Fundamentals of Artificial Intelligence

Introduction to Machine Learning

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Artificial Intelligence

Artificial Intelligence is demonstrated when a **task**, **formerly performed by a human** and thought of as **requiring the ability to learn, reason** and solve problems, **can be done by a machine**. Artificial Intelligence is the **ability of machines to seemingly think** for themselves.

Two strands of AI activity

1. The *cognitive approach* seeks to understand how intelligent behaviour arises.
2. Other strand adopts an *engineering approach* and the goal is to construct intelligent machines.

Artificial Intelligence

Intelligence is the ability to solve problems!

Problem solving demands an eclectic mix of search methods operating upon different knowledge representations.

Two broad approaches to solving problems

1. The **first is to treat every problem to be solved using first principles.**
   First Principles - agent solve a problem by reasoning about actions, exploring combinations, and choosing ones that lead to the solution.
2. The **second approach is to harness the knowledge gleaned from experience** or from other agents.

Where does this knowledge come from ?

- If one **were to rely on human programmers** to provide all knowledge / fine tune the system; then
  - The **evolution of machine intelligence would be slow**.
  - Any such system **would not be adaptive** to changing world.
- **Machines need the ability** to explore the world and **acquire the requisite knowledge** they need for problem solving on their own.
  - All knowledge accrues through a process of learning.

What is Machine Learning?

Artificial Intelligence and machine learning are often used interchangeably.

Machine learning is a subset of Artificial Intelligence and focuses on the **ability of machines to** receive a set of data and **learn** for themselves, **changing algorithms as they learn more** about the information they are processing.

Machine learning address the question of how to build computer programs that improve performance automatically through experience.

What is Learning?

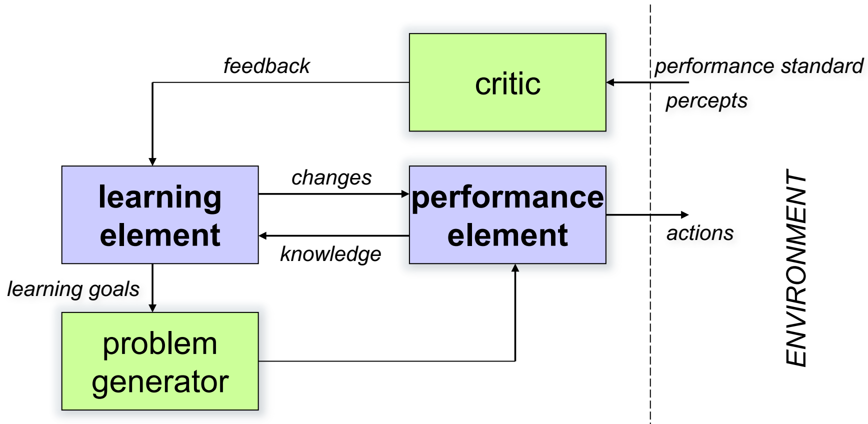
Learning denotes changes in a system that enable a system to do the same task more efficiently the next time.

- Herbert Simon

Learning is constructing or modifying representations of what is experienced.

