

# Machine Learning

## Introduction

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- ① What is Machine learning?**
- ② When do we use Machine learning**
- ③ Types of learning**
- ④ Components of every ML application**
- ⑤ Machine learning process**

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- ① **What is Machine Learning?**
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- ⑤ **Machine Learning process**

# What is Machine Learning?

## What is Machine Learning?

# What is Machine Learning?

## What is Machine Learning?

*Machine Learning is any process by which a system improves performance in a task from experience*

(Herbert Simon)

A well defined learning task is given by  $\langle T, E, P \rangle$ :

- A task  $T$
- A set of data examples (experience)  $E$
- A function to measure improvement  $P$

# Traditional programming vs Machine Learning

## Traditional programming

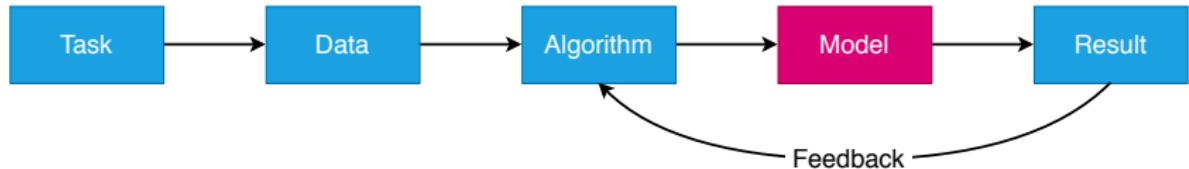


# Traditional programming vs Machine Learning

## Traditional programming



## Machine Learning



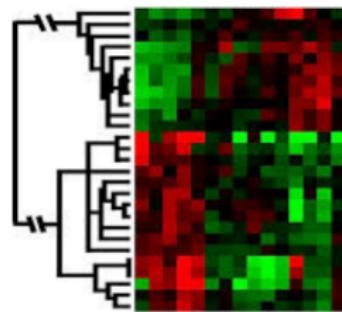
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# When do we use Machine Learning?

## Tasks involving Big Data

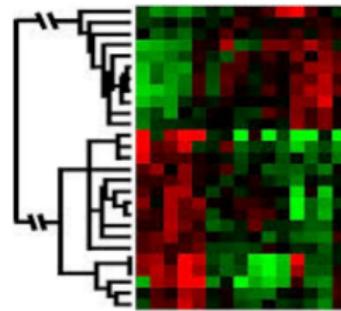
- Genomics
- Internet search
- Anomaly detection



# When do we use Machine Learning?

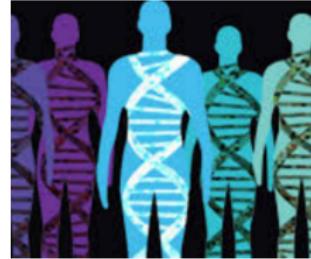
## Tasks involving Big Data

- Genomics
- Internet search
- Anomaly detection



## Tasks requiring customization

- Email filters
- Personalized medicine
- Movie recommendation



# When do we use Machine Learning?

**Tasks for which it is challenging  
to specify our knowledge**

- Facial recognition
- Speech recognition
- Medical diagnosis



# When do we use Machine Learning?

## Tasks for which it is challenging to specify our knowledge

- Facial recognition
- Speech recognition
- Medical diagnosis



## Tasks which we don't have human expertise

- Space exploration
- Undersea manipulation
- House price estimation



# When we don't use it

## Tasks with lack of data / good data

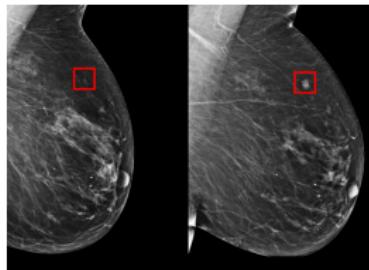
- Lack of mammography data from black women

## Tasks for which a simpler solution may suffice

- Estimate taxes

## Tasks with ethical considerations

- Uyghur facial recognition for persecution



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# Types of learning

## Supervised learning

- Training data + desired outputs (labels)

## Unsupervised learning

- Training data (without labels)

## Semi-supervised learning

- Training data + some labels

## Reinforcement learning

- Observations and periodic rewards as the agent takes sequential action in an environment

