Introduction to Computational Intelligence

Iran University of Science and Technology

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Winter 2025

Text Books

- Pattern Recognition and Machine Learning, C. Bishop, Springer, 2006.
- Machine Learning,T. Mitchell, MIT Press,1998.
- Deep Learning: Foundations and Concepts. Bishop, Christopher M. and Hugh Bishop (2022). Springer.
- Deep Learning. Goodfellow, Ian, Yoshua Bengio, and Aaron Courville (2016). The MIT Press.
- Nature-Inspired Optimization Algorithms
- Xin-She Yang (2nd Edition, 2021), Academic Press (Elsevier).
- Hands-On Machine Learning with Scikit-Learn, Keras & TensorFlow (3rd Edition, 2022) - Aurélien Géron
- Fuzzy Logic with Engineering Applications (4th Edition, 2020) - Timothy J. Ross

Course information and Policies

Grading Policy:

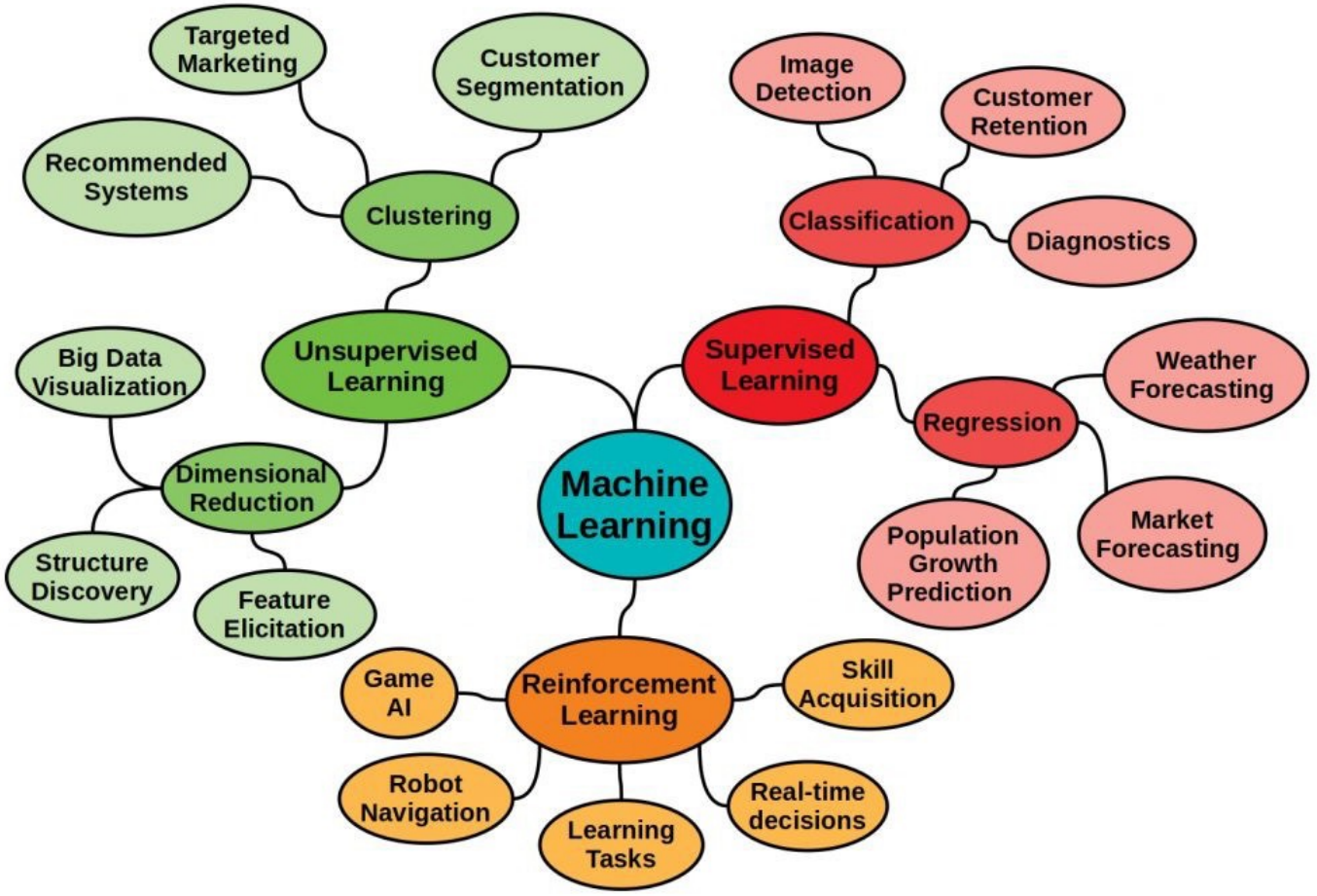
Homework and Programming Assignment	7 marks
Main Project	2 marks
Short Quizzes	4 marks
Midterm Exam	4 marks
Final Exam	5 marks
Sum	**22** marks

