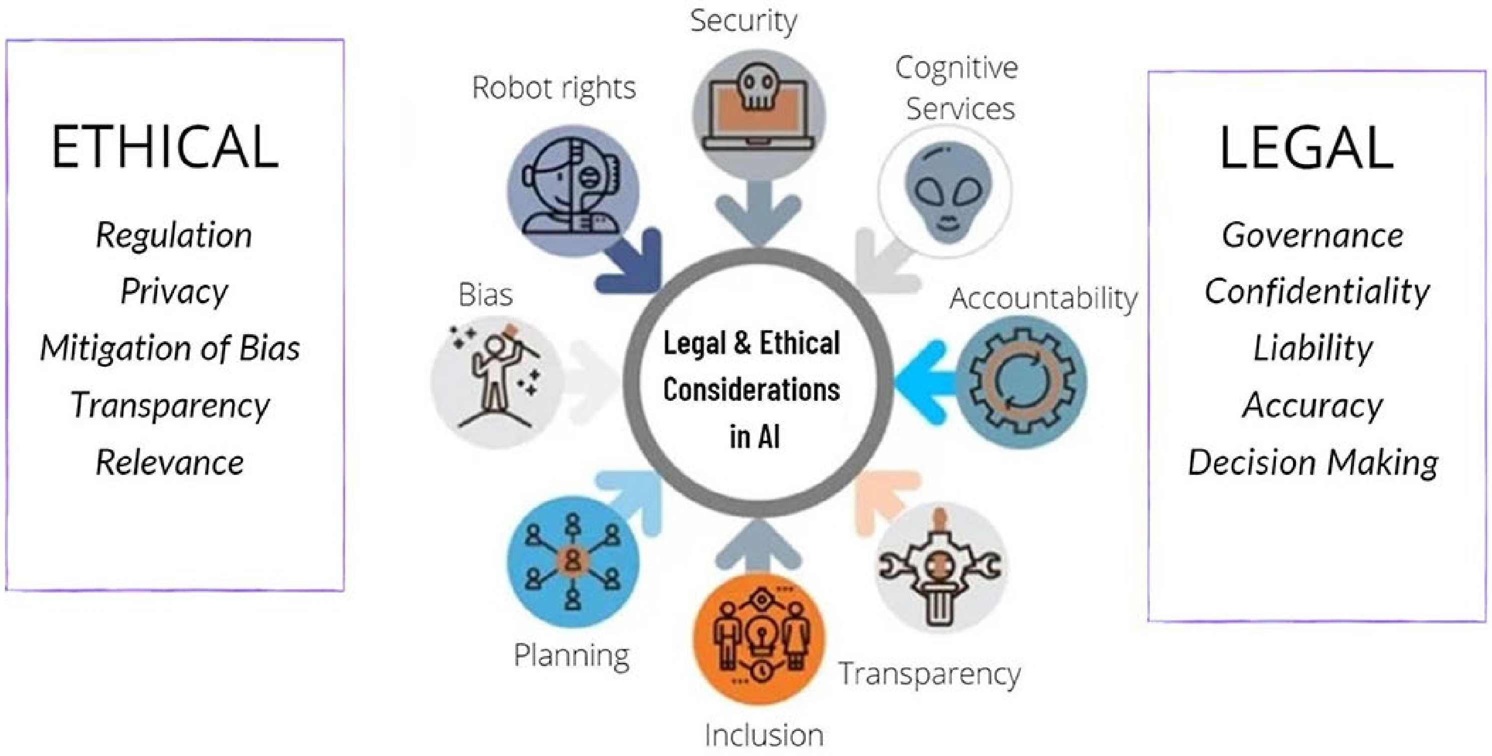


Jaro education: What is the Future of Generative AI?

