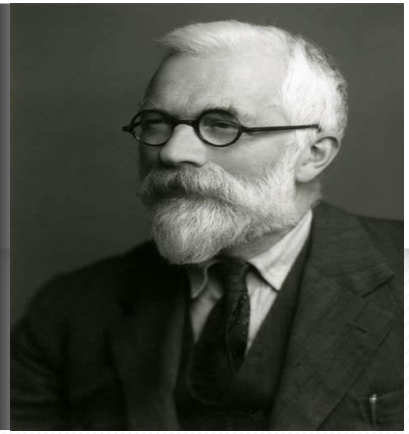
# 化繁为简、大巧不工

(The object of statistical methods is the reduction of data)

——罗纳德·费希尔（Ronald Fisher）



机器学习是一种“数据驱动学习（data-driven learning）”的范式，它从数据出发来学习数据中所蕴含的模式，对数据进行抽象。统计学家罗纳德·艾尔默·费希尔（Ronald Aylmer Fisher）将这一过程概括为“化繁为简（the object of statistical methods is the reduction of data）”。

1959 年7 月，IBM 公司的工程师阿瑟·塞缪尔（Arthur Samuel） 第一次使用了“机器学习（machine learning）”，将其定义为“让机器具有不需要明确编程而具有的一种学习能力（the ability to learn without being explicitly programmed）”的研究，其目标是构造一种学习机器（learning machine），使之像人一样具有自我学习能力， 而非按部就班完成预设任务。

# Objectives 目的

To describe the agents how can improve their behavior through learning from data.

描述智能体如何通过从数据中学习来改善其性能。

To discuss the perspectives on so many learning algorithms we have been faced with.

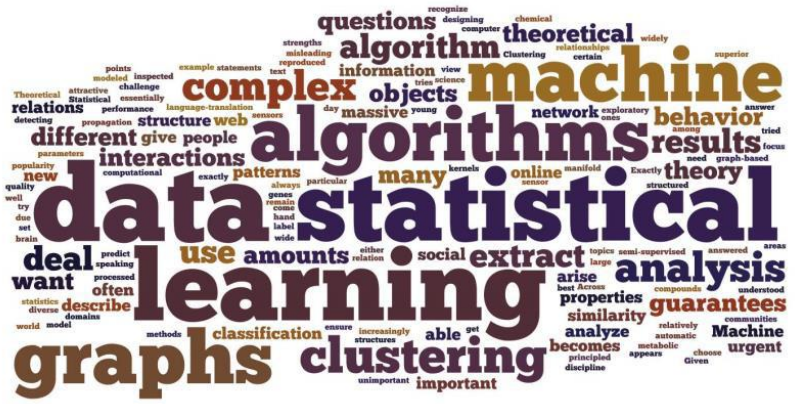
针对所面临的诸多机器学习算法，讨论一下我们的视角。

# （1）What is Machine Learning 什么是机器学习

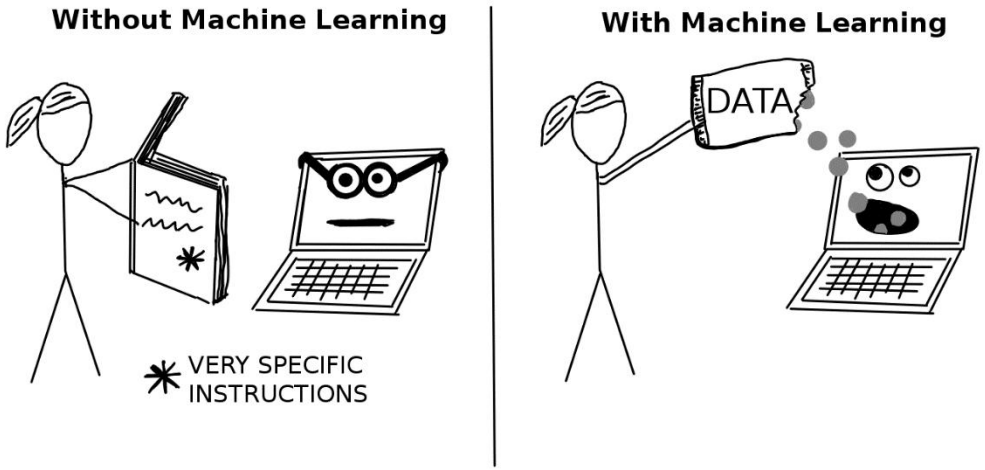
*Machine learning is a branch of artificial intelligence, concerns the construction and study of systems that can learn from data.*

机器学习是人工智能的一个分支，从事构建和研究可以从数据中学习的系统。

- Machine Learning used to be the **Queen.**
  机器学习曾经是王后。
- Machine Learning is now the **King.**
  如今机器学习是国王。




