Introduction to Machine Learning

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Lecture objectives

- By the end of this lecture, students will be able to:
  - ✓Definition of machine learning
  - ✓Significant thoughts on ML
  - ✓Related fields to ML
  - ✓Where and when to use ML

What is machine learning?

- Machine Learning is a branch of **artificial intelligence** that is concerned with the design and application of techniques that allow computers to evolve behaviors based on verifiable data.
  - ➢ It involves programming computers to optimize a performance criterion using historical data or past experience.
- Machine Learning (ML) models a function from a dataset of inputs in relation to possible outputs.
  - $f = x^2$
  - $f = x + 2y$
  - $f = x(y+1) + 3y^2$
  - $f = x(y+1) + y/3z^2$

Definition of machine learning…

- Machine learning is about:
  - ✓Automating automation
  - ✓Getting computers to program themselves
  - ✓Letting the data instead do the work

➢Machine learning is primarily concerned with the accuracy and effectiveness of the computer system.

Significant Quotes on ML

- “A breakthrough in machine learning would be worth ten Microsofts” (Bill Gates, Chairman, **Microsoft**)
- “Machine learning is the next Internet” (Tony Tether, Director, **DARPA**)
- “Machine learning is the hot new thing” (John Hennessy, President, **Stanford**)
- “Web rankings today are mostly a matter of machine learning” (Prabhakar Raghavan, Dir. Research, **Yahoo**)
- “Machine learning is going to result in a real revolution” (Greg Papadopoulos, CTO, **Sun**)
- “Machine learning is today’s discontinuity” (Jerry Yang, CEO, **Yahoo**)

Science Paradigms

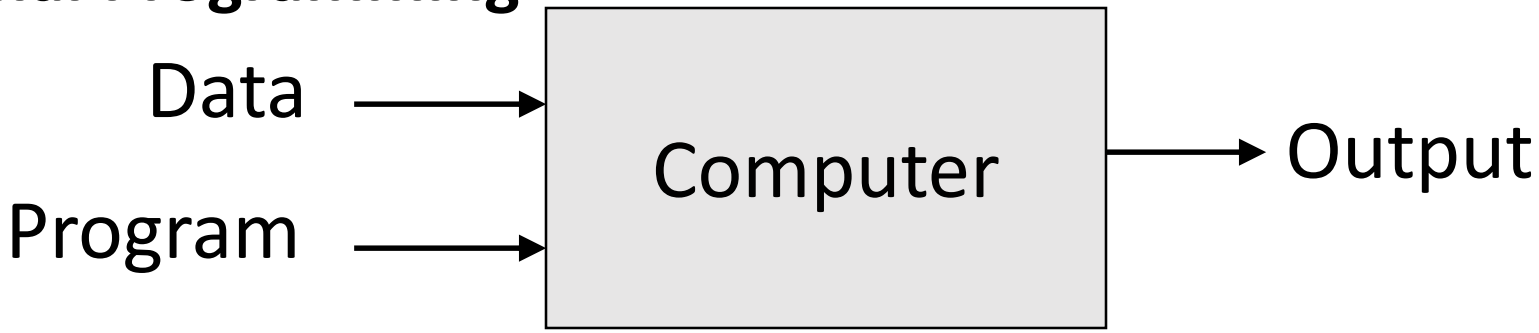
- Thousand years ago:
  science was **empirical**
  describing natural phenomena
- Last few hundred years:
  theoretical branch
  using models, generalizations
- Last few decades:
  a **computational** branch
  simulating complex phenomena
- Today: **data exploration** (eScience)
  unify theory, experiment, and simulation
  - Data captured by instruments or generated by simulator
  - Processed by software
  - Information/knowledge stored in computer
  - Scientist analyzes database/files using data management and statistics