Artificial Intelligence

Limitations and Ethical considerations

- Bias and discrimination
- Transparency and Accountability
- Creativity and Ownership
- Social Manipulation and Misinformation
- Privacy, Security, and Surveillance
- Social impact: job displacement
- Autonomous Weapons



N. Naik et al. Legal and Ethical Consideration in Artificial Intelligence in Healthcare: Who Takes Responsibility? (2022)

Applications in Agriculture

- Yield prediction
  - Help farm owners to take informed management decisions for their farm
- Disease detection
  - Identify diseased plants with good accuracy
- Crop quality
  - Grading of commodities, according to parameters
- Livestock management
  - Manage farms under controlled conditions

N.K. Sinha et al. : Application of Artifical Intelligence (AI) in Agriculture An Indian Perspective (2023)

Applications to agriculture

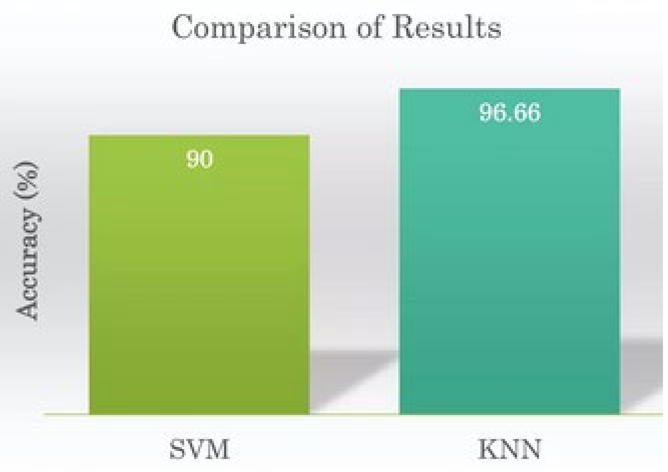
How is AI being used in agriculture today?

Tractorjunction

Applications to agriculture

1) Classification of grape leaves using KNN and SVM classifiers as healthy/unhealthy

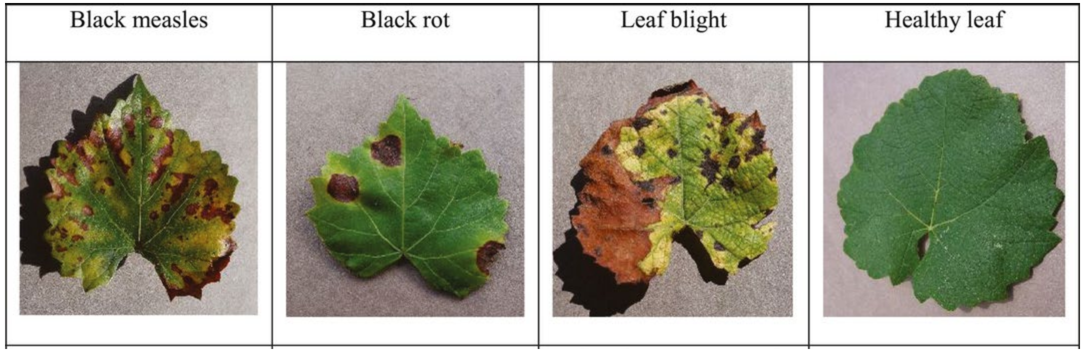
- Feature extraction (texture and colour)
- Prevent their plants from diseases and increment the yield
- KNN better accuracy than SVM