Source: http://www.computervisionblog.com/2015_06_01_archive.html

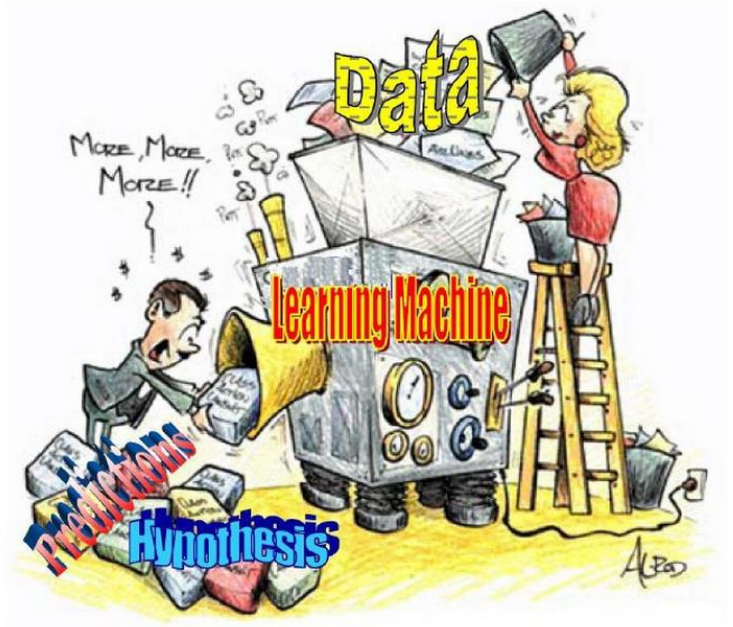

Without Machine Learning
With Machine Learning
DATA
VERY SPECIFIC
INSTRUCTIONS

- 传统程序


数据
程序
计算机
输出

- 机器学习


数据
输出
计算机
机器学习系统


Data
More, More, More!!
Learning Machine
Predictions
Hypothesis

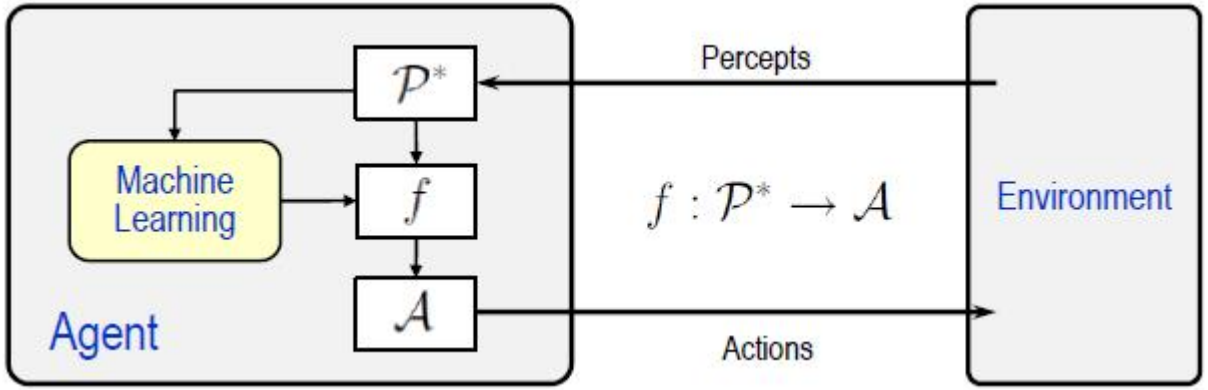
# Artificial Intelligence vs. Machine Learning 人工智能与机器学习

- Artificial Intelligence (AI): 人工智能(AI)to study "agents" that perceive the environment and take actions for some goal.

  研究感知外部环境并为某个目标采取行动的"**智能体**"。

- Machine Learning: 机器学习a branch of AI, concerns the construction of systems that can learn from data.

  **人工智能的一个分支**，从事构建可以从数据中学习的系统。




# Relations to Other Disciplines 与其他学科的关系

- **Statistical Learning 统计学习**
  a machine learning framework drawing from statistics.
  取自于统计学的机器学习框架。
- **Pattern Recognition 模式识别**
  the recognition of patterns in data. ( ≈ machine learning + data patterns)
  识别数据中的模式。( ≈ 机器学习+ 数据模式)
- **Data Mining 数据挖掘**
  the discovery of unknown properties in data. ( ≈ machine learning + database)
  发现数据中的未知特性。( ≈ 机器学习+ 数据库)
- **Computer Vision 计算机视觉**
  to extract information from images.( ≈ machine learning + image processing)
  从图像中提取信息。( ≈ 机器学习+ 图像处理)

# Human Learning vs. Machine Learning 人类学习与机器学习

- **Human Human Learning Learning 人类学习**

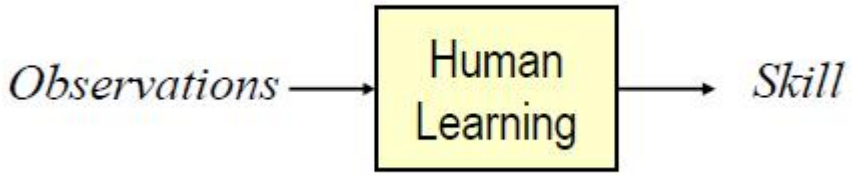
  acquiring skill with acquiring skill with experience accumulated from observations.

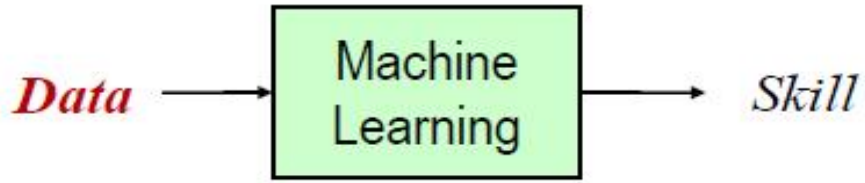
  从观察中积累经验来获取技能。

- **Machine Learning 机器学习**

  acquiring skill with experience accumulated/computed from data.

  从**数据**中积累或者计算的经验获取技能。



# What is Skill in Machine Learning 什么是机器学习的技能

- Skill 技能

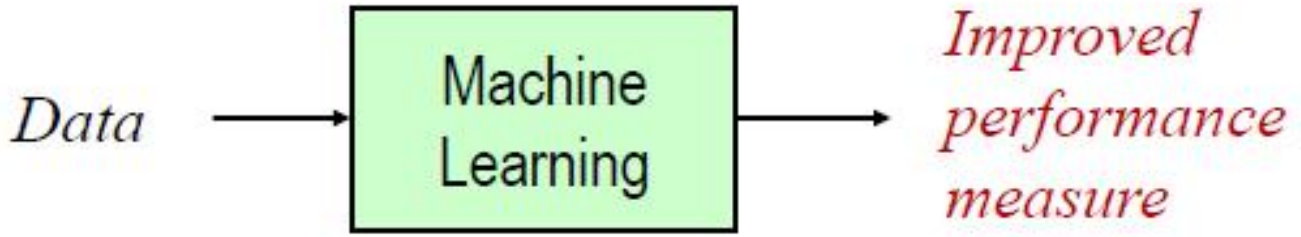
  improving some performance measure. (e.g. prediction accuracy)

  改善某些性能指标(如预测精度)。

- Why Use Machine Learning 为什么使用机器学习

  acquiring skill with experience accumulated/computed from data.

  机器学习可以通过从数据中学到的经验来改善某些性能指标。



# Two General Types of Learning 两种通用的学习类型

## ☐ Inductive learning 归纳学习

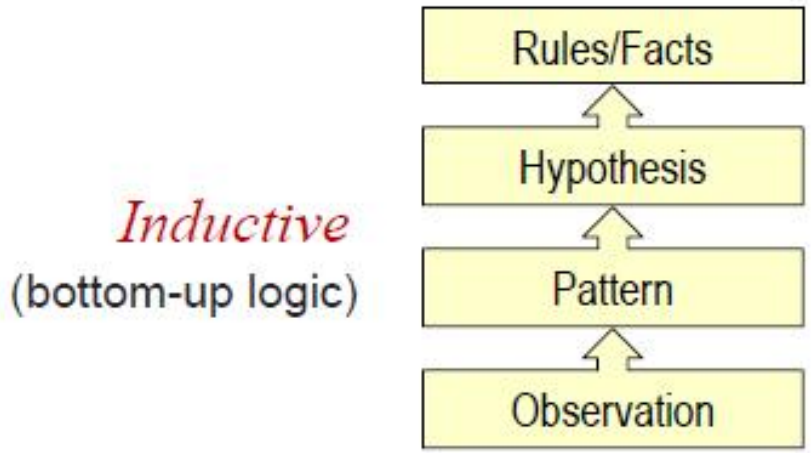
to obtain or discover general rules/facts from particular training samples.