Extra Point: Submitted Paper on ISI Journal, Conference Paper, Survey Research, 1-3 marks

Research Topics

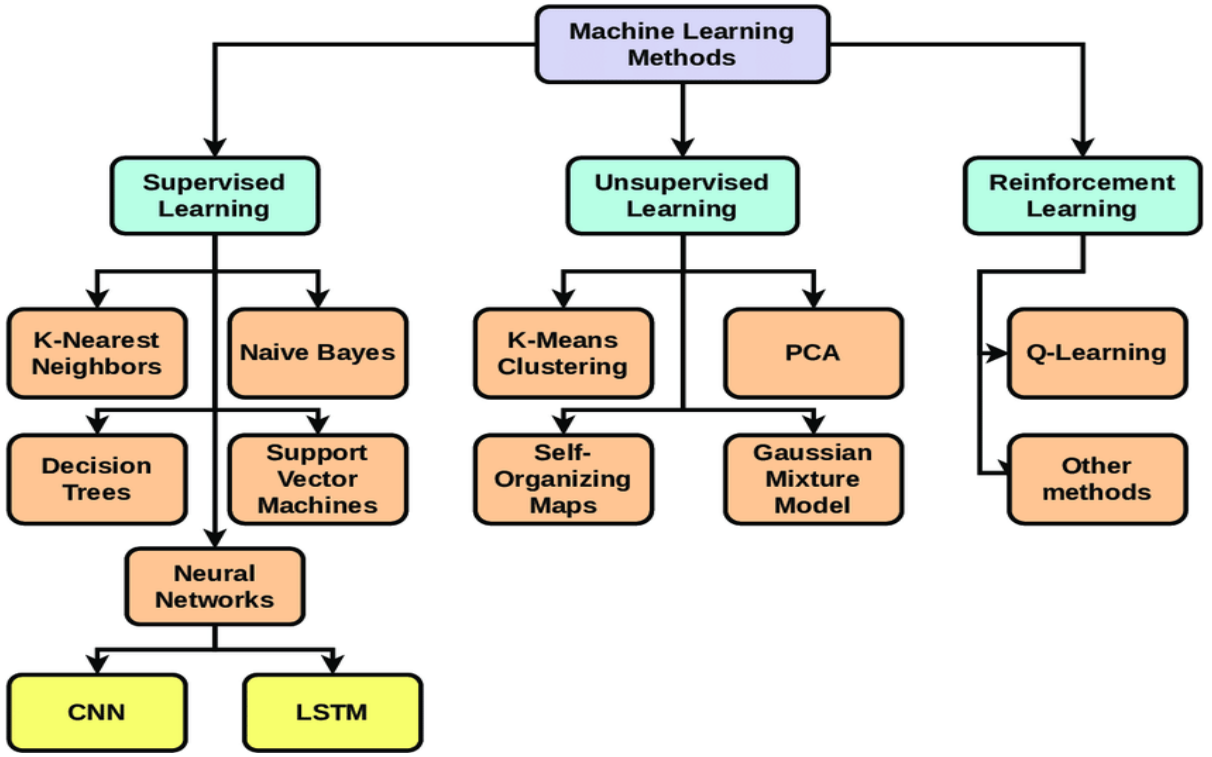
Key words	Sample Paper
Social Networks, Online Communities, anthropomorphism in bots and chatbots	Anthropomorphic response: Understanding interactions between humans and artificial intelligence agents
Human traits enable modeling in bots and chatbots	A Survey of Personality, Persona, and Profile in Conversational Agents and Chatbots
Cognitive features in bots and chatbots, personality in bots and chatbots	How Do People Ascribe Humanness to Chatbots? An Analysis of Real-World Human-Agent Interactions and a Theoretical Model of Humanness
Chatbots decision-making capabilities	Research: The Decision-Making Mystery of AI Chatbots | Cornell SC Johnson
Trustworthy Machine Learning	Robust Physical-World Attacks on Deep Learning Models
Artificial intelligence; machine learning; neoplasms; drug design; databases	Advances of Artificial Intelligence in Anti-Cancer Drug Design: A Review of the Past Decade
Graph neural network, Graph representation and featurization, Protein–ligand binding, Drug design, Ensemble learning	Multiphysical graph neural network (MP-GNN) for COVID-19 drug design
Domain generalization, Domain adaptation, Transfer learning, Out-of-distribution generalization	Generalizing to Unseen Domains: A Survey on Domain Generalization
Neural Network Interpretability, Explainable artificial intelligence, Global interpretation	A Survey on Neural Network Interpretability Explaining deep neural networks: A survey on the global interpretation methods
Graph analysis, graph neural networks, explainability, interpretability	Explainability in Graph Neural Networks: A Taxonomic Survey