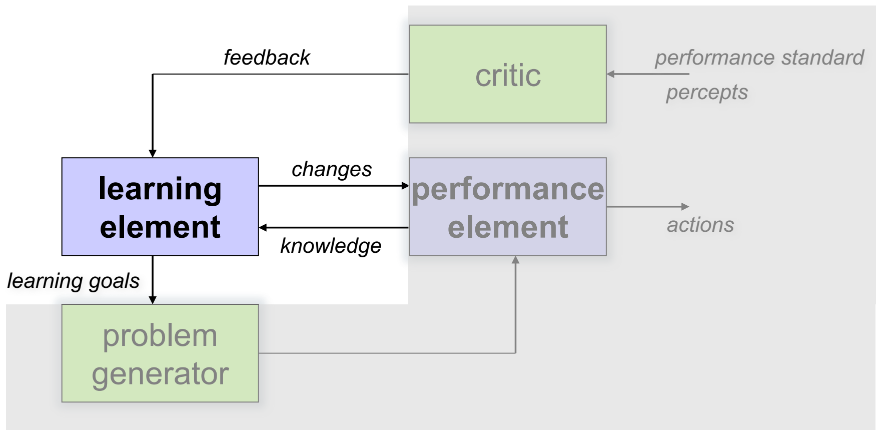
- Ryszard Michalski

Architecture of a Learning System



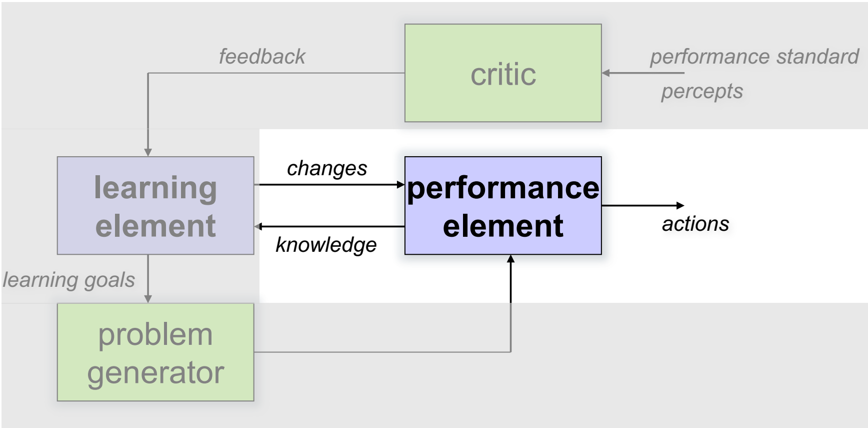
Learning refers to the capability of autonomous acquisition and integration of knowledge.

Learning Element



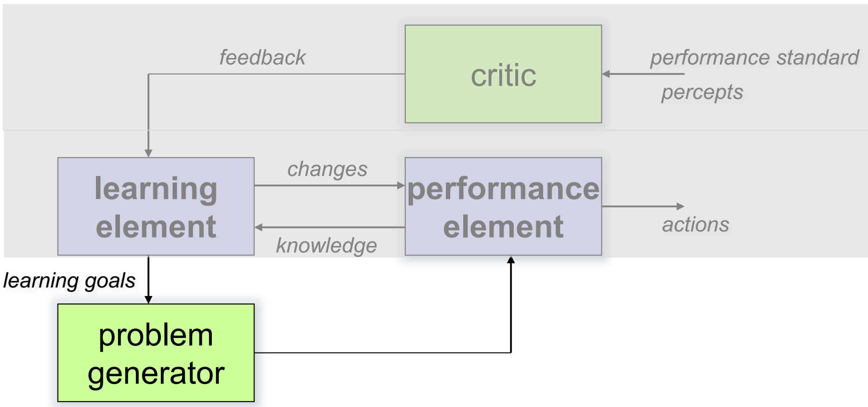
- Responsible for **making improvements**.
- **Knowledge** and **feedback** to improve performance.

Performance Element



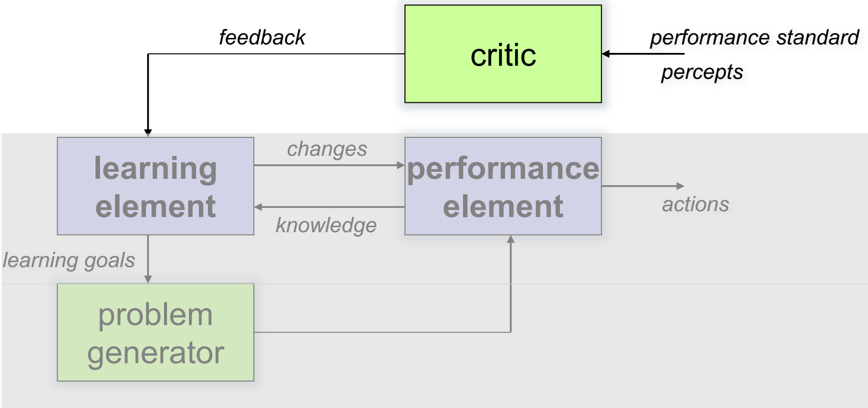
- Selects external actions; **drives the learning element**.
- Collects percepts, decides on actions.

Problem Generator



- Suggests actions that might **lead to new experiences**.
- **Ensures exploration**; better actions discovered.

Critic



- **Informs learning** element about the performance.
- Use a fixed **standard of performance**.