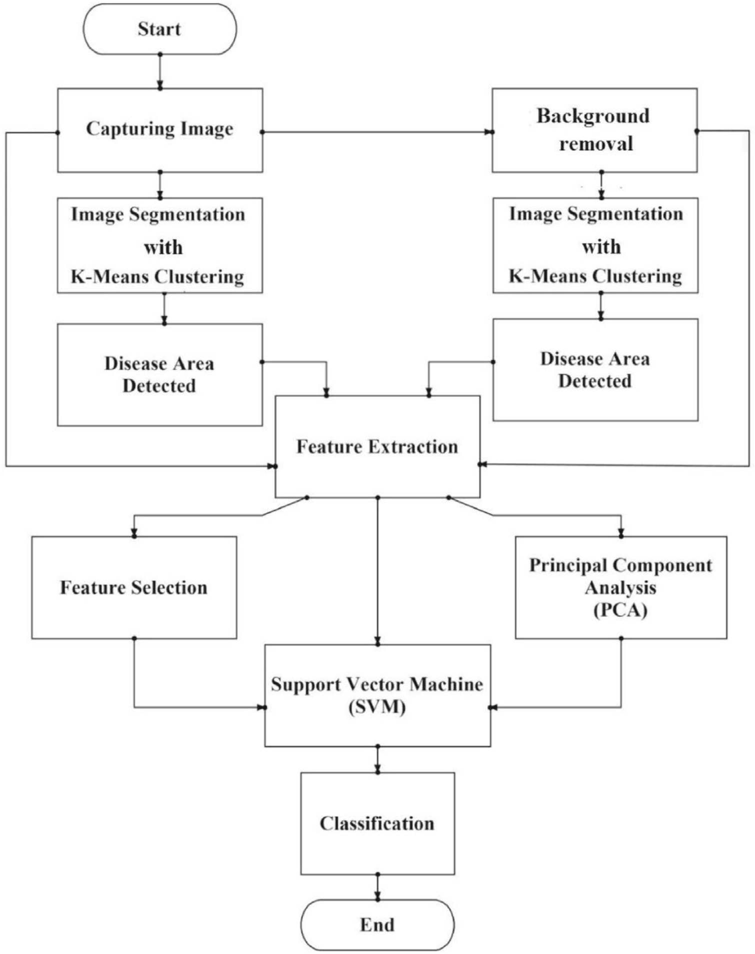


A. A. Bharate, M.S. Shirdhonkar (2020)

Applications to agriculture

2) Diagnosis of grape leaf diseases using automatic K-means clustering and machine learning



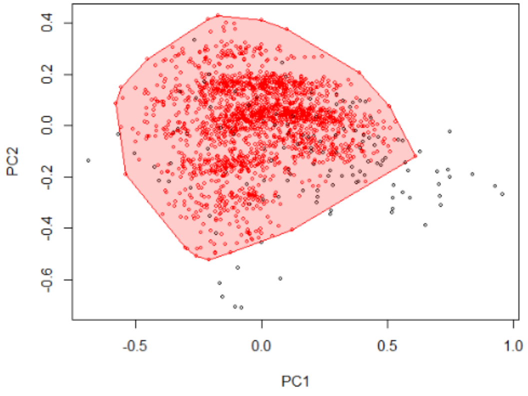


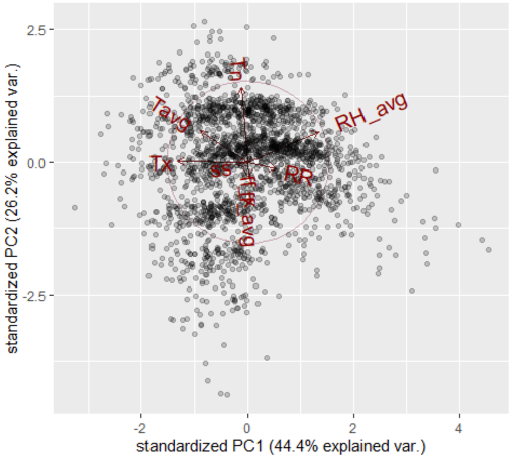
- K-means (automatic clustering): separate area of disease from healthy parts
- Feature extraction in three colour models: RGB, HSV, l*a*b
- SVM classification: black measles, black rot, leaf blight, and healthy leaves

S.M. Javidan et al. (2023)