# Supervised learning

	$X_1$	$\dots$	$X_n$	$Y$
$(\mathbf{x}^{(1)}, y^{(1)})$	$x_1^{(1)}$	$\dots$	$x_n^{(1)}$	$y^{(1)}$
$(\mathbf{x}^{(2)}, y^{(2)})$	$x_1^{(2)}$	$\dots$	$x_n^{(2)}$	$y^{(2)}$
$\dots$	$\dots$	$\dots$	$\dots$	$\dots$
$(\mathbf{x}^{(m)}, y^{(m)})$	$x_1^{(m)}$	$\dots$	$x_n^{(m)}$	$y^{(m)}$

## Regression

- $X_i$  is continuous
- $Y$  is continuous

## Classification

- $X_i$  is discrete/continuous
- $Y$  is discrete

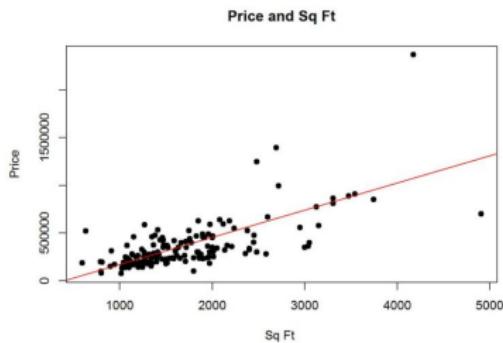
# Supervised learning: Regression



**How much money should we ask for it?**

# Supervised learning: Regression

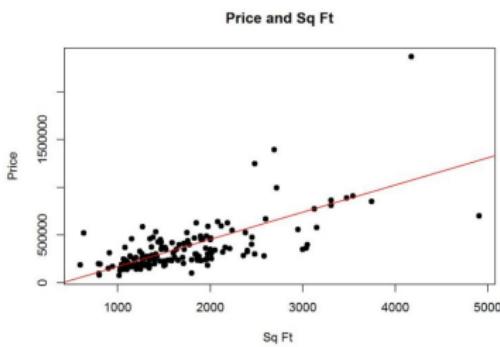
- Given  $(\mathbf{x}^{(1)}, y^{(1)})$  learn a function  $f(\mathbf{x})$  to predict  $y$  given  $\mathbf{x}$
- $y$  is continuous



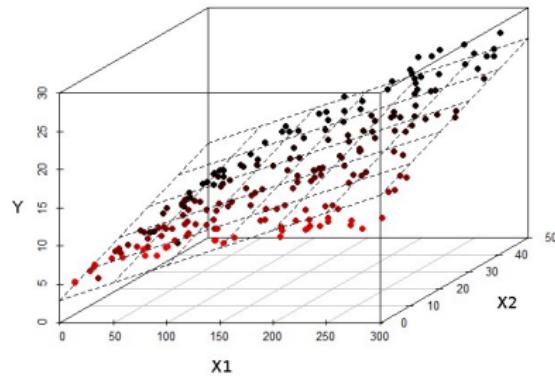
One-dimensional

# Supervised learning: Regression

- Given  $(\mathbf{x}^{(1)}, y^{(1)})$  learn a function  $f(\mathbf{x})$  to predict  $y$  given  $\mathbf{x}$
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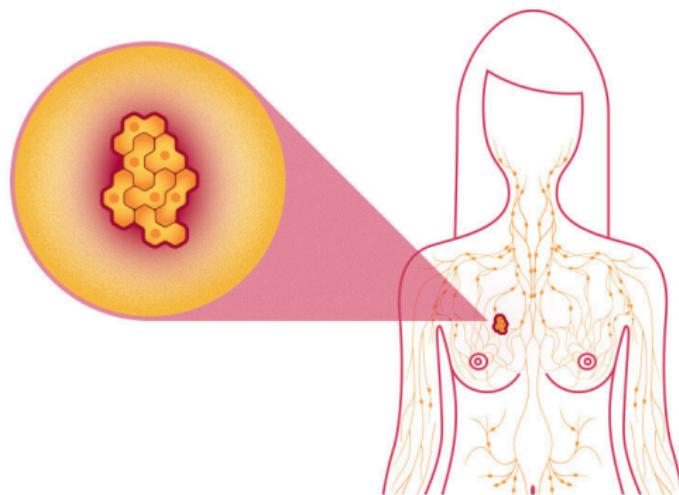