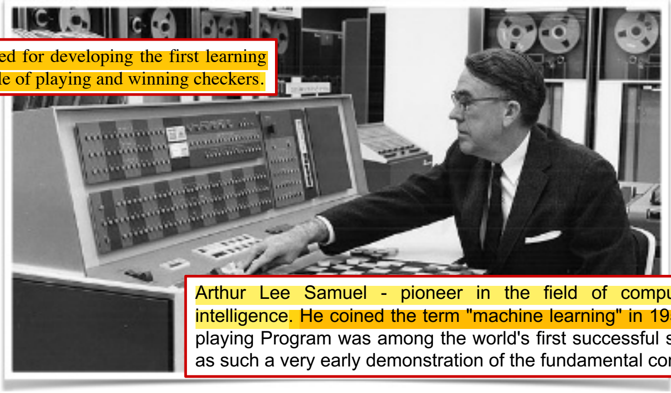
Machine Learning

A **computer program** is said to **learn** from **experience E** with respect to some class of **tasks T** and **performance measure P**, if its **performance** at tasks in T, as measured by P, **improves with experience** E.

– Tom Mitchell

Machine learning has progressed dramatically over the past two decades, from laboratory curiosity to a practical technology in widespread commercial use. Within AI, machine learning has emerged as the method of choice for development of practical software.

Machine Learning – Early History



Machine Learning is the field of study that gives computers the ability to learn without being explicitly programmed.

Arthur Samuel

Samuel, Arthur L. (1959). **Some Studies in Machine Learning Using the Game of Checkers**. *IBM Journal of Research and Development.*

Machine Learning – Early History

Abstract: Two machine-learning procedures have been investigated in some detail using the game of checkers. Enough work has been done to verify the fact that a computer can be programmed so that it will learn to play a better game of checkers than can be played by the person who wrote the program. Furthermore, it can learn to do this in a remarkably short period of time (18 or 10 hours of machine-playing time) when given only the rules of the game, a sense of direction, and a redundant and incomplete list of parameters which are thought to have something to do with the game, but whose correct signs and relative weights are unknown and unspecified. The principles of machine learning verified by these experiments are, of course, applicable to many other situations.

The main driver of the machine was a search tree of the board positions reachable from the current state. Since he had only a very limited amount of available computer memory, Samuel implemented what is now called alpha-beta pruning.

Machine Learning – Early History

A computer program is said to learn from experience E with respect to some class of **tasks T** and **performance measure P**, if its performance at tasks in T, as measured by P, improves with **experience E**.

– Tom Mitchell

For a checkers *learning problem*:

T: playing checkers

P: percent of games won against opponents

E: playing practice games against itself

Idea of Machine Learning

- **Build a model** that is a **good and useful approximation** to the data.

Machine learning focuses on the development of computer programs that can access data and use it learn for themselves.

- Model defined up to some parameters; **learning is the execution of a computer program** to **optimize** the parameters of the **model** using the training data or experience.

Machine Learning Philosophy

- The **philosophy** is to **automate** the **creation of analytical models** in order to enable **algorithms to learn** continuously with the help of available data.

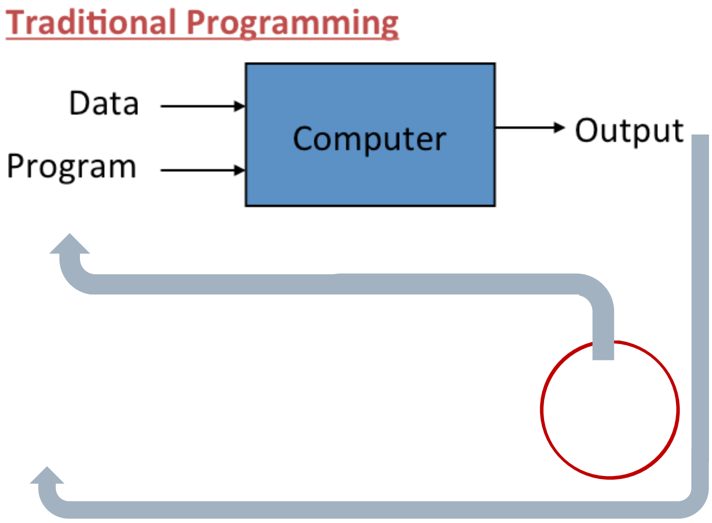
- The **model may be predictive** to make predictions in the future, **or descriptive** to gain knowledge from data, **or both**.