$$\left(\frac{\dot{a}}{a}\right)^2 = \frac{4\pi G\rho}{3} - K\frac{c^2}{a^2}$$

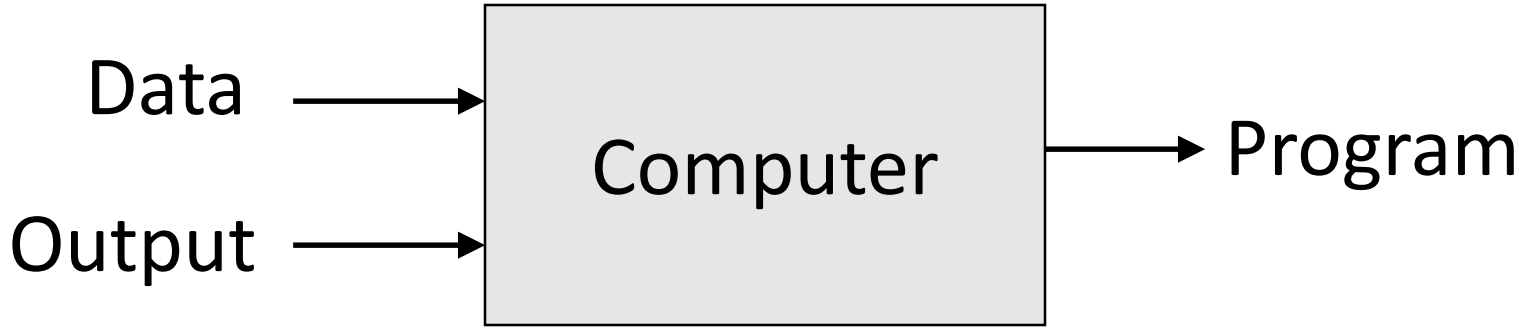
Ref: The Fourth Paradigm by **Jim Gray**