Applications to agriculture

3) Multivariate weather anomaly detection using DBSCAN clustering algorithm





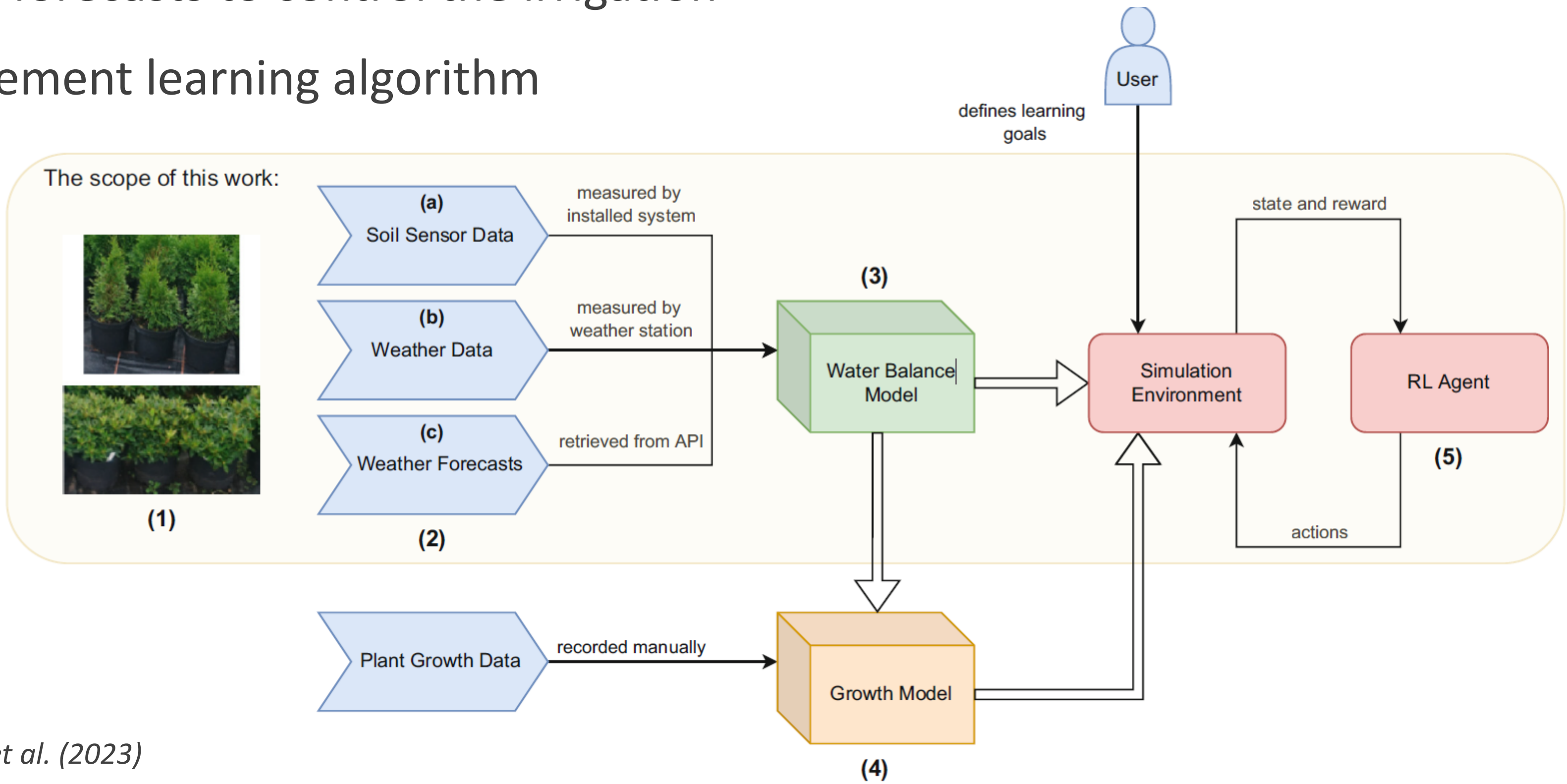
- Separate between normal and anomalous weather data
- PCA over weather variables: temperature, humidity, Sun exposure, wind speed, rainfall, etc.