> Machine Learning is based on the idea that systems can learn from data: identify patterns, make decisions with minimal human intervention.

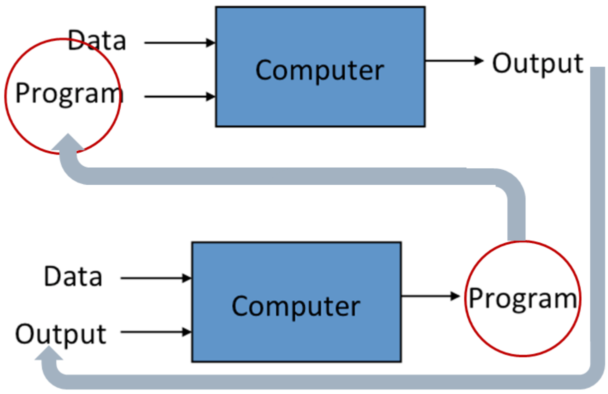
Machine Learning

Statistics	Machine Learning
Low-dimensional data [e.g. less than 100 D]	High-dimensional data [e.g. more than 100 D]
Lots of noise in the data .	Noise **not sufficient to obscure** the structure in the data.
There is not much structure in the data; structure can be represented by a **fairly simple model**.	Huge amount of structure in the data; structure is **too complicated** to be grasped by a simple model.
The main problem is **distinguishing true structure** from noise.	Figuring out a way to **represent the structure** that allows it to be learned.

Machine Learning



Machine Learning



Machine learning is a **method of data analysis** that automates **analytical model building.**

Machine Learning

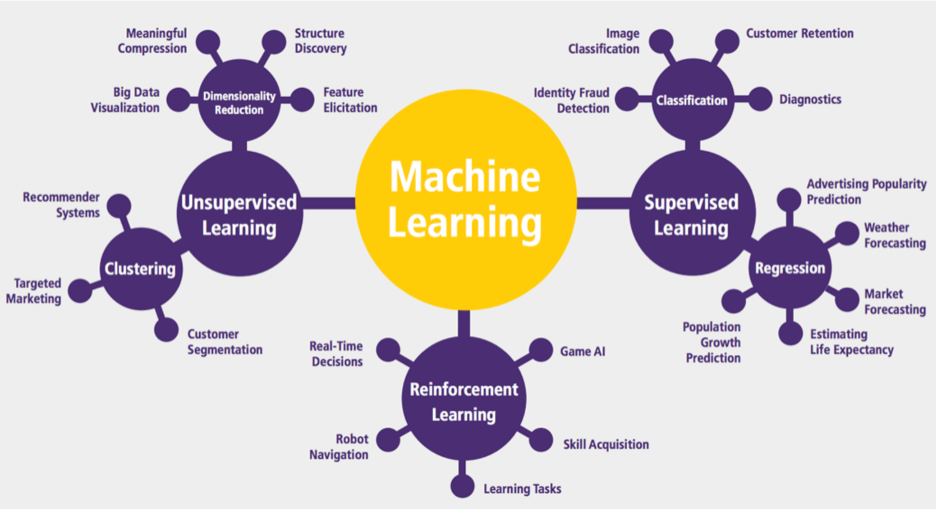


Image Source: DHL, Artificial Intelligence in Logistics, 2018.

Supervised Learning

The set of (training/learning) data consists of a set of input data and correct responses (labels) corresponding to every piece of data.

