ECE 469/ECE 568 Machine Learning

Textbook:
Machine Learning: a Probabilistic Perspective by Kevin Patrick Murphy

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Types of Machine Learning - Unsupervised Learning
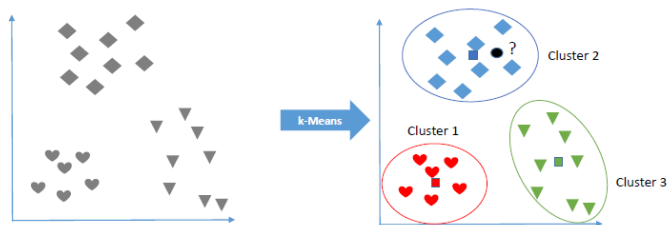
Unsupervised Learning

In descriptive or unsupervised learning, we are only given inputs, $\mathcal{D} = \{x_i\}_{i=1}^{N}$, and the goal is to find "interesting patterns" or "structures" in the data. This is referred to as "knowledge discovery". This is a much less well-defined problem, since we are not told what kinds of patterns to look for, and there is no obvious error metric to use.

Unsupervised Learning - Clustering
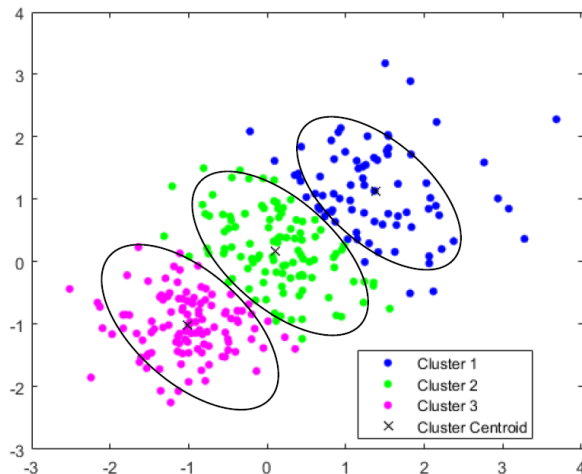
Source: A survey on Machine Learning-based Performance Improvement of Wireless Networks: PHY, MAC and network layer by Merima Kulin et. al.

Unsupervised Learning - K-Means
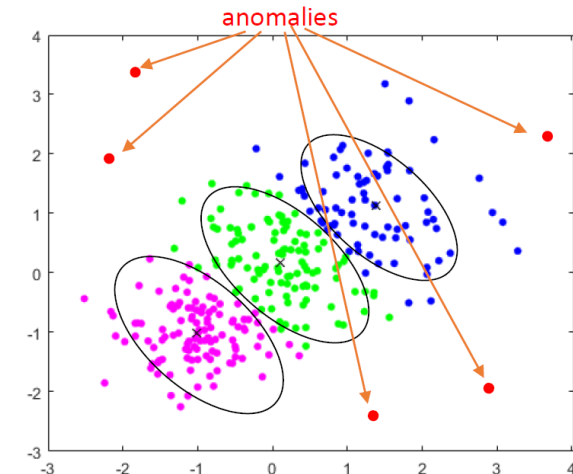

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Unsupervised Learning - Anomaly detection

Source: A survey on Machine Learning-based Performance Improvement of Wireless Networks: PHY, MAC and network layer by Merima Kulin et. al.

Types of Machine Learning - Reinforcement Learning

Reinforcement Learning

We can think of reinforcement learning as a computational approach that is intended for understanding and automating goal-directed learning and decision-making.

Distinct property: It emphasizes on learning by an agent from direct interaction with its environment, without relying on supervision or complete models of the environment.

- Search over actions to maximize expected utility
- Predict effects of actions using probabilistic model
- Use utility theory to decide which outcome is best
- Tries to learn a controller that simulates the above behavior

Types of Machine Learning - Deep Learning

Deep Learning

Deep learning is way of classifying, clustering, and predicting things (via supervised, unsupervised or reinforcement concepts) by using an artificial neural network that has been trained on big data.

- An Artificial Neural Network (ANN) is a set of algorithms, modeled loosely after the human brain, that are designed to recognize patterns.

- Deep learning creates many layers of neurons, attempting to learn structured representation of big data, layer by layer.

- Summary: Deep neural networks are mathematical models of intelligence designed to mimic human brains.