W. Wibisono et al. (2021)

Applications to agriculture

4) Learning to Irrigate - A Model of the Plant Water Balance

- Create a plant-water balance model based on recorded soil sensor data, weather data and weather forecasts to control the irrigation
- reinforcement learning algorithm



M. Maszuhn et al. (2023)

Applications to agriculture

5) Free and Unfree Weed Classification in Young Palm Oil Crops Using Artificial Neural Network

- An automatic classification of whether a circle area of a young palm oil crop is free or unfree from unwanted weed
- Classify the condition of a young palm oil crop which is based on the condition of ground cover management

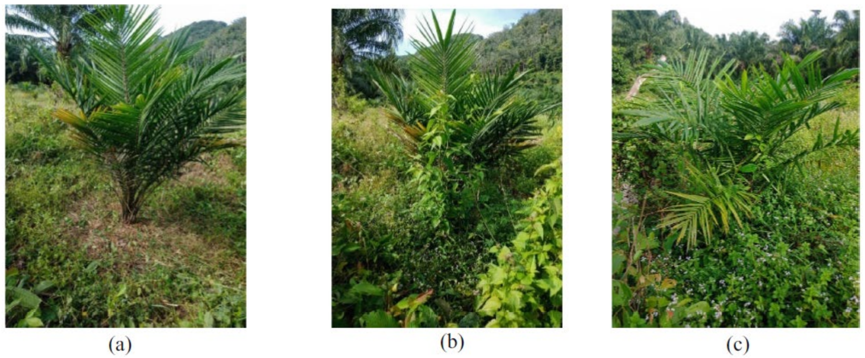


Fig. 3. Young Palm Oil without (a) and with (b and c) Weed in the Circle Area.

S.T.Jopony et al. (2023)

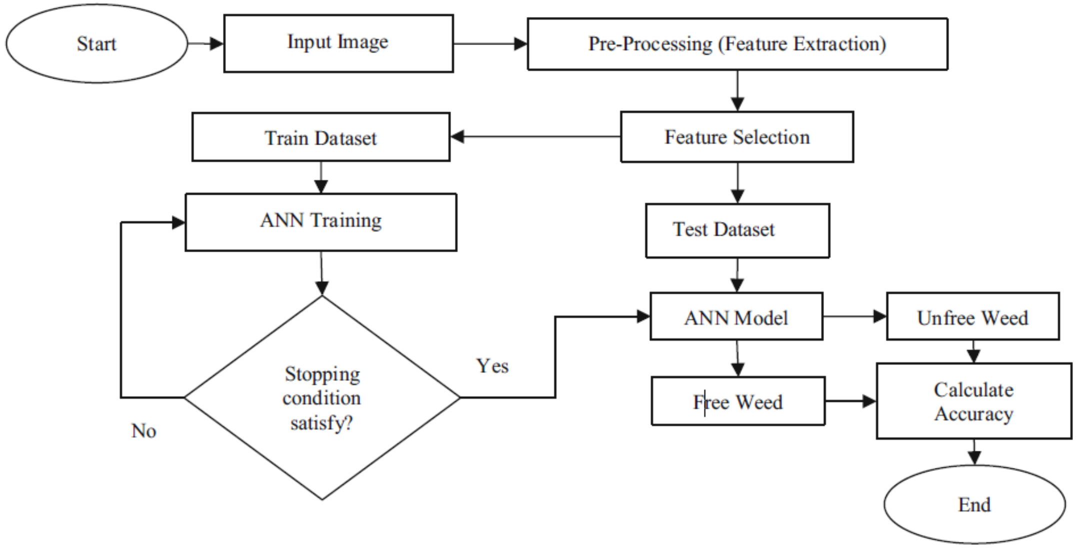
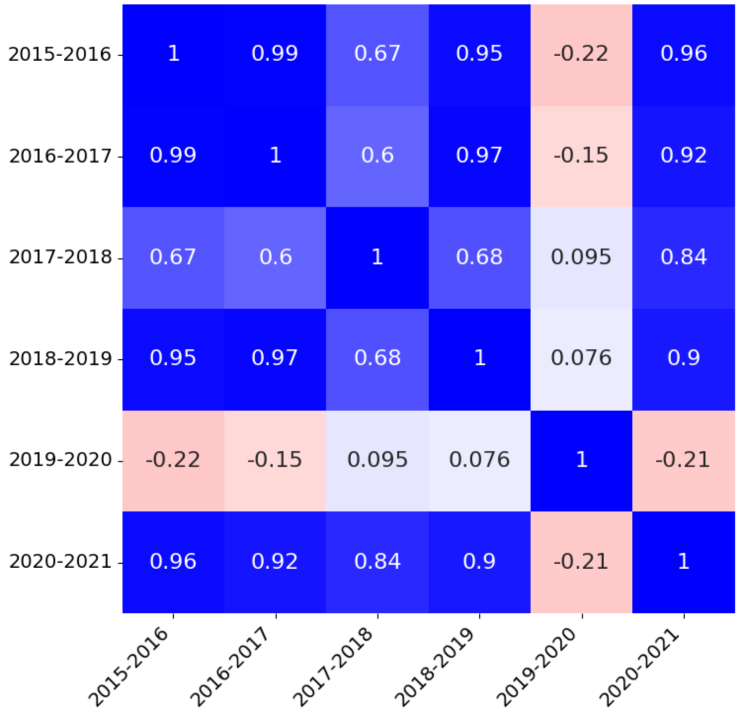