Supervised learning: a type of machine learning that learns from training data with labels as learning targets. It is the most widely used type of machine learning

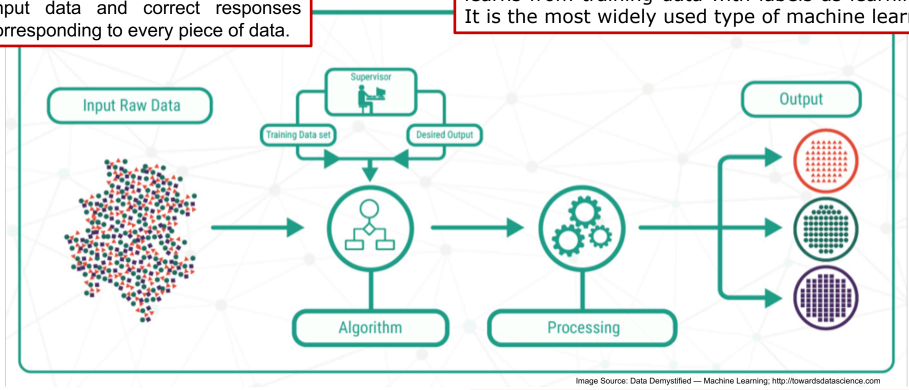


Image Source: Data Demystified — Machine Learning; http://towardsdatascience.com

The algorithm has to generalize such that it is able to correctly (or with low error margin) respond to all possible inputs.

Learn to predict output when **given an input vector**

Supervised Learning

Supervised learning exemplify the function approximation problem; where the goal is to produce a prediction y* in response to a query x*. The inputs x may be classical vectors or they may be more complex objects such as documents, images, DNA sequences, or graphs.

Prediction of future cases: Use the rule to **predict output for novel instances in future**.

Knowledge extraction: The rule is easy to understand and **explain the process underlying the data.**

Supervised learning generally form their predictions via a learned mapping, which produces an output for each input. Many different forms of mapping exist, including decision trees, logistic regression, support vector machines etc.

Supervised Learning

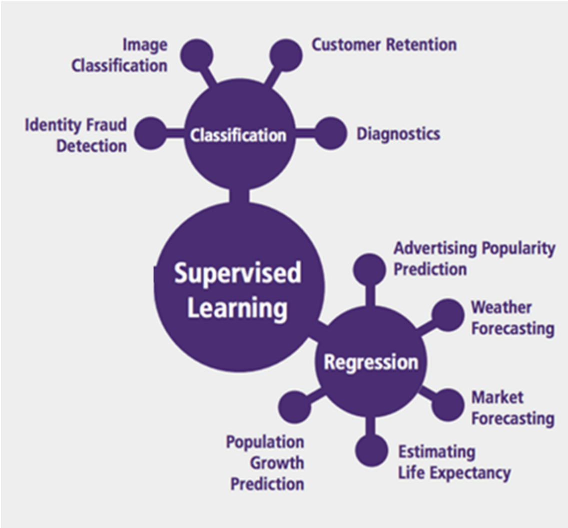
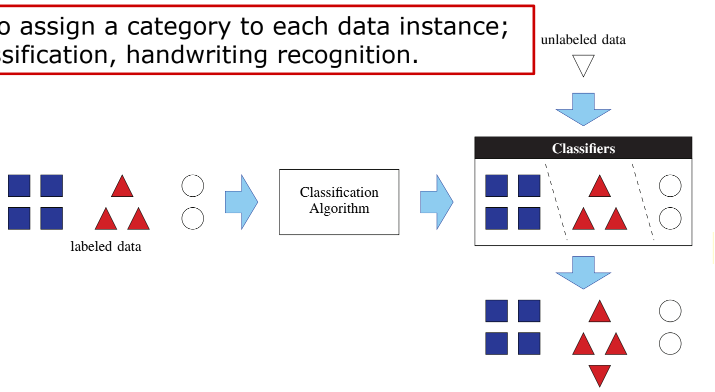


Image Source: DHL, Artificial Intelligence in Logistics, 2018.

Classification

Classification: to assign a category to each data instance;
E.g., image classification, handwriting recognition.

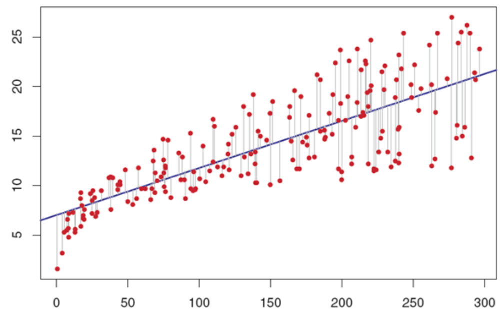


A classification problem is when the output variable is a category, such as "red" or "blue" or "disease" and "no disease". A classification model attempts to draw some conclusion from observed values. Given one or more inputs a classification model will try to predict the value of one or more outcomes.