Traditional programming vs Machine Learning

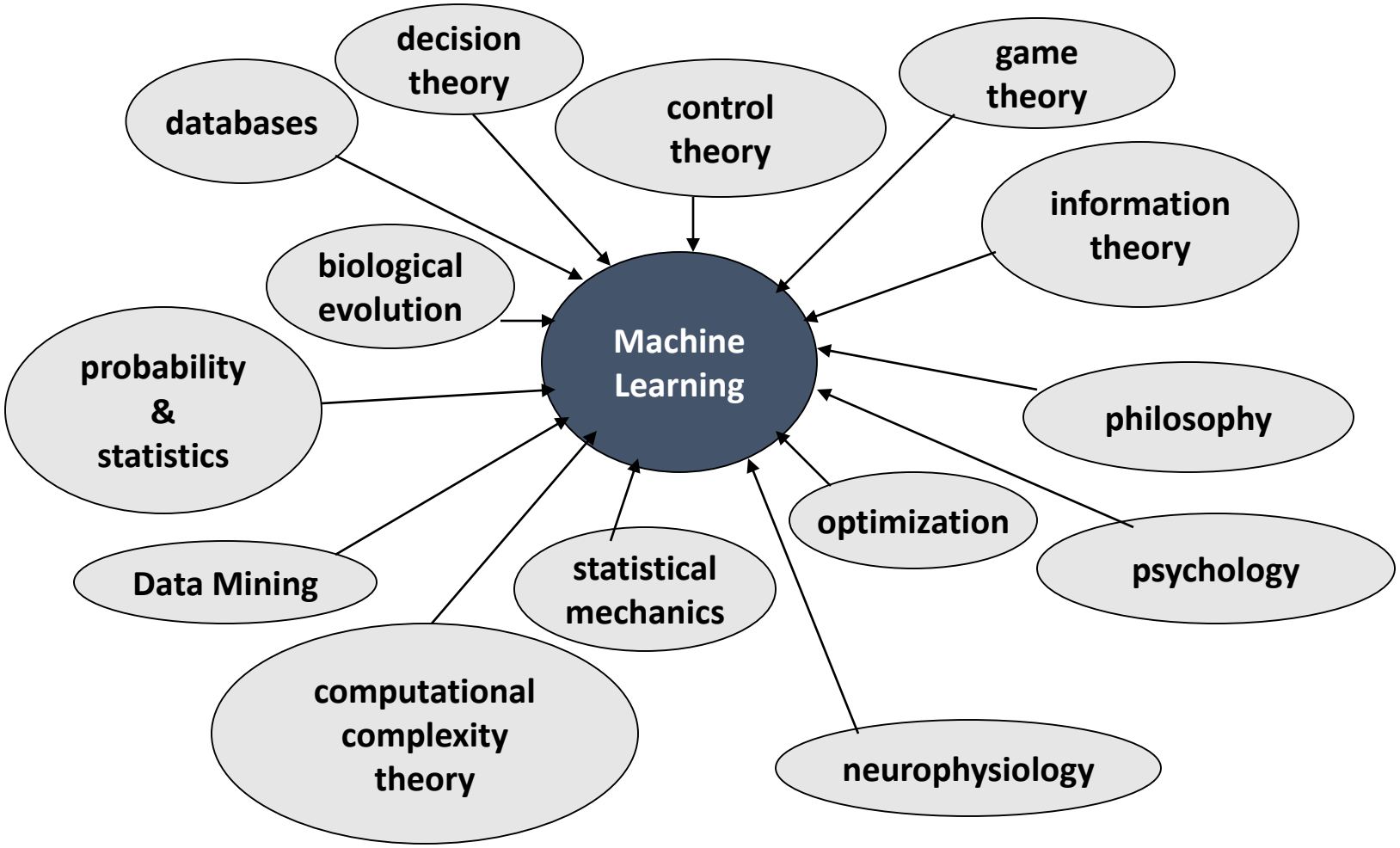
Traditional Programming



Machine Learning



Related Disciplines to ML



Machine Learning: Analogy

ML is more like gardening:

- ✓**Gardener** = You
- ✓**Seeds** = Algorithms/techniques
- ✓**Nutrients** = Data
- ✓**Plants** = Programs

When and Where to apply machine learning

- ML is used where:
  - ✓Human expertise does not exist
    - E.g. In navigating on Mars, other astronomic discoveries.
  - ✓Humans are unable to explain their expertise
    - E.g. In speech recognition
  - ✓Solution changes with time
    - E.g. In routing on a computer network
  - ✓Rapid changing phenomena
    - E.g. In credit scoring, financial modeling, diagnosis, fraud detection
  - ✓Solution needs to be adapted to particular cases
    - E.g. User biometrics

Why machines need learning

- To understand, so as to improve, the efficiency of human learning
- To discover new things that is unknown to humans
- To fill the incomplete knowledge in a domain

ML in Practice

- In practices, ML involves:
  - ✓Collecting data — **Data mining**
  - ✓Understanding the data
    - ➢Exploring the data
    - ➢Visualizing the data
  - ✓Data cleaning
    - ➢Dealing with missing values
    - ➢Dealing with outliers
    - ➢Normalizing (or scaling) the values

  Data preprocessing
  - ✓Applying a ML algorithm
    - ➢Building the model
      - For prediction and classification

    Training the Model
  - ✓Evaluating the output
    - ➢Based on standard metrics

  Verification & Validation

- Thus, ML begins with data mining.
  - ➢Data mining is the process of discovering useful patterns from large data sets to facilitate later transforming it to an understandable form.
    - ❑ The data mining task can be fully automated, or be semi automatic.

Data mining tools

Classification Learning Techniques

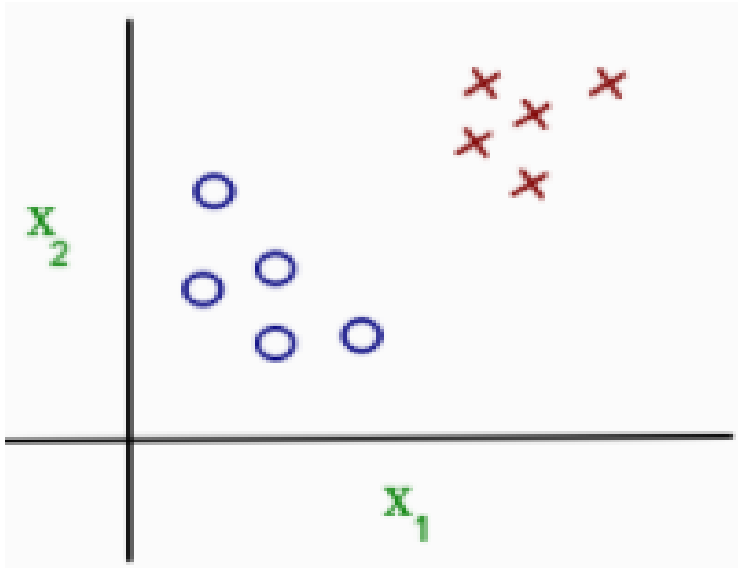
- Machine learning can be classified on either of two bases:
  a. On the basis of nature of the learning feedback available to the system
  b. On the basis of the output desired from the ML system

a. Classifying ML based on learning feedback

- Methods includes:
  - ✓Supervised learning
  - ✓Semi-supervised learning
  - ✓Unsupervised learning
  - ✓Reinforcement learning