Machine Learning Categories



Machine Learning Categories

- The three broad categories of ML are summarized in:
  - **Supervised Learning**
  - **Unsupervised Learning**
  - **Reinforcement Learning**



Paradigms of ML

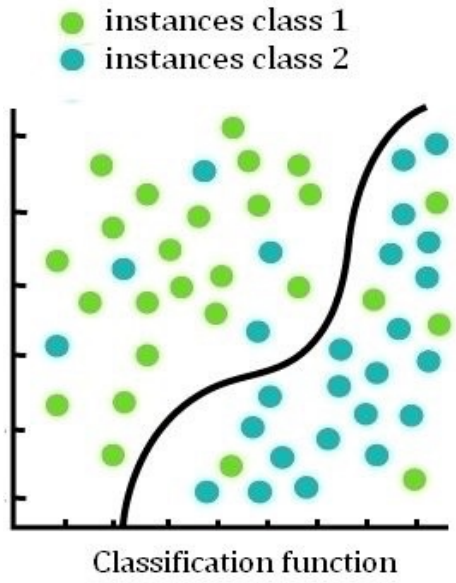
- Supervised learning (regression, classification)
  - predicting a target variable for which we get to see examples.
- Unsupervised learning
  - revealing structure in the observed data
- Reinforcement learning
  - partial (indirect) feedback, no explicit guidance
  - Given rewards for a sequence of moves to learn a policy and utility functions
- Other paradigms: semi-supervised learning, active learning, online learning, zero-shot and few-shot learning.

Supervised Learning

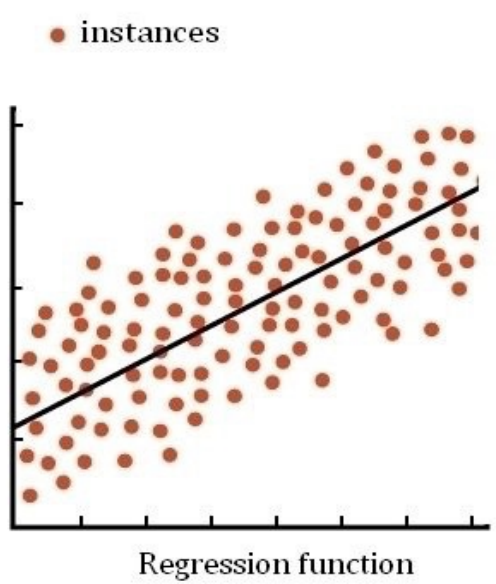
- Whats is Supervised Learning?