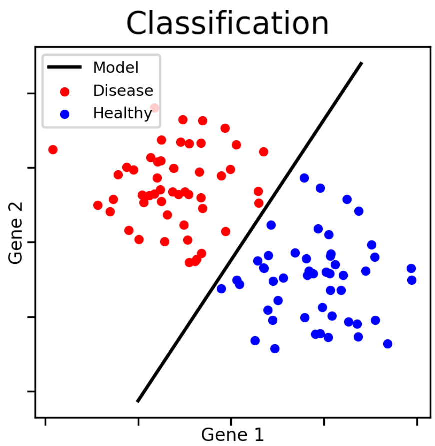
Regression

Regression: to predict a value for each data instance;
E.g., temperature/age/income prediction.

Approach for **modeling the relationship between** a scalar **dependent variable** Y and one or more **explanatory variables** (or independent variables) denoted X



Classification vs. Regression



Unsupervised Learning

No information about correct outputs (labels) is available Algorithm must determine the data patterns on its own.

Tends to restructure the data into something else, such as new features that may represent a class or a new series of uncorrelated values.

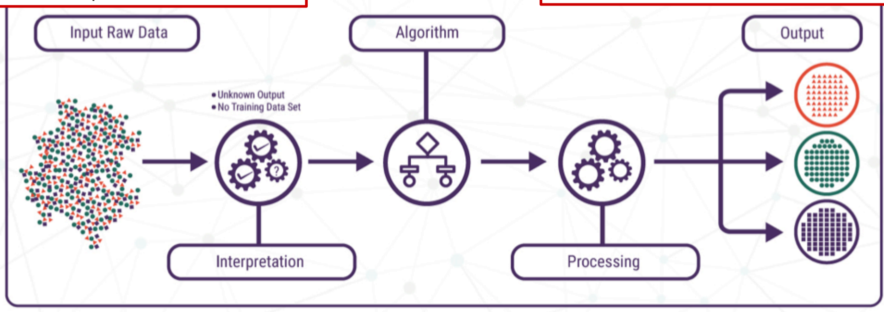


Image Source: Data Demystified — Machine Learning; http://towardsdatascience.com

The main goal of these types of algorithms is to study the intrinsic and hidden structure of the data in order to get meaningful insights, segment the datasets in similar groups or to simplify them.

Create an internal representation of the input e.g. form clusters; extract features

Unsupervised Learning

Unsupervised learning is a machine learning technique, where you do not need to supervise the model. Instead, you need to allow the model to work on its own to discover information.

Learning relations between data components. No specific outputs given by a Supervisor. Only input data. Finding **clusters or groupings** (of similar examples) of input.

Determine the distribution of data within the input space.

Unsupervised Learning

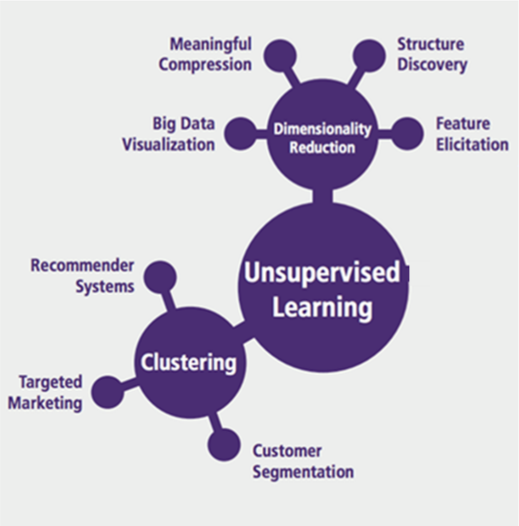
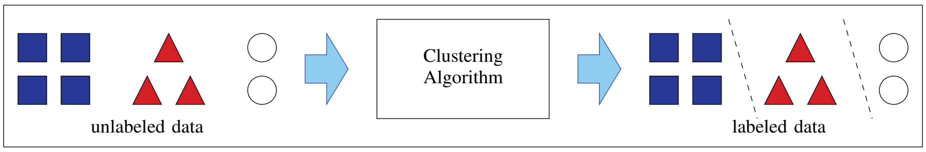


Image Source: DHL, Artificial Intelligence in Logistics, 2018.