Artificial Neural Networks (ANN)
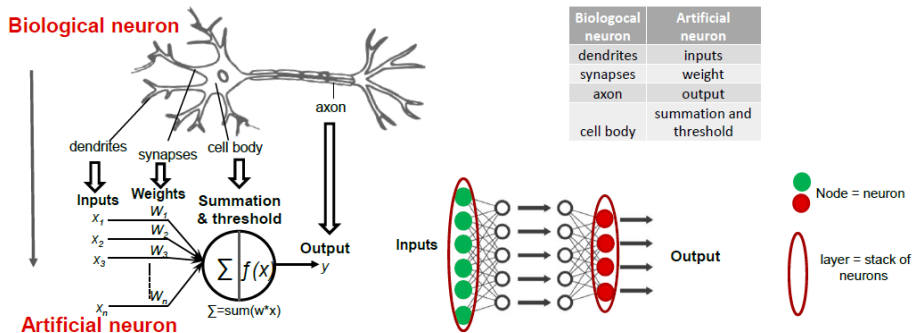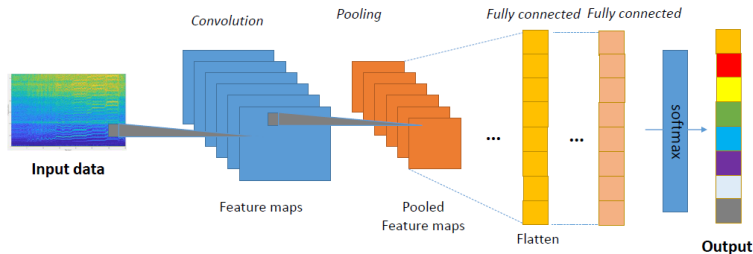

Source: Texas Instruments

Graphical representation for a neural network
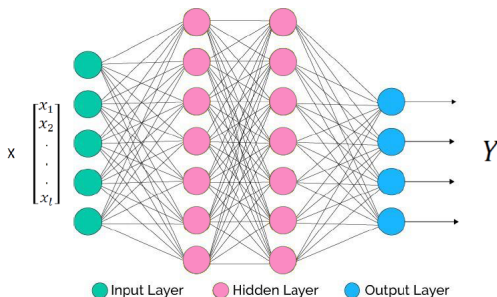
Source: A survey on Machine Learning-based Performance Improvement of Wireless Networks: PHY, MAC and network layer by Merima Kulin et. al.

- Deep neural networks (DNN)

- Convolutional neural networks (CNN)

- Recurrent neural networks (RNN)

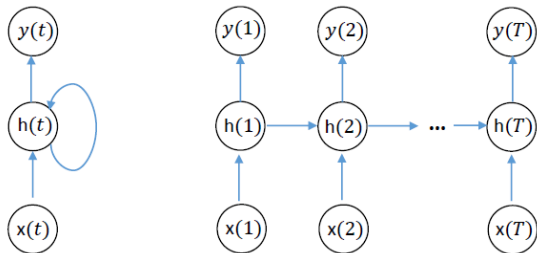- Deep belief networks (DBN)

Graphical representation of Convolutional Neural Networks

Source: A survey on Machine Learning-based Performance Improvement of Wireless Networks: PHY, MAC and network layer by Merima Kulin et. al.

- Convolutional neural networks (CNN) perform feature learning via non-linear transformations implemented as a series of nested layers.

Graphical representation of Recurrent Neural Networks

Source: A survey on Machine Learning-based Performance Improvement of Wireless Networks: PHY, MAC and network layer by Merima Kulin et. al.

- Recurrent neural networks (RNN) are a type of neural networks where connections between nodes form a directed graph along a temporal sequence.

- They are called recurrent because of the recurrent connections between the hidden units.

Machine Learning Algorithms
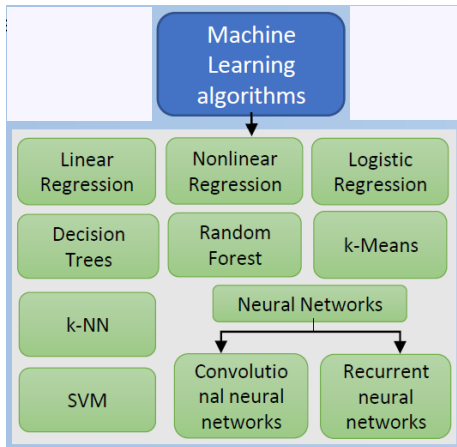
Source: A survey on Machine Learning-based Performance Improvement of Wireless Networks: PHY, MAC and network layer by Merima Kulin et. al.