  Supervised Learning is the subcategory of machine learning that focuses on learning from labeled training data, which can be divided to two main categories:

  - Classification: Predicting the discrete values such as male/female, etc.
  - Regression: Predicting the continuous values such as price, age, etc.



Classification function



Regression function

Unsupervised Learning

- What is Unsupervised Learning?

  Unsupervised Learning, in contrast to supervised learning, is concerned with unlabeled data.

- Common tasks in unsupervised learning are:
  - Clustering
  - Dimensionality Reduction

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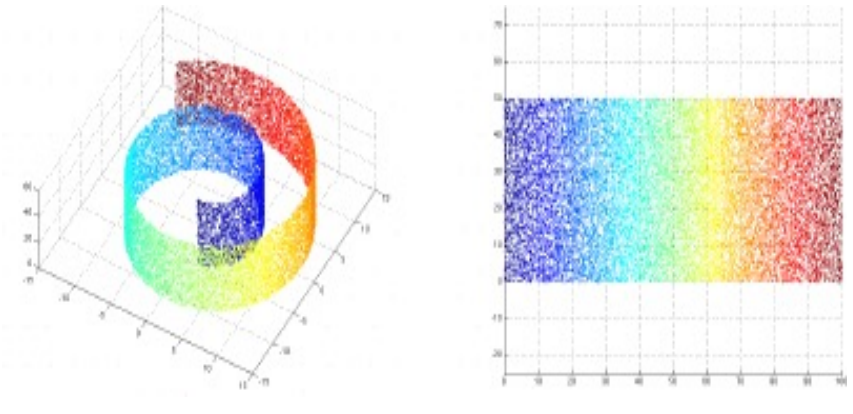
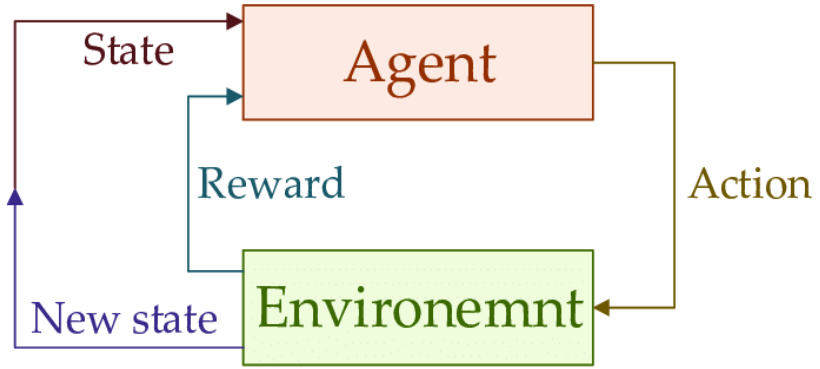


(b) Dimensionality Reduction, Source

Clustering vs Dimensionality Reduction

Reinforcement Learning

- Reinforcement is the process of learning from rewards while performing a series of actions.
- An agent in this context is a learning system that observes the environment, selects and performs actions, and receives rewards.
- As time goes on, it must learn how to get the most rewards using the best strategy, called a policy.