Clustering

Clustering: to partition instances into homogeneous regions;
E.g., pattern recognition, market/image segmentation

Clustering is an important concept when it comes to unsupervised learning. It mainly deals with finding a structure or pattern in a collection of uncategorized data.



Clustering algorithms will process your data and find natural clusters(groups) if they exist in the data. You can also modify how many clusters your algorithms should identify. It allows you to adjust the granularity of these groups.

Dimensionality Reduction

Dimensionality is the number of variables, characteristics or features present in the dataset. In most cases, the features are correlated and, therefore, there is some information that is redundant which increase the dataset's noise.

This redundant information impacts negatively in Machine Learning model's training and performance and that is why using dimensionality reduction methods becomes of paramount importance.

Dimensionality reduction is the process of reducing the number of random variables under consideration, by obtaining a set of principal variables.

Dimensionality Reduction

Categories:

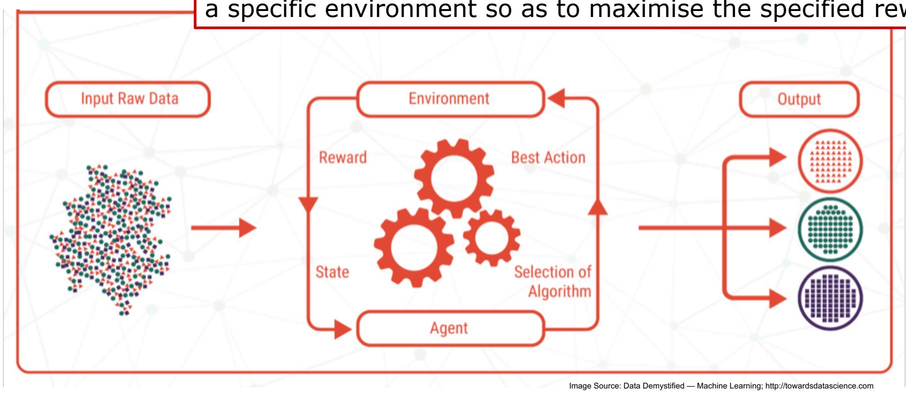
Dimension reduction: to reduce the training complexity; E.g., dataset representation, data pre-processing.

a. Feature selection: Find a subset of the original set of variables, or features, to get a smaller subset which can be used to model the problem.

b. Feature extraction: Reduces the data in a high dimensional space to a lower dimension space, i.e. a space with lesser no. of dimensions. The output features will not be the same as the originals. When using feature extraction, we project the data into a new feature space, so the new features will be combinations of the original features, compressed in a way that they will retain the most relevant information.

Reinforcement Learning

Reinforcement learning: a type of machine learning where the data are in the form of sequences of actions, observations, and rewards, and the learner learns how to take actions to interact in a specific environment so as to maximise the specified rewards.



Learn **action to maximize payoff.**

Reinforcement Learning

In Reinforcement learning, the information available for training is intermediate between supervised and unsupervised learning. Instead of training examples that indicate the correct output for a given input, the training data are assumed to provide only an indication as to whether an action is correct or not.

Concerned with the **problem of finding suitable actions** to take in a given situation **in order to maximize a reward.**

Assess the goodness of policies, **learn from past good action sequences**, and generate a policy.

Reinforcement learning problems typically involve a general control-theoretic setting – learn a policy – ties to formulations such as Markov Decision Problems and Partially Observable Markov Decision Problems.

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Reinforcement Learning

Control: to control actions to maximise rewards;
E.g., game playing

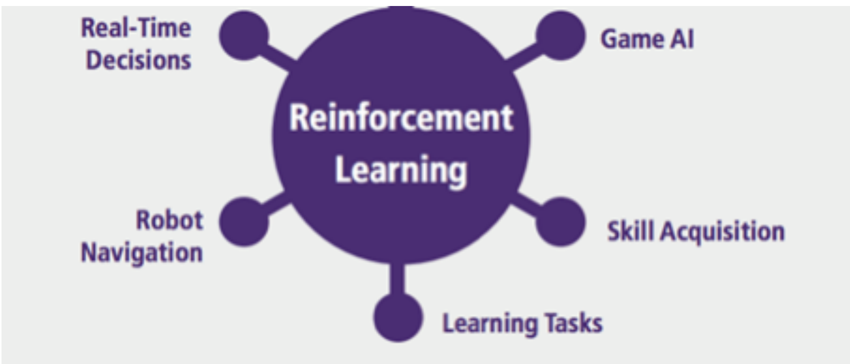

Image Source: DHL, Artificial Intelligence in Logistics, 2018.