One-dimensional



Multi-dimensional

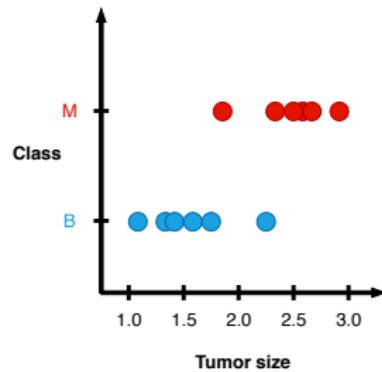
# Supervised learning: Classification



**Predict if a tumor is malignant**

# Supervised learning: Classification

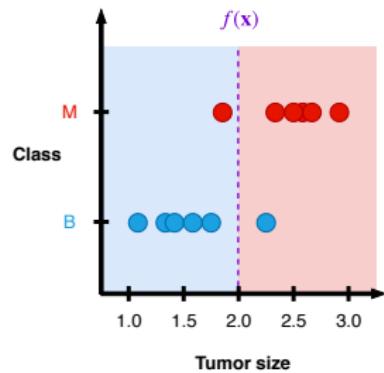
- Given  $(\mathbf{x}^{(1)}, y^{(1)})$  learn a function  $f(\mathbf{x})$  to predict  $y$  given  $\mathbf{x}$
- $y$  is discrete



One-dimensional

# Supervised learning: Classification

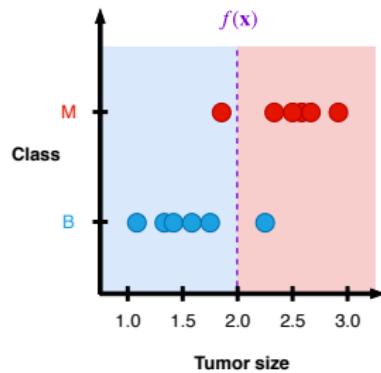
- Given  $(\mathbf{x}^{(1)}, y^{(1)})$  learn a function  $f(\mathbf{x})$  to predict  $y$  given  $\mathbf{x}$
- $y$  is discrete



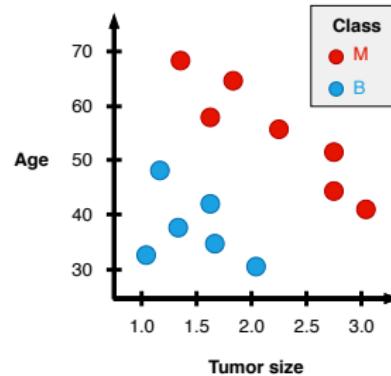
One-dimensional

# Supervised learning: Classification

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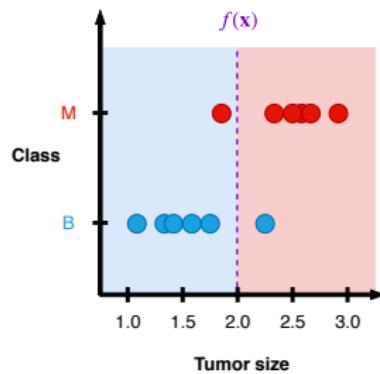
One-dimensional



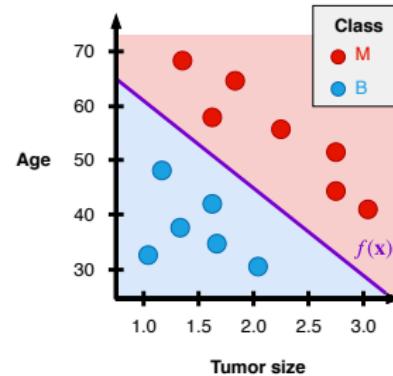
Multi-dimensional

# Supervised learning: Classification

- Given  $(\mathbf{x}^{(1)}, y^{(1)})$  learn a function  $f(\mathbf{x})$  to predict  $y$  given  $\mathbf{x}$
- $y$  is discrete