Steps in a machine learning pipeline

Problem definition	Data collection	Data preparation	Model training	Model deployment
Problem statement	Raw data	Transformation	Training	Deployment
Data science problem formulation	Data storage	Data cleaning	Model selection	Prediction
		Normalization	Hyper-parameter tuning	Performance monitoring
		Feature engineering	Model evaluation	Retraining

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Summary of types of learning notions

Source: A survey on Machine Learning-based Performance Improvement of Wireless Networks: PHY, MAC and network layer by Merima Kulin et. al.
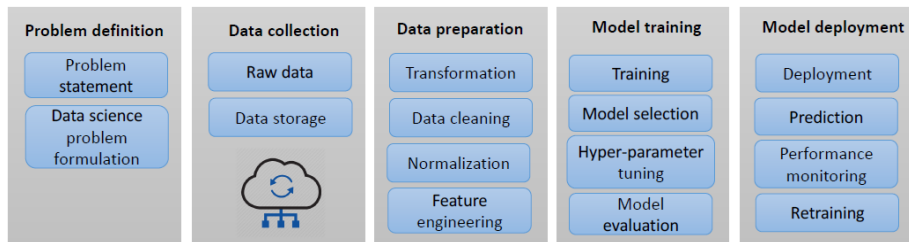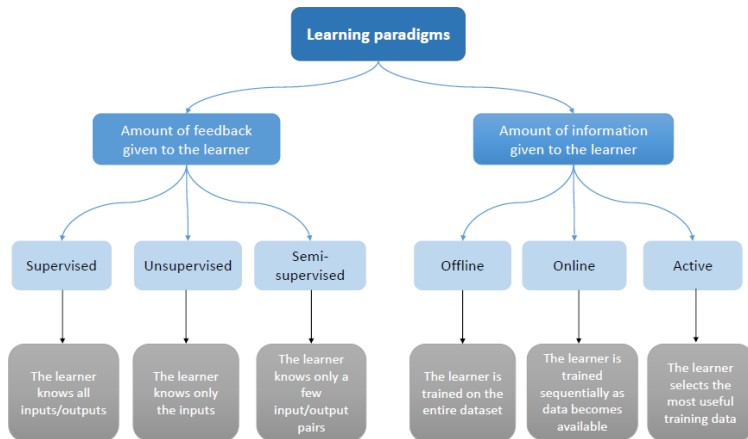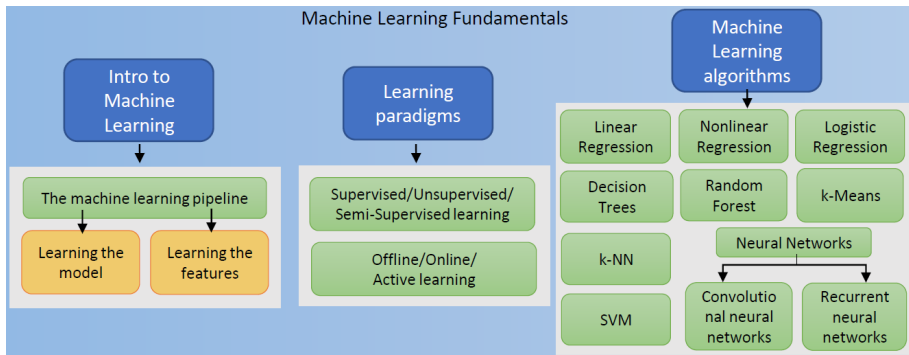
Why we need Machine Learning?

- Machine learning is all about programming computers to optimize a performance criterion using example data or past experience.

- There is no need to "learn" for mechanical tasks such as "calculating payroll"

- Machine learning is used

  - When humans are not in the operational loop −> Deep space missions
  - When humans are unable to explain their expertise −> Speech recognition
  - When solution changes in time −> Routing in computer networks
  - When solution needs to be adapted to particular cases −> User biometrics

Summary - Fundamentals of Machine Learning

Machine Learning Fundamentals

Intro to Machine Learning
- The machine learning pipeline
  - Learning the model
  - Learning the features

Learning paradigms
- Supervised/Unsupervised/Semi-Supervised learning
- Offline/Online/Active learning

Machine Learning algorithms

Linear Regression	Nonlinear Regression	Logistic Regression
Decision Trees	Random Forest	k-Means
k-NN	Neural Networks	
SVM	Convolutional neural networks	Recurrent neural networks

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Learning objectives

Key goals

- Understand how machine learning algorithms work

- Enable you to build machine learning engineering applications

- Enable you to do research in machine learning in engineering

By the end of this course, you should be able to

- Understand basics of machine learning techniques that are used in Engineering applications and its connection to other fields

- Derive the relevant mathematical expressions needed for familiar and novel machine learning models/ algorithms in engineering

- Implement various familiar and novel machine learning model/ algorithms for engineering applications

- Choose an appropriate method and apply it to various kinds of data/ problem domains in engineering

Pre-requisites

- Basic multivariate calculus

- Basic linear algebra

- Basic probability/statistics

- Basic data structures and algorithms (e.g., trees, lists, sorting, dynamic programming, etc)

- Matlab/Octave/Python (NumPy library)/C++

Textbook

- Machine Learning - A Probabilistic Perspective by Kevin P. Murphy