Supervised learning

- Is a method in ML where the computer presented with both the learning inputs and their desired outputs so that it learns a general rule that maps inputs into outputs, and this training process continues until a desired level of accuracy.
  - ➢ The learnt model can then predict the output once fed with a new input.
- Examples include:
  - ✓ Image classification
  - ✓ Market prediction
  - ✓ Network intrusion detection

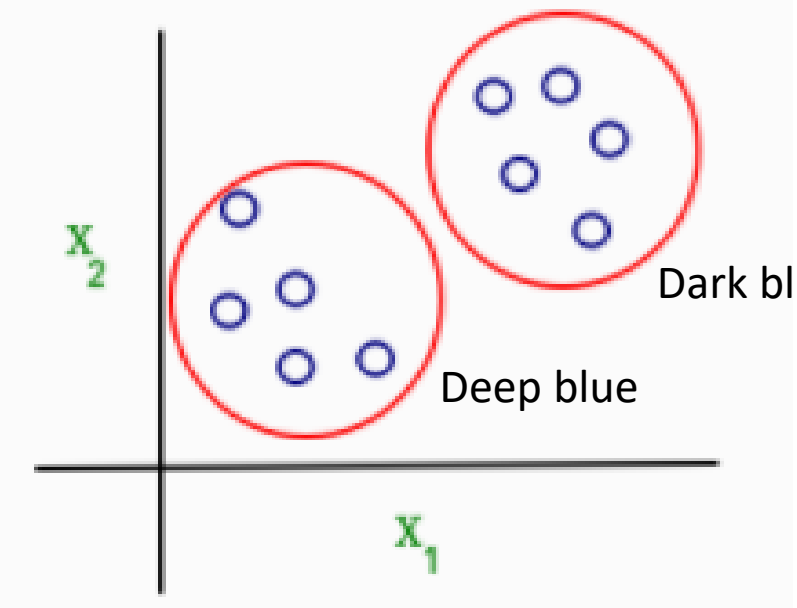


Semi-supervised learning

- Is supervised learning with large amount of input supplied but only some of which including labels.
- Examples include:
  - ✓ A photo archive where only some are labelled.

Unsupervised learning

- Is a method in ML where no labels are given to the learning algorithm, leaving it on its own to find the structure of the input to discover the hidden patterns in the data.
- Examples:
  - ✓Clustering (separating similar data into clusters)
  - ✓High dimension visualization
  - ✓Generative models



Reinforcement learning

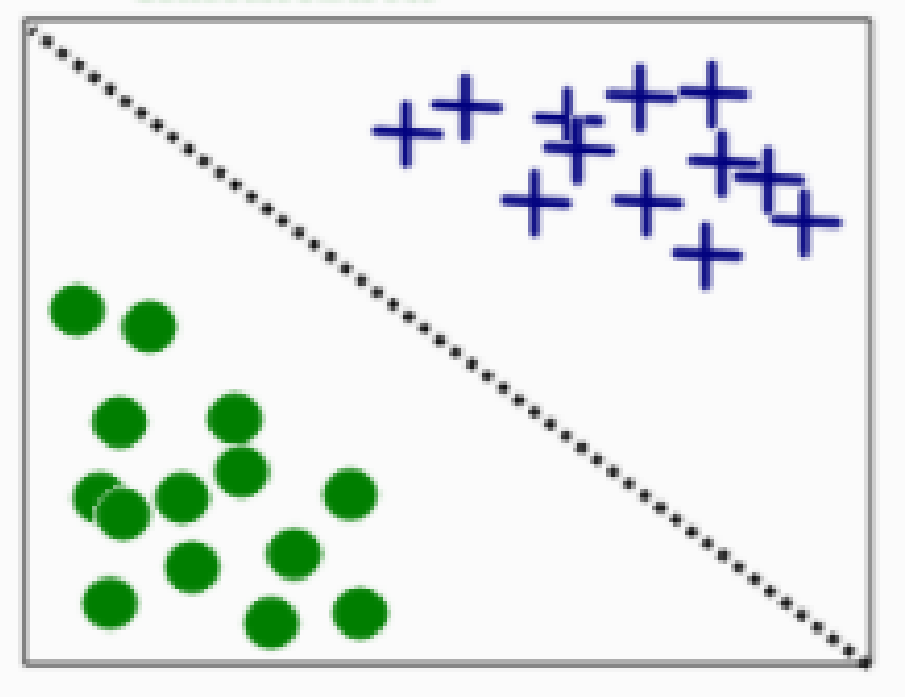
- Is a method in ML where a computer program interacts with a dynamic environment in which it must perform a certain goal, for which it is provided a feedback in terms of rewards or punishment as it navigates the problem space.
  - The machine learns to interact with the world from the reward or punishment got.