Fig. 2. Flow Chart of the ANN Classification System.

Applications to agriculture

6) A Feature-Based Correlation Approach for Analyzing Price Trends of Citrus in Valencia Province (Spain)

- Analysis of price variation among different citric varieties in Valencia province
- Compare price trends
- K-medoids and correlation analysis



R. Arnau et al. (2024)

Applications to agriculture

7) Data on agriculture exploitation of public data portals

- Open data in Valencia region
  - Project "**Maximizing the value of data in agriculture**"
  - Stable methodologies to evaluate and measure the quality, interoperability, blockchain and reuse of open data in the agricultural area.

- Self-organising maps with agriculture data*

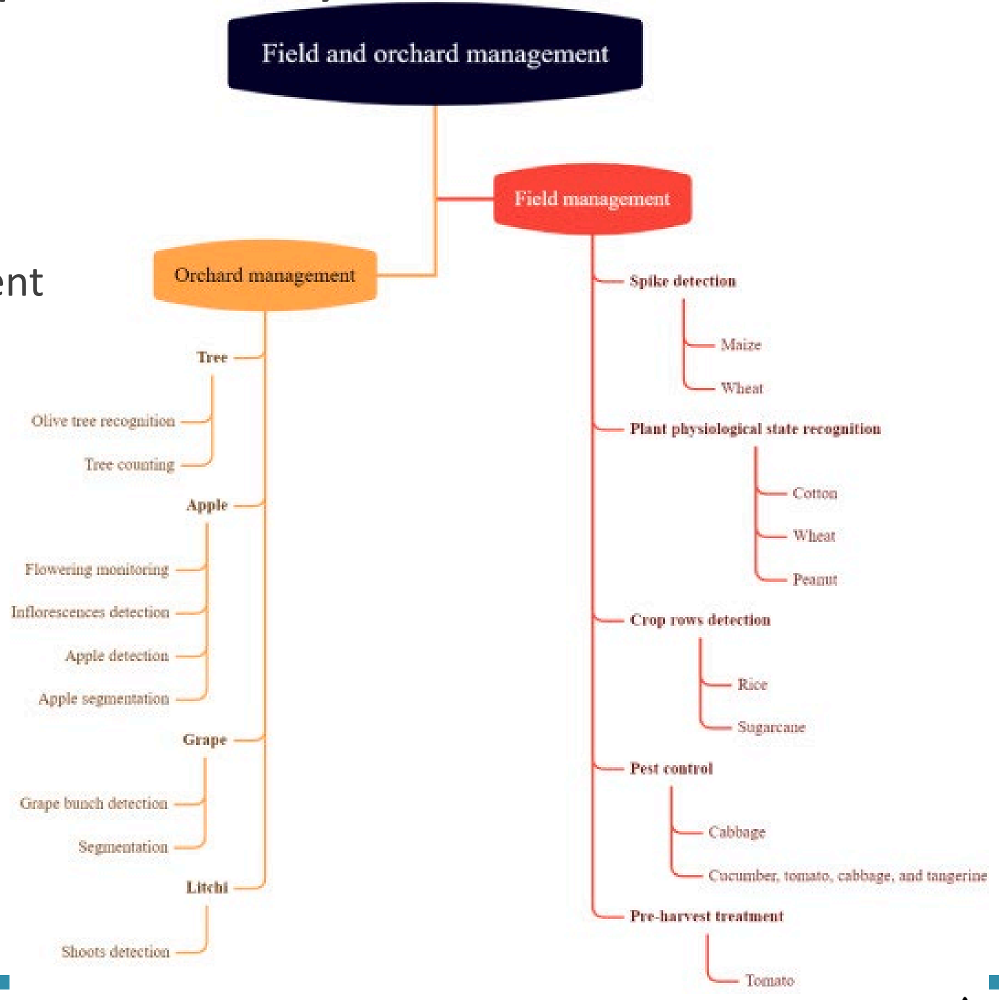
- Neural networks to study rice data in Valencia: weekly prices + meteo data*