One-dimensional



Multi-dimensional

# Unsupervised learning

	$X_1$	$\dots$	$X_m$	$Y$
$(\mathbf{x}^{(1)}, y^{(1)})$	$x_1^{(1)}$	$\dots$	$x_n^{(1)}$	?
$(\mathbf{x}^{(2)}, y^{(2)})$	$x_1^{(2)}$	$\dots$	$x_n^{(2)}$	?
$\dots$	$\dots$	$\dots$	$\dots$	$\dots$
$(\mathbf{x}^{(m)}, y^{(m)})$	$x_1^{(m)}$	$\dots$	$x_n^{(m)}$	?

## Clustering

- $X_i$  is discrete/continuous
- $Y$  is discrete

# Unsupervised learning

	$X_1$	$\dots$	$X_m$	$Y$
$(\mathbf{x}^{(1)}, ?)$	$x_1^{(1)}$	$\dots$	$x_n^{(1)}$	?
$(\mathbf{x}^{(2)}, ?)$	$x_1^{(2)}$	$\dots$	$x_n^{(2)}$	?
$\dots$	$\dots$	$\dots$	$\dots$	$\dots$
$(\mathbf{x}^{(m)}, ?)$	$x_1^{(m)}$	$\dots$	$x_n^{(m)}$	?

## Clustering

- $X_i$  is discrete/continuous
- $Y$  is discrete

## Dimensionality reduction

- $X_i$  is continuous
- $Y_1 \dots Y_K$  is continuous

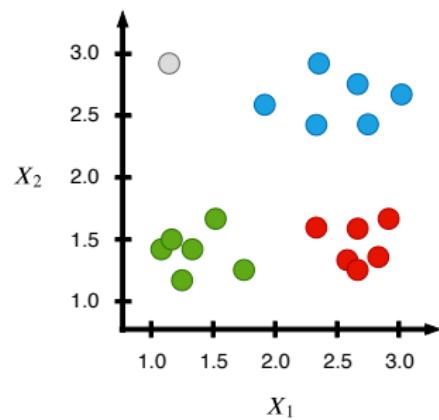
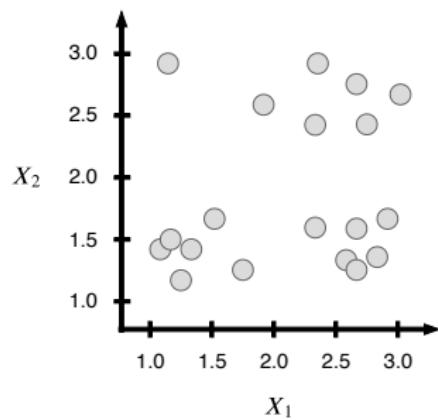
# Unsupervised learning: Clustering



**How many groups of customers?**

# Unsupervised learning: Clustering

- Given a set of instances  $\mathbf{x}^{(1)}, \mathbf{x}^{(2)}, \dots, \mathbf{x}^{(m)}$  (no labels)
- Output the **hidden** structure behind data



# Reinforcement learning



**How can we teach a machine to play Go?**

# Reinforcement learning

Why not simply use **supervised learning**?

We need a dataset with millions of games where

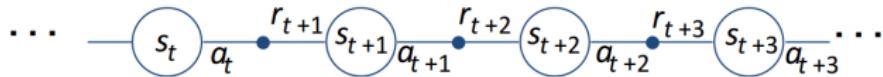
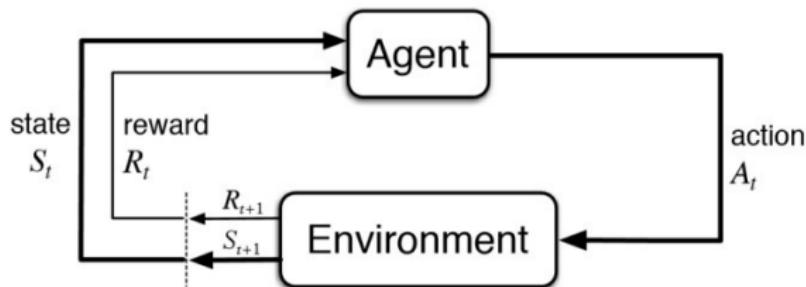
- Each possible game state is a row
- The class we want to predict is a sequence of optimal moves