b. Classifying ML based on desired output

- Methods include:
  - ✓Classification
  - ✓Regression
  - ✓Clustering
  - ✓Density estimation
  - ✓Density reduction

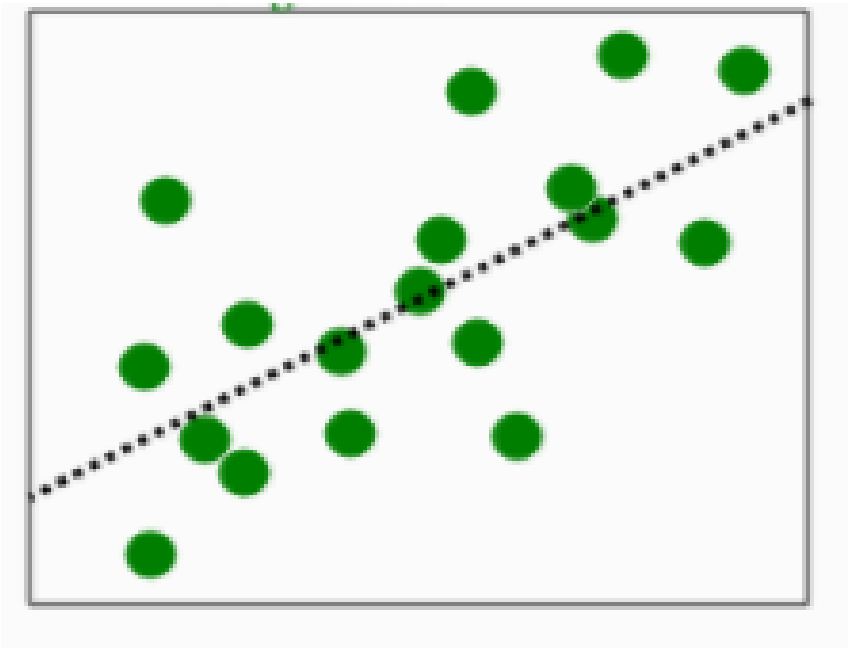
Classification

- Inputs are divided into two or more classes, and the learner must produce a model that assigns unseen inputs into one or more of these classes.
  - ➢Assignment of the later inputs to more than one label is referred to as multi-label classification
  - ➢This is tackled in a supervised way.
- Example: spam filtering.