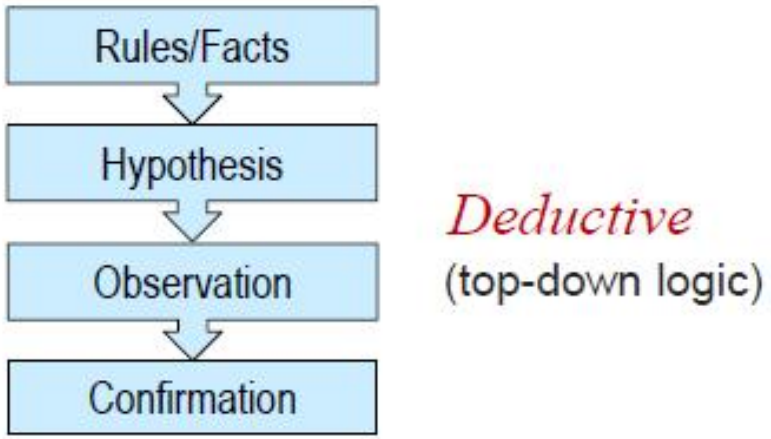
从特定的训练实例中获得或发现通用的规则或事实。

## ☐ Deductive learning 演绎学习

to use a set of known rules/facts to derive hypothesis that fit the training data.

使用一套已知的规则和事实去推导适合该训练数据的猜测。



# Some Definitions about Machine Learning 机器学习的若干定义

| Who | When | Definition | Publication |
|---|---|---|---|
| Arthur Samuel,<br>American pioneer of ML<br>亚瑟·塞缪尔，美国机器学习先驱 | 1959 | The **field** of study that gives computers the ability to learn without being explicitly programmed.<br>研究给予计算机学习能力而不必显式编程的**领域**。 | |
| Herbert Simon,<br>American computer scientist<br>赫伯特·西蒙，美国计算机科学家 | 1983 | A **process** by which a system improves its performance.<br>一种**系统**用它来改善其性能的过程。 | |
| Ethem Alpaydin,<br>Turkish professor<br>埃塞姆·阿培丁，土耳其教授 | 2004 | **Programming computers** to optimize a performance criterion using example data or past experience.<br>运用示例数据或经验的**计算机程序**来优化性能指标。 | "Introduction to Machine Learning", MIT Press |
| Mehryar Mohri,<br>Afshin Rostamizadeh and<br>Ameet Talwalkar | 2012 | The **computational methods** using experience to improve performance or to make accurate predictions.<br>运用经验来改善性能或做出正确预测的**计算方法**。 | "Foundations of Machine Learning", MIT Press |

# A Formal Definition about Machine Learning 机器学习的形式化定义

- Tom Mitchell (CMU Professor) 汤姆·米切尔（CMU教授）

in his 1997 publication of “Machine Learning”, provided a widely quoted, more formal definition of the algorithms studied in the machine learning field:

在1997年出版的《机器学习》一书中，为机器学习领域研究算法提供了一个广泛引用、更为形式化的定义：

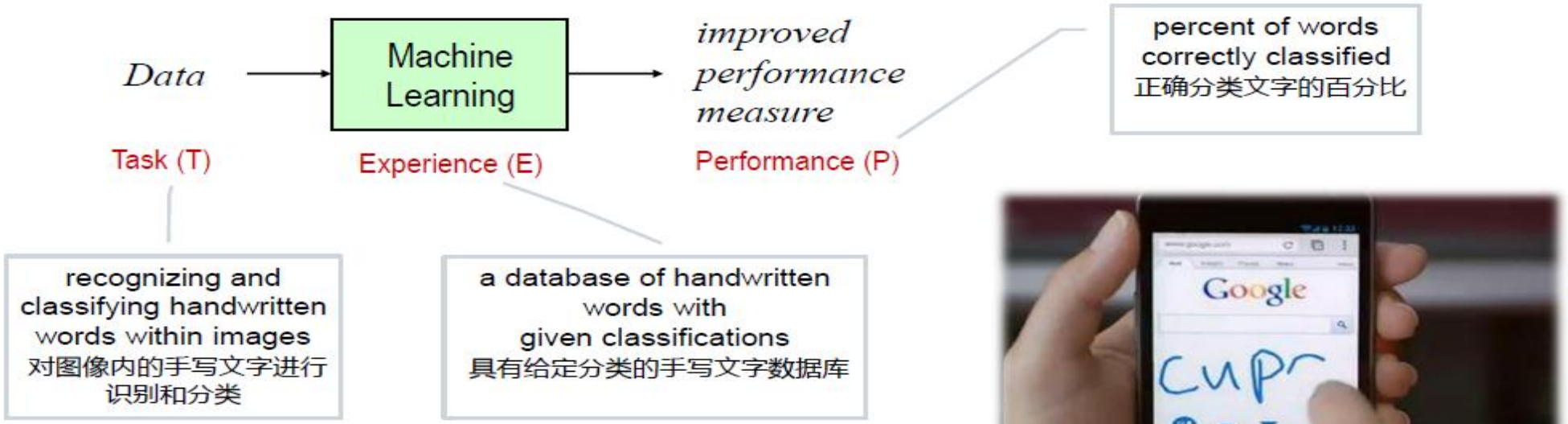
A **computer program** is said to **learn from experience E** with respect to some class of tasks T and performance measure P, if its performance at tasks in T, as measured by P, improves with experience E.

一个能根据某类任务T和性能度量P中的经验E学习的计算机程序，如果它在任务T中的性能P度量随经验E而改善。

# Three Key Elements in the Formal Definition 形式化定义的三要素

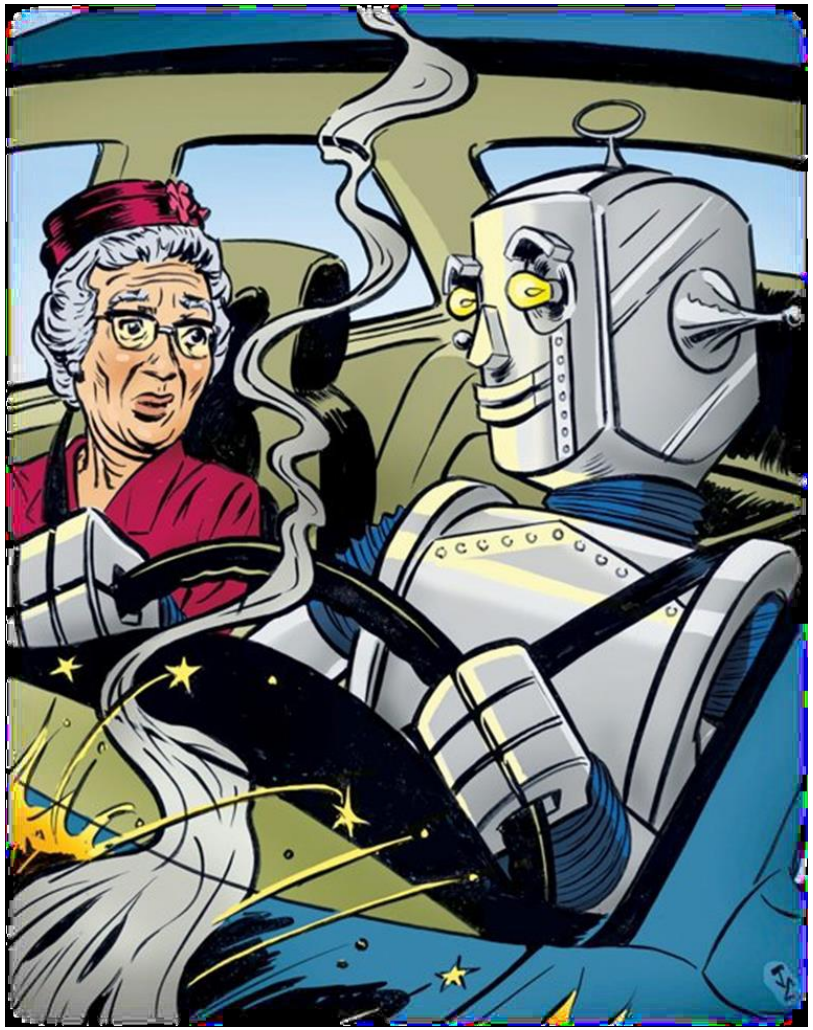
- To have a well-defined learning problem, we must identity those three features:

  要得到一个明确定义的学习问题，我们必须识别如下三个特性：




*Example*1: A handwriting recognition problem 手写识别问题

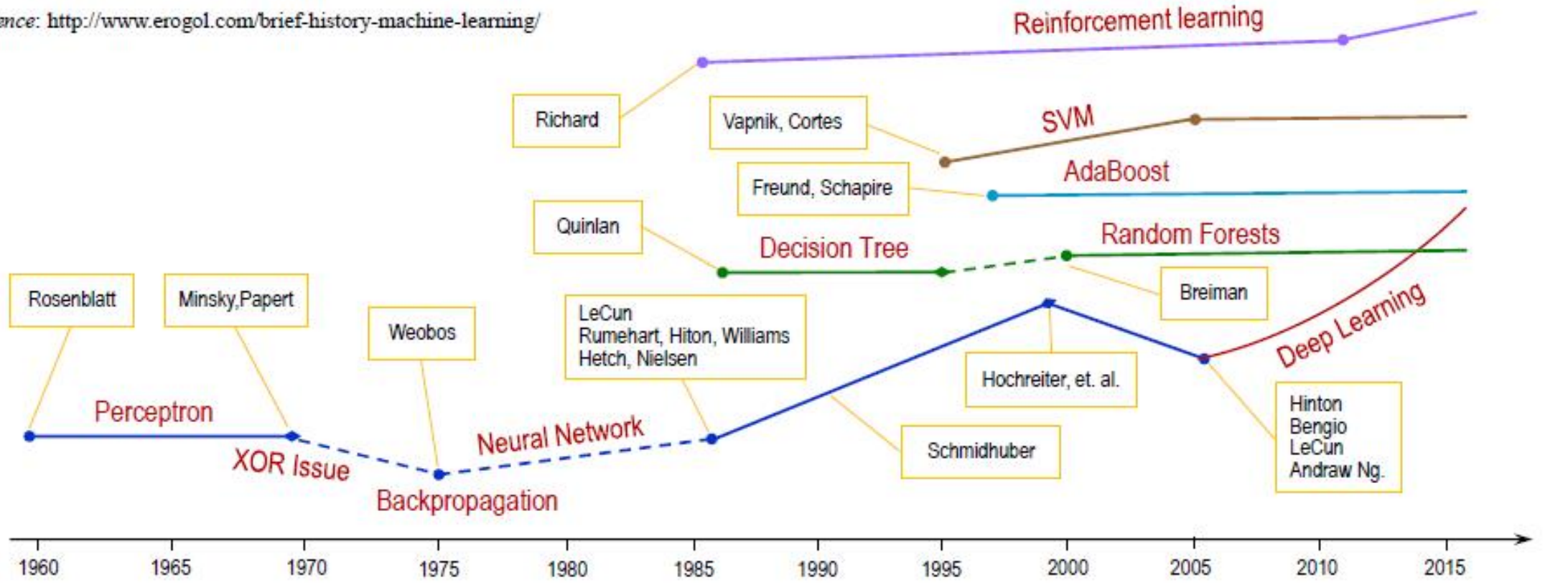
# *Example2*: A robot driving problem 机器人驾驶问题



- Task (T):
  driving on public four-lane highways using vision sensors
  使用视觉传感器在公共四车道高速公路上驾驶
- Performance (P):
  average distance traveled before an error (as judged by human overseer).
  出错之前行驶的平均距离（由人类督察评判）
- Experience (E):
  a sequence of images and steering commands recorded while observing a human driver
  观察人类驾驶员时所记录的一系列图像和操纵命令。

# Timeline of Machine Learning 机器学习的大事年表

*Reference*: http://www.erogol.com/brief-history-machine-learning/




**Perceptron** an algorithm of binary classifiers

**XOR Issue** perceptrons can't process XOR circuit

**Backpropagation** a common method of training neural networks

**Neural Network** learning algorithms inspired by biological neural networks

**Reinforcement Learning** concerned with how an agent take actions in an environment

**Decision Tree** a decision support tool that uses a tree-like graph

**SVM** support vector machine

**AdaBoost** adaptive boosting algorithm

**Random Forests** a multitude of decision trees

**Deep Learning** deep networks, hierarchical learning

# Difficulty in Understanding Machine Learning 理解机器学习的难点

- Which algorithm should choose 应该选择哪种算法

  Suppose we have an application that machine learning might be good for, so we need an appropriate algorithm for learning from data.

  假设我们有一个应用程序，机器学习会有帮助，因此需要一个适当的从数据中学习的算法。

  The problem we faced is how to choose one of machine learning algorithms.

  我们面临的问题是如何选择一个机器学习算法。

- How many learning algorithms 有多少种算法

  So many algorithms for machine learning.

  机器学习的算法如此之多。

  Literally thousands available, and hundreds more published each year.

  大概有数千种，每年又会发表数百种。

# Difficulty in Understanding Machine Learning 理解机器学习的难点

- What is the difficulty 难点是什么

  Without a category of machine learning, how to determine which algorithm could be used?

  没有机器学习的分类法，如何确定哪种算法适用？

  The categorization relates our perspective on machine leaning.

  这种分类关系到我们观察机器学习的视点。

- Is one perspective enough 一个视点够吗?

  To outlook on most of machine learning algorithms, one perspective is so hard.