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Blends Across

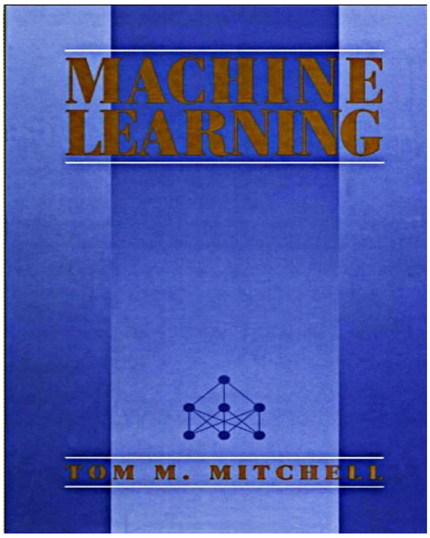
- Although these three learning paradigms help to organize ideas, **much current research involves blends across these categories**.
  - **Semisupervised learning** makes use of **unlabeled data to augment labeled data** in a supervised learning context, and **discriminative training** blends architectures developed for unsupervised learning with **optimization formulations that make use of labels**.
  - **Active learning** arises when the learner is allowed to choose data points and **query the trainer to request targeted information**, such as the label of an otherwise unlabeled example.

Emerging Trends

- The field of **machine learning is sufficiently young that it is still expanding**, often by inventing new formalizations of **machine-learning problems driven by practical applications**.

- Machine-learning systems are **increasingly taking the form of complex collections of software** that run on large-scale parallel and distributed computing platforms and **provide a range of algorithms and services.**

Annotated Bibliography



Machine Learning

Tom M. Mitchell
McGraw-Hill, 1997

This book provides a **single source introduction** to the field. It is written for advanced undergraduate and graduate students, and for developers and researchers in the field. **No prior background** in artificial intelligence or statistics is assumed.

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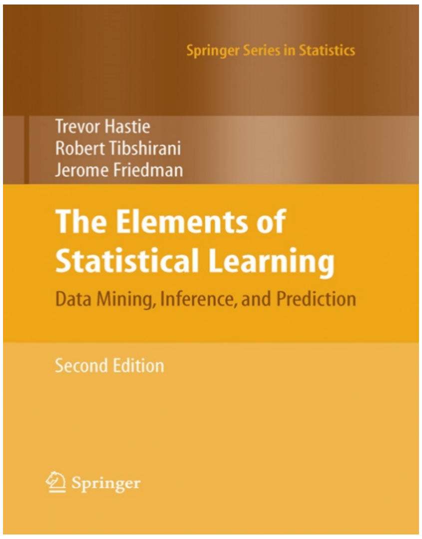

The Elements of Statistical Learning

Trevor Hastie, Robert Tibshirani and Jerome Freidman
Springer, 2009

This book describes the **important ideas in a common conceptual framework**. While the **approach is statistical, the emphasis is on concepts rather than mathematics**. Many examples are given. The book's coverage is broad, from supervised learning to unsupervised learning.

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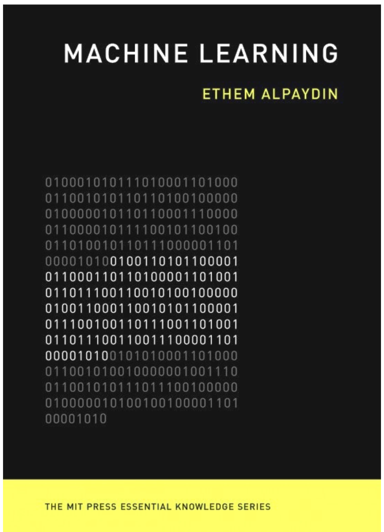

Machine Learning: The New AI

Ethem Alpaydin
MIT Press, 2016

A **concise overview of machine learning** — computer programs that learn from data — which **underlies applications** that include **recommendation systems, face recognition, and driverless cars**.

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