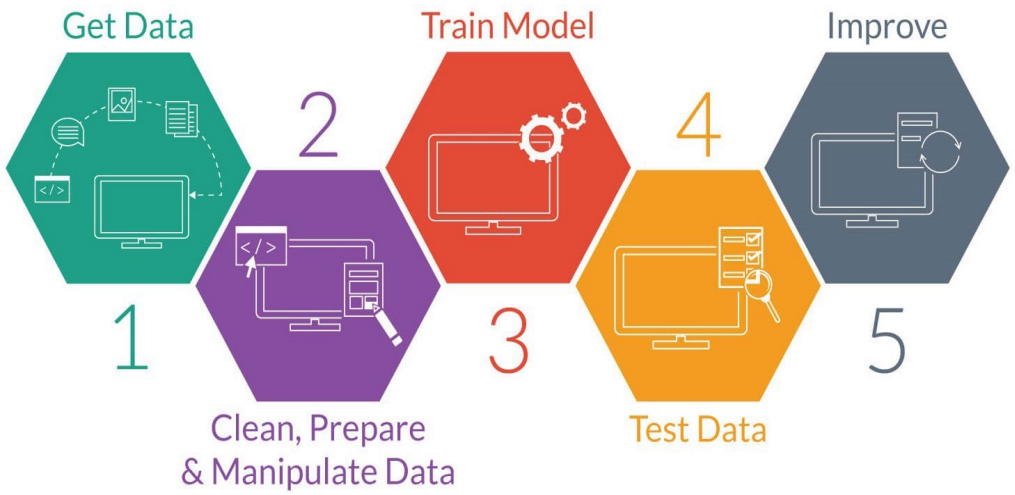
- Data in supervised learning:
  (input, correct output)
- Data in Reinforcement Learning:
  (input, some output, a grade of reward for this output)

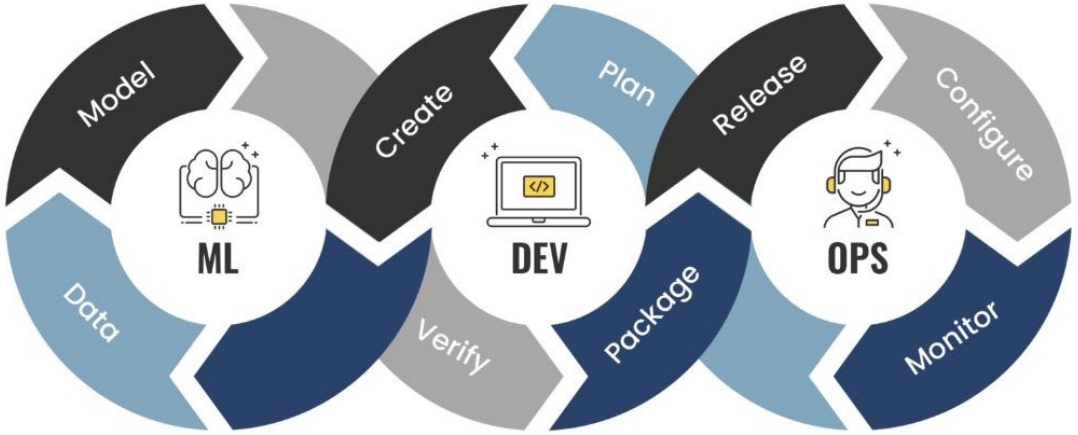
ML Categorization Schemes

- Parametric vs Non-parametric:
  - Parametric models have ”fixed” number of parameters.
  - Non-Parametric models are more ”flexible” and do not have a pre-specified number of parameters.
- Eager vs Lazy:
  - Eager learners are algorithms that process training data immediately.
  - Lazy learners, however, defer the processing step until the prediction.
- Batch vs Online:
  - Batch learning refers to the fact that the model is learned on the entire set of training examples.
  - Online learners, in contrast, learn from one training example at the time.
- Generative vs Discriminative:
  - Generative models (classically) describe methods that model the joint distribution $P(X, Y) = P(Y)P(X|Y) = P(X)P(Y|X)$ for training pairs (x_i, y_i).
  - Discriminative Discriminative models are taking a more ”direct” approach, modeling $P(Y|X)$ directly.

How to Solve a Machine Learning Problem

- Collect data.
- Preprocess the data.
- Select a suitable model and train it.
- Evaluate the generalization error on the test dataset.
- Improve the model using various techniques.





MLOps