  要了解大多数机器学习算法，仅有一个视点是不够的。

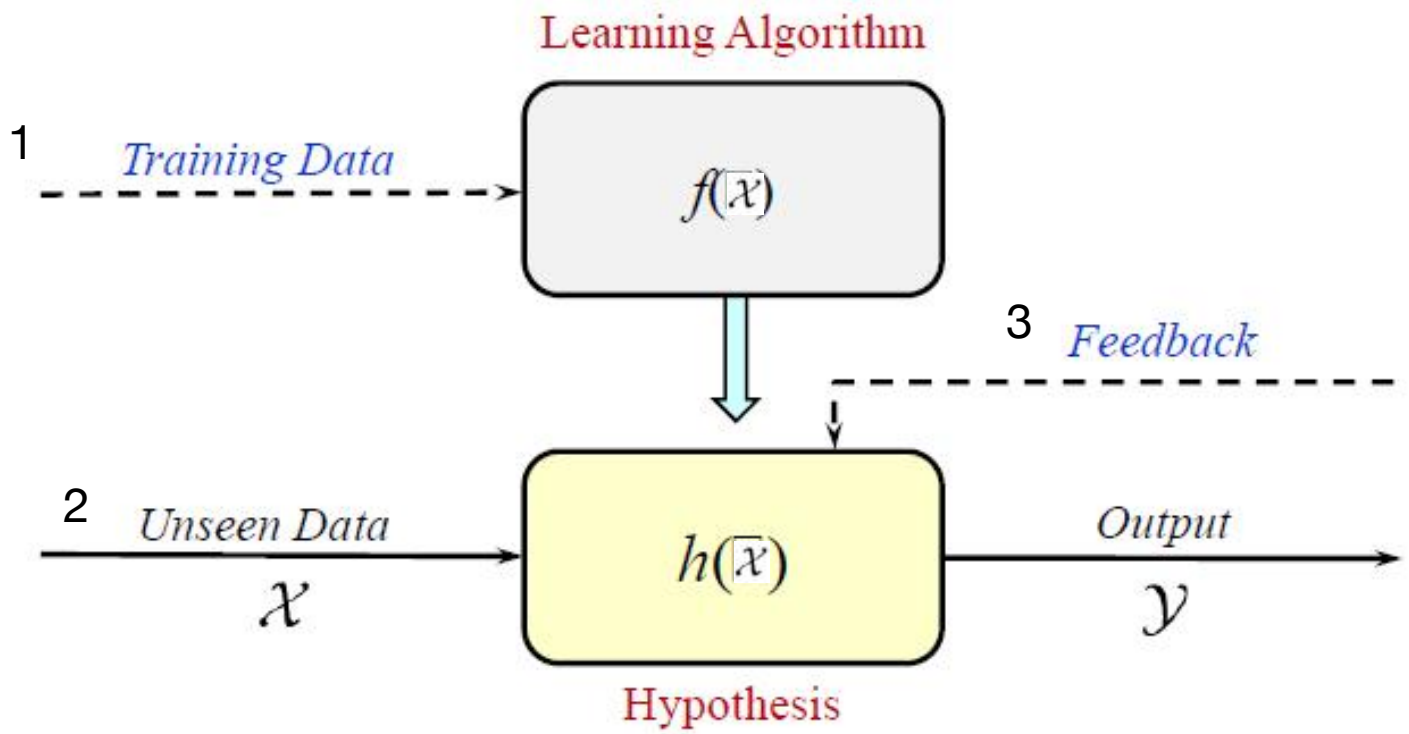
  We should look from multiple perspectives to have a full view of machine learning.

  我们应该从多个视点来观察，使之对机器学习有一个完整的把握。

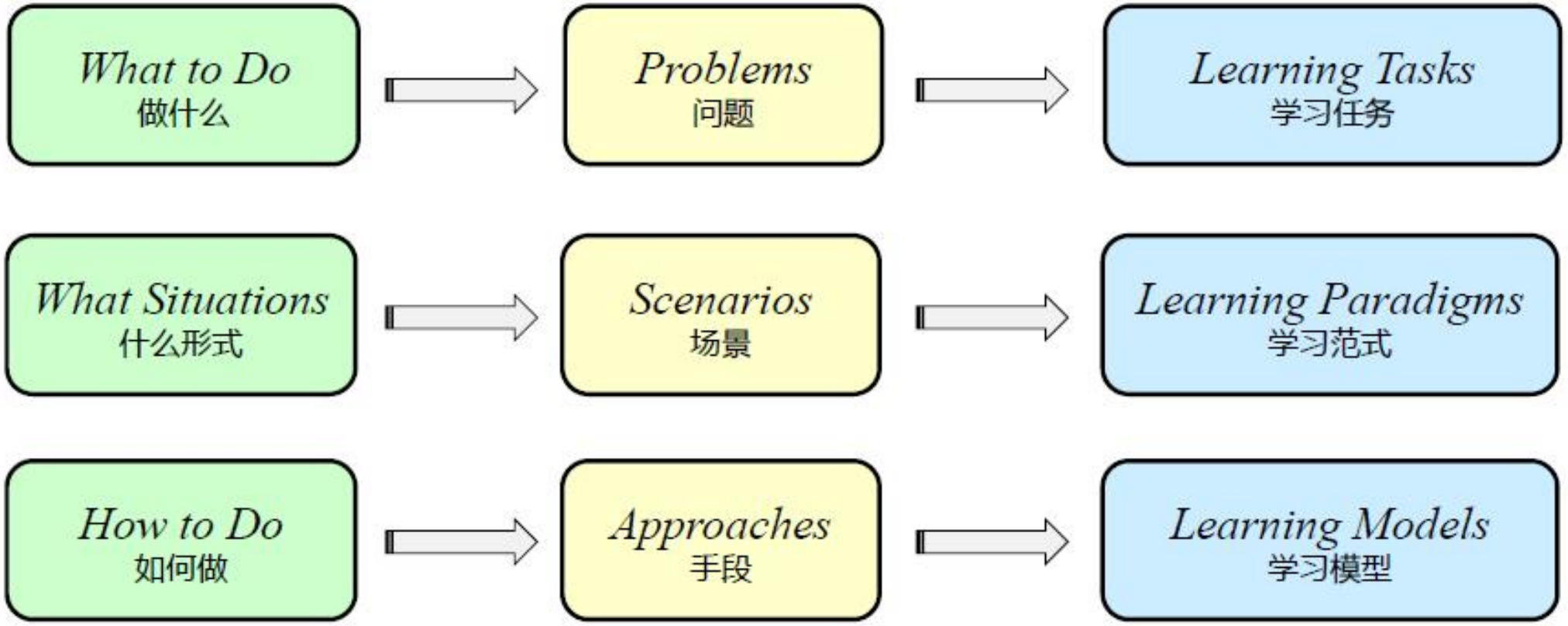
# How Machine Learning Works 机器学习如何工作

- It uses experience or interacts with environment to improve performance, or makes accurate predictions.

