02-750 Week 3
Automation of Scientific Research

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Artificial Intelligence

Note that machine learning is a subset of artificial intelligence. Deep learning is a subset of machine learning.

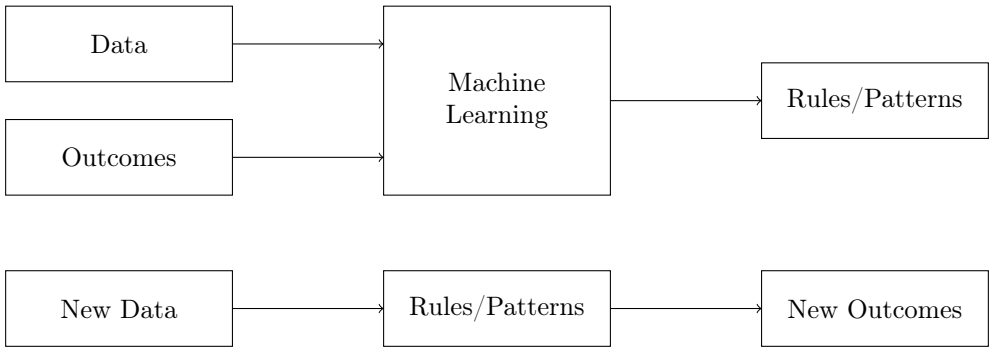
What is Artificial Intelligence (AI)?

"Any task performed by a machine that would have previously been considered to require human intelligence." - Professors Mavin Minsky and John McCarthy (1956)

- "It is the science and engineering of making intelligent machines, especially intelligent computer programs. It is related to the similar task of using computers to understand human intelligence, but AI does not have to confine itself to methods that are biologically observable." - Professor John McCarthy (2004)
- "A system's ability to adapt and improvise in a new environment, to generalize its knowledge and apply it to unfamiliar scenarios." - AI researcher Français (2020)

What is Machine Learning (ML)?

- A branch of AI
- "Study of computer **algorithms** that allow computer programs to automatically **improve** through **experience**." - Prof. Tom Mitchell (1997)



Types of Machine Learning

- Supervised Learning
  - Input: Training data and labels.
  - Goal: Learn function to map new unlabelled data to labels.
  - For example, classification and regression.

- Semi-Supervised Learning
  - Input: Training data, some of which is labelled.
  - Goal: Learn function to map new unlabelled data to labels and/or learn structure in the data.
- Reinforcement Learning
  - Given a sequence of states and actions with (delayed) rewards, output a policy
  - Policy is a mapping from states to actions that tells you what to do in a given state.
  - Agent and environment interact at discrete time steps. Agent commits ana action on the environment, which changes its state and rewards (either positively or negatively) the agent.
  - For example, training a self-driving car.
- Unsupervised Learning
  - Input: Training data without labels.
  - Goal: Learn structure in the data.
  - For example, K-means Clustering

When to Use Machine Learning

Machine Learning is used when:

- human expertise does not exist (e.g., navigating on Mars)
- humans can't explain their expertise (e.g., speech recognition)
- models must be customized (e.g., personalized medicine)
- models are based on huge amounts of data (e.g., genomics)

Learning isn't always useful:

- There is no need to "learn" to calculate payroll

Designing a Learning System

- Choose the training experience
- Choose exactly what is to be learned (i.e., the *target function*)
- Choose how to represent the target function
- Choose a learning algorithm to infer the target function from the experience

Training vs. Test Distribution

- We generally assume that the training and test examples are independently drawn from the same overall distribution of data
  - We call this "i.i.d" which stands for "independent and identically distributed"
- If examples are not independent, it requires *collective classification.*
- If the test distribution is different, it requires *transfer learning.*

ML in a Nutshell

- Tens of thousands of machine learning algorithms. (Hundreds of new ones every year)
- Every ML algorithm has three components:
  - Representation
  - Optimization
  - Evaluation
- Deep Learning tends to do better than most machine learning algorithms when the amount of data grows large.

Various Function Representations

- Numerical functions
  - Linear Regression
  - Neural Networks
  - Support Vector Machines
- Symbolic functions
  - Decision trees
  - Rules in propositional logic
  - Rules in first-order predicate logic
- Instance-based functions
  - Nearest-neighbor
  - Case-based
- Probabilistic Graphical Models
  - Naïve Bayes
  - Bayesian networks
  - Hidden-Markov Models (HMMs)
  - Probabilistic Context Free Grammars (PCFGs)
  - Markov networks

Various Search / Optimization Algorithms

- Gradient Descent
  - Perceptrons
  - Backpropagation
- Dynamic Programming
  - HMM Learning
  - PCFG Learning
- Divide and Conquer
  - Decision tree induction
  - Rule learning

- Evolutionary Computation
  - Genetic Algorithms (GAs)
  - Genetic Programming (GP)
  - Neuro-evolution

Evaluating ML Models

- Accuracy
- Precision and Recall
- Squared Error
- Likelihood
- Posterior Probability
- Cost / Utility
- Margin
- Entropy
- K-L Divergence
- etc.