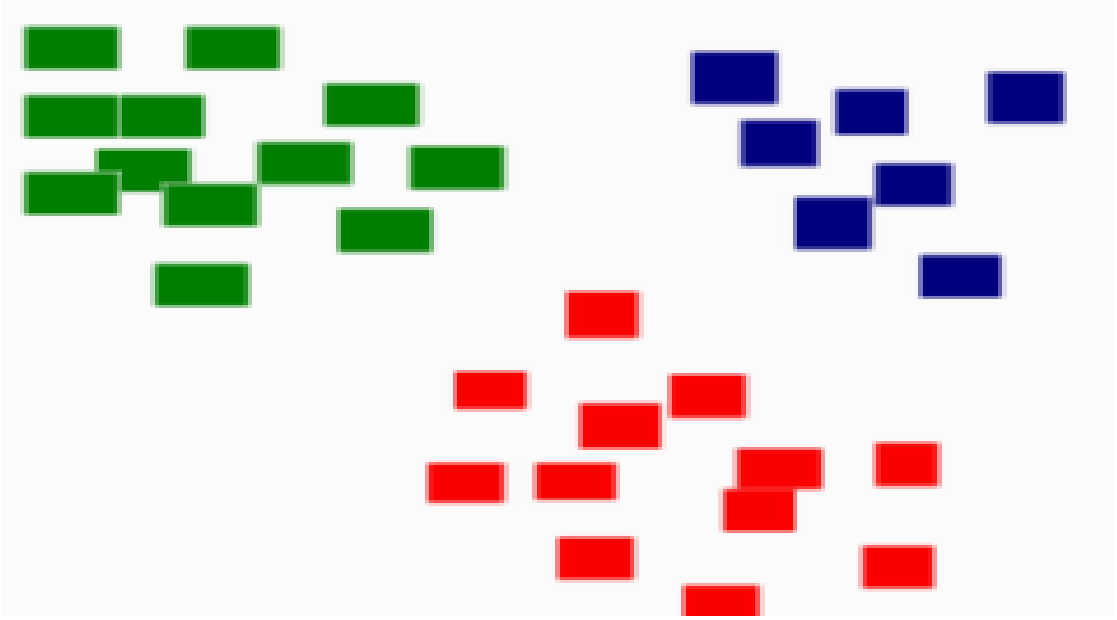
Regression

- Is a method for supervised learning problems where outputs are continuous rather than discrete.
- Example: predicting tock prices using historical data.



Clustering

- a method in ML in which a set of inputs is divided into groups, where the groups are not known beforehand
  - This is typically unsupervised learning.



Density estimation and Dimensionality reduction

- Density estimation is a method in ML where the task is to find the distribution of inputs in some space.
- Dimensionality reduction is a method in ML that simplifies inputs by mapping them into a lower dimensional space.
  - Example: Topic modeling.

ML Algorithms: Model

- ML involves training over a set of data, by providing it with an algorithm that it can use to reason over and learn from those data.
  - ➢ This results into a machine learning model
    - ○ A machine learning model is a file that contains a trained function to recognize certain types of patterns.
- A model can be trained and tested on different data than the one used for training.
  - ➢ This is referred to as the generalization property of a model
- A model may be a linear model, or a non-linear model
  - ➢ A linear model draws a clear straight line of separation of categories
  - ➢ A non-linear model draws a non-straight line of separation of the categories

Linear models **vs** Nonlinear models…

- Examples of common techniques include:

- LINEAR MODELS:
- 1. Logistical Regression (LR)
- 2. Linear Discriminant Analysis (LDA)

- NON-LINEAR MODELS:
- 1. K-Nearest Neighbors (KNN)
- 2. Classification and Regression Trees (CART) e.g. Decision Tree Classifier
- 3. Naive Bayes (NB)
- 4. Support Vector machines (SVM)

Machine learning paradigms

- Major paradigms include:
- Learning by example – a system induces a general rule from a set of observed instances.
  - Also called inductive learning or learning by being told.
  - It is the essence of supervised learning.
- Rote learning – is learning by memorization technique that is based on repetition
  - Examples: $5! = 5 * 4 * 3 * 2 * 1 = 120$,
    $6! = 6 * 5! = 6 * 120 = 720$
- Learning by taking advice – involves taking high level abstract advice and converting it into rules that guide performance of the elements of the system.

Machine learning paradigms

- Others include:
  - ✓Learning with a problem solving – solving problems by examining patterns in data and adapting to them.
  - ✓Learning by macro operators – sequence of actions are treated as a whole (called macro-operators) such that once a problem is solved, the learning component takes the computed plan and stores it as a macro-operator.

Future of Machine Learning

- The ML trend is accelerating:
  - ✓Improved machine learning algorithms
  - ✓Improved data capture, networking, faster computers
  - ✓Software too complex to write by hand
  - ✓New sensors / IO devices
  - ✓Demand for self-customization to user and environment is higher
  - ✓It turns out to be difficult to extract knowledge from human experts

Machine Learning algorithms – a timeline summary

- Past and recently:
  - First-generation algorithms e.g. Neural networks, decision trees, etc.
- Today:
  - Recently boosting algorithms and deep learning algorithms e.g. AdaBoost algorithm
- Future:
  - Everything smart
    - Smart remote controls, phones, cars, homes, cities, etc.
    - Data and communication networks, intelligent software, etc.
    - Internet of Things

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