使用经验或与环境交互来改善性能，或做出精确预测。



# Why Three Perspectives 为什么有三个视点



# Definition of the Three Perspectives 三个视点的定义

| Types 类型 | Description 描述 |
| --- | --- |
| Learning Tasks<br>学习任务 | Denoting the general **problems** that can be solved by machine learning.<br>表示可以用机器学习解决的基本**问题**。 |
| Learning Paradigms<br>学习范式 | Denoting the **typical scenarios** that are happened in machine learning.<br>表示机器学习中发生的**典型场景**。 |
| Learning Models<br>学习模型 | Denoting the **approaches** that can handle to fulfil a learning task.<br>表示可以处理完成一个学习任务的**方法**。 |

# Perspective 1：Learning Task 学习任务

## What are Learning Tasks 什么是学习任务

- The learning tasks are used to denote the general problems that can be solved by learning with desired output.

  学习任务用于表示可以用机器学习解决的基本问题。

## Why Study Learning Tasks 为什么要研究学习任务

- Various types of problems arising in applications:

  应用中会产生各种类型的问题：

  - computer vision，计算机视觉，
  - pattern recognition，模式识别，
  - natural language processing, etc. 自然语言处理， 等等。

# Typical Tasks in Machine Learning 机器学习中的典型任务

| Tasks<br>任务 | Brief Statements<br>简短描述 | Typical algorithm<br>典型算法 |
|---|---|---|
| Classification<br>分类 | Inputs are divided into two or more known classes.<br>将输入划分成两个或多个类别。 | SVM<br>支撑向量机 |
| Regression<br>回归 | Outputs are continuous values rather than discrete ones.<br>输出是连续值而不是离散的。 | Bayesian linear regression<br>贝叶斯线性回归 |
| Clustering<br>聚类 | Inputs are divided into groups which are not known beforehand.<br>输入被划分为若干个事先未知的组。 | *k*-means<br>*k*-均值 |
| Ranking<br>排名 | Data transformation in which values are replaced by their rank.<br>用它们的排名来代替值的数据转换。 | PageRank<br>网页排名 |
| Density estimation<br>密度估计 | Find the distribution of inputs in some space.<br>寻找某个空间中输入的分布。 | Boosting Density Estimation<br>增强式密度估计 |
| Dimensionality reduction<br>降维 | Simplify inputs by mapping them into a lower dimensional space.<br>通过将输入映射到低维空间来将其简化。 | Isomap<br>等距特征映射 |
| Optimization<br>优化 | Find the best solution from all feasible solutions<br>从所有可能的解中寻找最优解。 | Q-learning<br>Q-学习 |

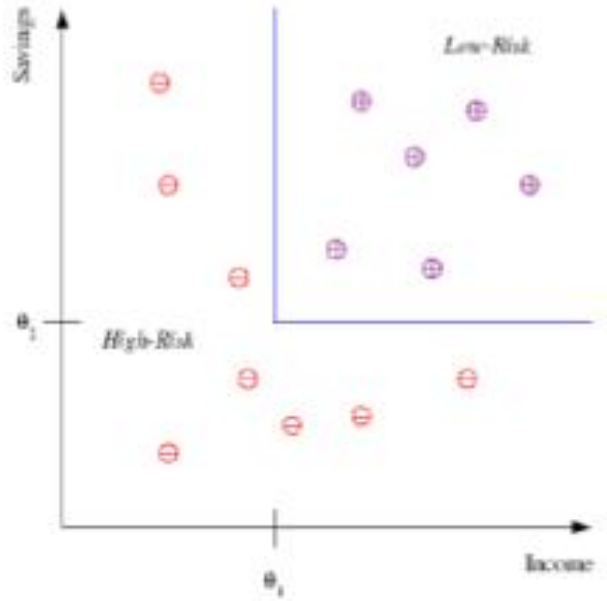
# *Case study*: Credit scoring 信用评分

- Two classes: Low-risk and high-risk customers.
  二分类：低风险和高风险客户。
- A customer information makes up the input to one of the two classes.
  客户信息使该输入构成二分类中的一个。
- After training with past data, a classification rule learned may be:
  用过去的数据训练之后，可以学习得到如下分类规则:

IF *income*> $\theta_1$ AND *savings*> $\theta_2$

THEN *low-risk*

ELSE *high-risk*



# Perspective 2: Learning Paradigms 学习范式

## What are Learning Paradigms 什么是学习范式

- The learning paradigms are used to denote the typical scenarios that are happened in machine learning.

  学习范式用于表示机器学习中发生的**典型场景**。

## How to Distinguish Learning Paradigms 怎样区分学习范式

- by the scenarios or styles in machine learning about

  根据机器学习的**典型场景或样式**:

  - how it learns from data,

    它怎样从数据中学习,

  - how it interactives with environment.

    它如何同环境互动。

# Typical Paradigms in Machine Learning 机器学习中的典型范式

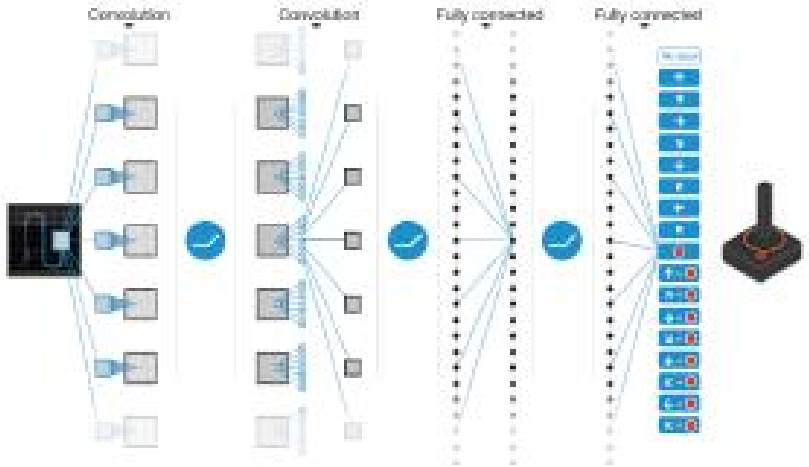
| Paradigms<br>范式 | Brief Statements<br>简短描述 | Typical Algorithm<br>典型算法 |
|---|---|---|
| Supervised<br>有监督 | The algorithm is trained by a set of labeled data, and makes predictions for all unseen points.<br>算法采用一组标注好的数据进行训练，再对所有的未知点做出预测。 | Support vector machines<br>支撑向量机 |
| Unsupervised<br>无监督 | The algorithm exclusively receives unlabeled data, and makes predictions for all unseen points.<br>算法仅接收未标注的数据，再对所有的未知点做出预测。 | $k$-means<br>$k$-均值 |
| Reinforcement<br>强化 | The algorithm interacts with environment, and receives an reward for each action.<br>算法与外部环境交互，每个动作得到一个回报。 | Q-learning<br>Q-学习 |

# *Case Study*: Deep Reinforcement Learning 深度强化学习

- Reinforcement Learning **强化学习**

  learning from state and reward, take better action to the environment.