## Problems

- Datasets like this don't exist for all domains we care about
- Creating such dataset could be expensive and infeasible
- Difficult to learn such a pattern (how many class labels?)
- It would only **imitate** instead of actually learn **the best strategy**

# Reinforcement learning

- A policy is produced from a sequence of states  $\mathbf{S}$  and actions  $\mathbf{A}$ , where each step  $\{S_t, A_t\}$  has an associated reward  $R_t$
- Discrete time with Markov property



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# Components of every ML application

*Learning is equivalent to searching (**optimization**) through the space of potential models (**representation**) to find the one that best performs (**evaluation**) with the training data*

## Representation

- How is data specified?
- What is the form of the model?

## Optimization

- How is the model trained on the data?

## Evaluation

- How are we assessing the model's performance?

# Representation

Numerical functions	Symbolic functions	Instance-based functions	Probabilistic Graphical Models
Linear regression Linear discriminant analysis Neural network	Decision tree Propositional logic rules First-order logic rules	Nearest-neighbor Case-based	Naïve Bayes Bayesian network HMM Markov network

# Optimization and search techniques

- Gradient descent
- Expectation-Maximization
- Maximum likelihood estimation
- Dynamic programming
- Divide and Conquer
- Evolutionary Computation
- etc.

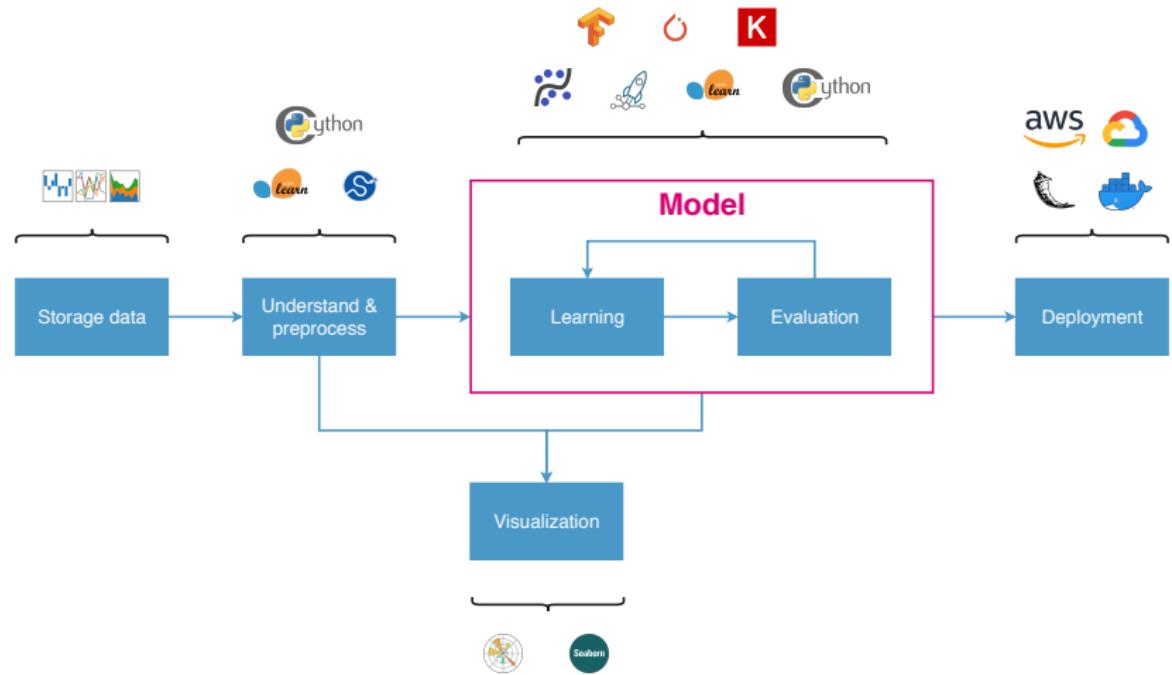
# Evaluation

- Squared error
- Likelihood
- Posterior probability
- Information gain
- Accuracy
- Precision/recall
- etc.

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# Machine Learning Process



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