L. Petrosyan et al. (2024)

Applications to agriculture

8) Recent advances in Transformer technology for agriculture: A comprehensive survey

- Plant disease detection
- Fruit and vegetable evaluation
- Pest detection and recognition
- Field and orchard management
- Crop mapping
- Seed assessment
- Yield estimation
- Livestock management
- Weed control
- Fishery management
- Food recognition

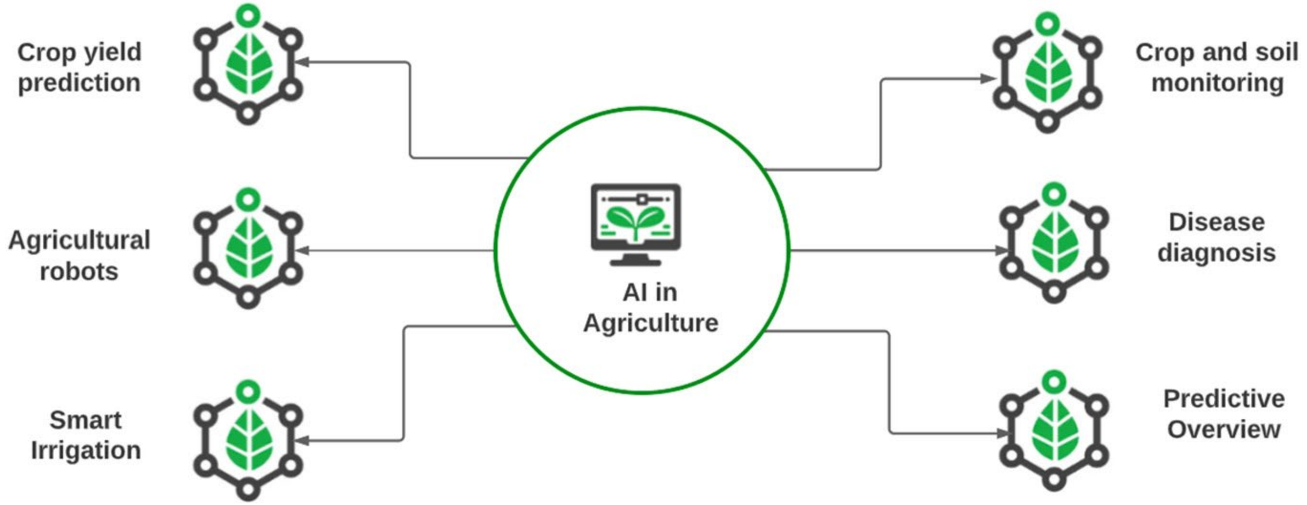


W. Xie et al. (2024)

Applications to agriculture

Overview of Artificial Intelligence in Agriculture: An Impact of Artificial Intelligence Techniques on the Agricultural Productivity

- the use of AI will change agriculture in a big way by giving farmers smart tools that can increase crop productivity and reduce costs
- ANN and DL techniques have been applied more extensively (65%) than classical ML techniques (35%) in the agriculture sector



S. Belattar et al. (2023)

Advances in Machine Learning and Artificial Intelligence: Applications to Agriculture

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