  从状态和回报中学习，对环境采取更好的动作。

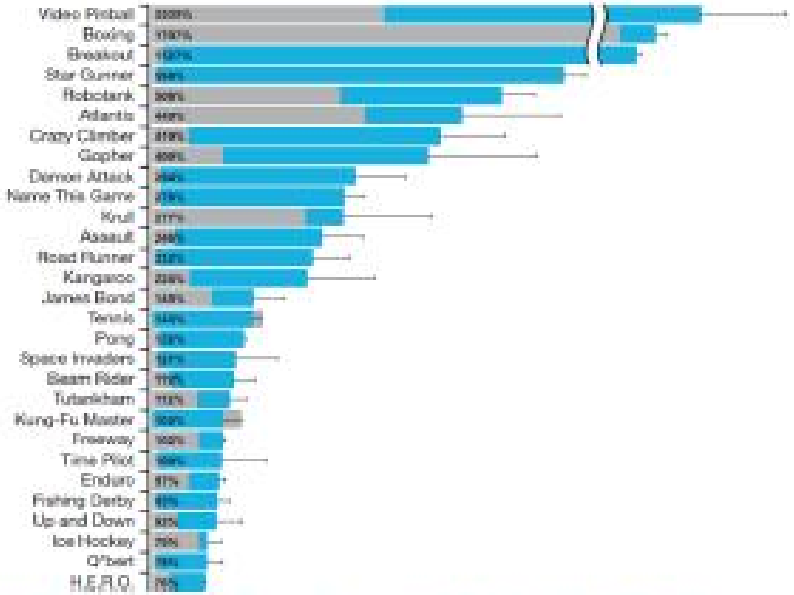

- Deep Q-network (DQN) 深度Q-网络 (DQN)
  - combines CNN with Q-learning (a form of reinforcement learning),
    将CNN与Q-学习（一种强化学习的形式）相结合.
  - input is raw pixels and output is a value function estimating rewards.
    输入是原始像素，输出是估计回报的价值函数。

# *Case Study*: Deep Reinforcement Learning 深度强化学习

- Feb. 2015, Google DeepMind published Deep Q-Network, the human-level control through deep reinforcement learning.

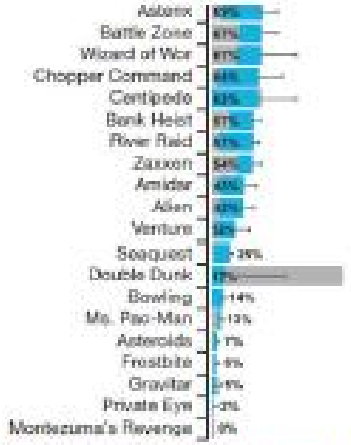
  2015年2月，谷歌DeepMind发表了**深度Q-网络**，通过深度强化学习达到人类水平的操控。

Tested on classic Atari video games (late-1970s and early-1980s)




At human-level or above (29/49 ≈ 59.18%)

*Source: NATURE, Feb. 2015*




Below human-level (20/49 ≈ 40.82%)

# Perspective 3：Learning Models 学习模型

## What are Learning Models 什么是学习模型

- The learning paradigms are used to denote the typical scenarios that are happened in machine learning.

  学习范式用于表示机器学习中发生的典型场景 。

## Why Study Learning Models 为什么要研究学习模型

- The result of machine learning is heavily dependent on the choice of an approach for solving the learning task.

  机器学习的效果在很大程度上取决于解决该学习任务时所选用的方法。

# Typical Models for Machine Learning 机器学习的代表性模型

| Models 模型 | Brief Statements 简短描述 | Sub-models 子模型 | Typical Algorithm 典型算法 |
|---|---|---|---|
| Geometric 几何 | Use geometric models such as line, plane, distance or manifold to construct learning algorithms. 采用线、面、距离或流行等几何图形模型来构建学习算法。 | Line 线 | Linear Regression 线性回归 |
| | | Plane 面 | SVM 支撑向量机 |
| | | Distance 距离 | *k*-NN *k*-近邻 |
| | | Manifold 流形 | Isomap 等距映射 |
| Logical 逻辑 | Use logical models to construct learning algorithms. 采用逻辑模型来构建学习算法。 | Logic 逻辑 | Inductive Logic Program. 归纳逻辑编程 |
| | | Rule 规则 | Association Rule 相关规则 |
| Networked 网络 | Use networked models to construct learning algorithms. 采用网络模式构建机器学习算法。 | Shallow 浅层 | Perceptron 感知机 |
| | | Deep 深层 | CNN 卷积神经网络 |
| Probabilistic 概率 | Use probabilistic models to denote the conditional dependence between random variables. 采用概率模式来表示随机变量之间的条件相关性。 | Bayes 贝叶斯 | Bayesian Network 贝叶斯网络 |
| | | Generative 生成 | Probabilistic Program. 概率规划 |
| | | Statistic 统计 | Linear Regression 线性回归 |

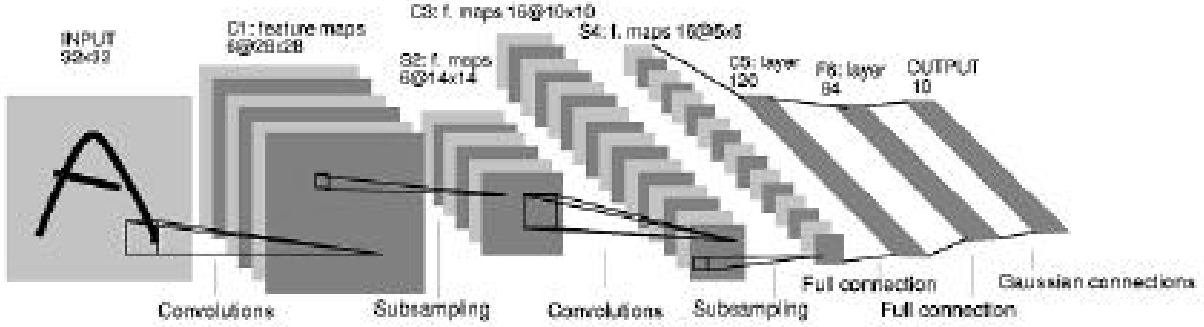
# *Case Study*: Convolutional neural network (CNN) 卷积神经网络

- CNN can be designed to recognize visual patterns directly from pixel images with minimal preprocessing.

  CNN可以设计为用最少的预处理来直接从像素图像中识别视觉模式。

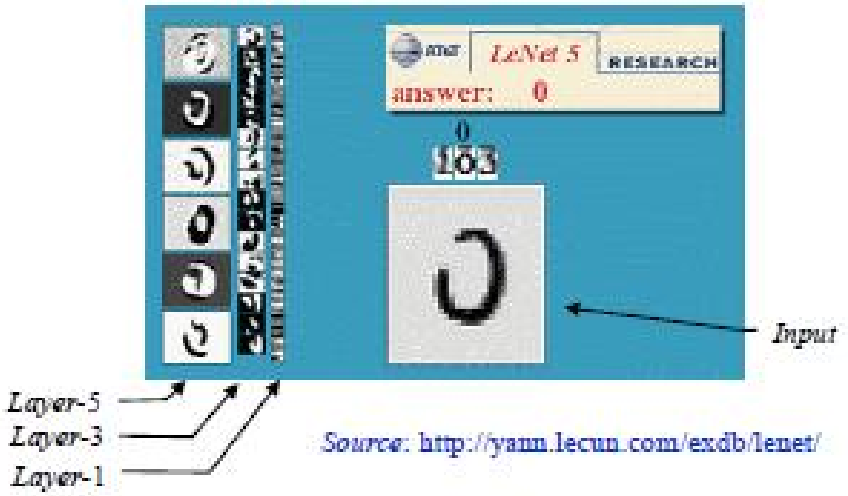
- CNN can recognize patterns with extreme variability, and with robustness to distortions and simple geometric transformations.

  CNN可以识别一些特殊情况的模式，如手写字符识别，对扭曲的以及几何形变的手写字符具有很强的鲁棒性。




LeNet-5, a pioneering 7-level convolutional neural network

LeNet-5, 一种开创性的7层卷积神经网络




MNIST Demos on Yann LeCun's website http://yann.lecun.com/exdb/lene

# Yann LeCun and Rene Descartes 雅恩·乐库与雷内·笛卡尔

Yann LeCun (1960-Current)

Rene Descartes (1596-1650)

- Yann LeCun (born near Paris, France, in 1960) 雅恩·乐库（1960年生于法国附近）
  - One of the fathers of Deep Learning, a founding father of CNN.
    深度学习的奠基人之一，CNN的创始人。
  - Professor at NYU, Director of AI Research at Facebook.
    美国纽约大学教授、Facebook人工智能实验室主任。
  - 2014 IEEE Neural Network Pioneer Award.
    2014年获得IEEE神经网络先锋奖。
  - Thought as a modern day Descartes.
    被认为是当代的笛卡尔。

# Application Fields of Machine Learning 机器学习的应用领域

- Machine Perception 机器感知
- Computer Vision 计算机视觉
- Video Analysis 视频分析
- Pattern Recognition 模式识别
  - Face/Speech/Fingerprint Recognition 人脸/语音/指纹识别
  - Optical Character Recognition (OCR) 光学字符识别 (OCR)
  - Handwriting Recognition 手写体识别
- Game Playing 玩游戏
- Natural Language Processing 自然语言处理
- Information Retrieval 信息检索

# Application Fields of Machine Learning 机器学习的应用领域

- Text or Document Classification (e.g. Spam Email Detection) 文本与文档分类（例如垃圾邮件检测）
- Recommender Systems 推荐系统
- Ad Placement 广告配置
- Credit Scoring 信用评分
- Fraud Detection 欺诈检测
- Stock Trading 股票交易
- Drug Design 新药设计
- Medical Diagnosis 医学诊断
- Robotics 机器人学

# Some Terminologies in Machine Learning 机器学习中的一些术语

## ☐ Samples 样本

- Items or instances of data used for learning or evaluation.
  用于学习或评估的数据项或实例。

## ☐ Features 特征

- The set of attributes, often represented as a vector associated to a sample:
  属性集，通常表示为与样本相关的向量：
  - Handcrafted features: 手工式特征
    e.g., SIFT, HOG, SURF, LBP, GLOH, LESH, CENTRIST.
    例如，SIFT、HOG、SURF、LBP、GLOH、LESH、CENTRIST。
  - Learned features: 学习式特征
    e.g., by convolutional neural network.
    例如，通过卷积神经网络。

# Some Terminologies in Machine Learning 机器学习中的一些术语

## ☐ Labels 标记

- Values or categories assigned to samples.
  在样本上指定的值或类别。
- In classification problems, samples are assigned specific categories.
  分类问题中，样本被指定特定的类别。
- In regression problems, items are assigned real-valued labels.
  回归问题中，项被指定为实值的标记。

## ☐ Training sample 训练样本

- Samples used for training learning algorithm.
  用于训练学习算法的样本。
- In spam problem, the training sample consist of a set of email samples along with their associated labels.
  对于垃圾邮件问题，训练样本由一组邮件样本以及相关标签组成。

# Some Terminologies in Machine Learning 机器学习中的一些术语

- **Validation sample 验证样本**
  - Samples used to tune the parameters of a learning algorithm when working with labeled data.
    用于在使用标记数据时调整学习算法参数的样本。
  - Learning algorithms typically have one or more free parameters, and validation sample is used to select appropriate values for these model parameters.
    学习算法通常具有一个或多个自由参数，因而验证样本用于为这些模型参数选择适当的值。
- **Test sample 测试样本**
  - Samples used to evaluate the performance of a learning algorithm.
    用于评估学习算法性能的样本。
  - These predictions are then compared with the labels of the test sample to measure the performance of the algorithm.
    然后将这些预测与测试样本的标签进行比较，以衡量算法的性能。

# Some Terminologies in Machine Learning 机器学习中的一些术语

## Loss function 损失函数

- To measure the difference, or loss, between a predicted label and a true label.
  用于度量预测标签和真实标签之间差异或损失。
- Denoting the set of all labels as Y and the set of possible predictions as Y', a loss function $L$ is a mapping:
  将所有的标签集表示为Y、并且可能的预测集为Y'，则损失函数$L$为映射：

$$L: Y \times Y' \rightarrow \mathbb{R}_+$$

## Hypothesis set 假设集

- A set of functions mapping features to the set of labels Y.
  将特征映射为标签Y的函数集。
- For example, the following are a set of functions mapping email features to:
  例如，映射电子邮件特征的函数集如下：

$$Y = \{spam, non-spam\}.$$

# Some Terminologies in Machine Learning 机器学习中的一些术语

- **Abstraction 抽象**
  - It involves the translation of data into broader representations.
    其含义是将数据转化为更广泛的表示。
- **Generalization 泛化**
  - It describes the process of turning abstracted knowledge into a form that can be utilized for action. It is also the ability of a learning algorithm to perform accurately on unseen samples after having experienced a learning data set.
    它形容将抽象知识转化为可用于动作形式的过程。它也是学习算法具有学习数据集的经验后，可以对未知样本正确地进行处理的能力。

- Machine learning is to study some algorithms that can learn from and make predictions on data.
  机器学习是研究一些可以从数据中学习、并对数据进行预测的算法。
- The different perspectives are aimed to try to have a taxonomy on the algorithms of machine learning, for being easy to understand machine learning.
  几个不同视角旨在尝试对机器学习的算法进行分类，以便于理解机器学习。
- Three perspectives on machine learning are proposed in this chapter, those are learning tasks, learning paradigms and learning models.
  本章提出了机器学习的三个视角，他们是：学习任务、学习范例以及学习模型。