Introduction to Machine Learning

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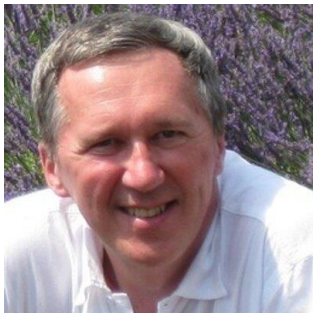
The Concept of Machine Learning

What is Machine Learning?

Arthur Samuel (1959)

- A field of study that **lets computers have the ability to learn** by themselves **without being explicitly programmed**.

Tom Mitchell (1998)



- A computer program 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.
- Short version: A study of computer algorithms that allow **computer program to automatically improve through experience**.

https://www.youtube.com/watch?v=f_uwKZIAeM0&spfreload=10

Example: Predicting Exam Scores

- Given a set of time-score pairs, predict an exam score.

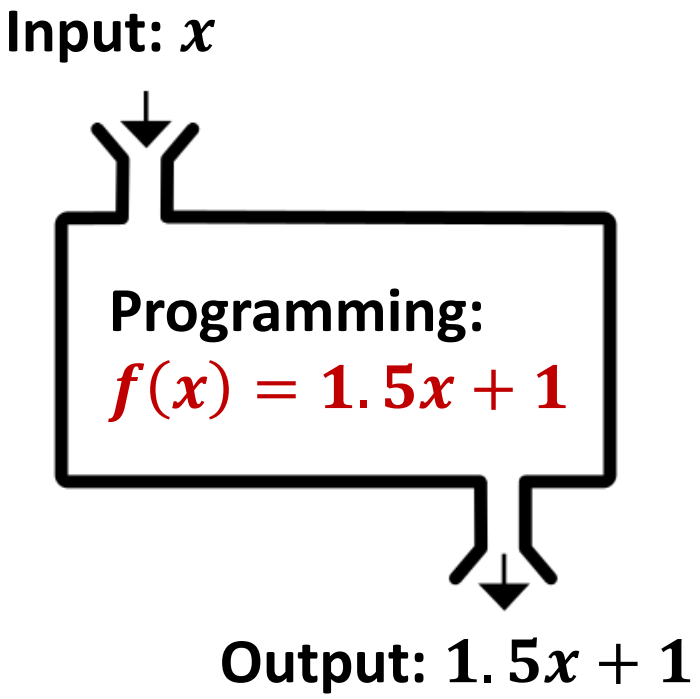
Time	*Score*
0	1
1	2
2	4
3	5
4	7
6	**???**

$$Score = f(Time) = w * Time + b$$

Conventional vs. Machine Learning

- A human explicitly finds a hidden pattern from a dataset and makes a program to implement the pattern.

X	Y
0	1
1	2
2	4
3	5
4	7

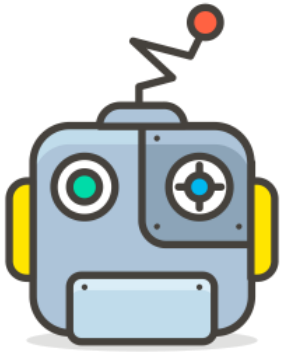


Conventional vs. Machine Learning

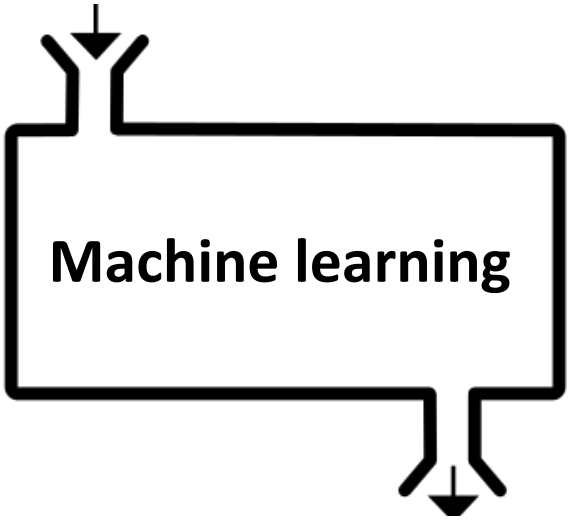
- **Computers automatically learn the hidden pattern from data without being explicitly programmed.**

X	Y
0	1
1	2
2	4
3	5
4	7

$$y = f(x) = w * x + b$$

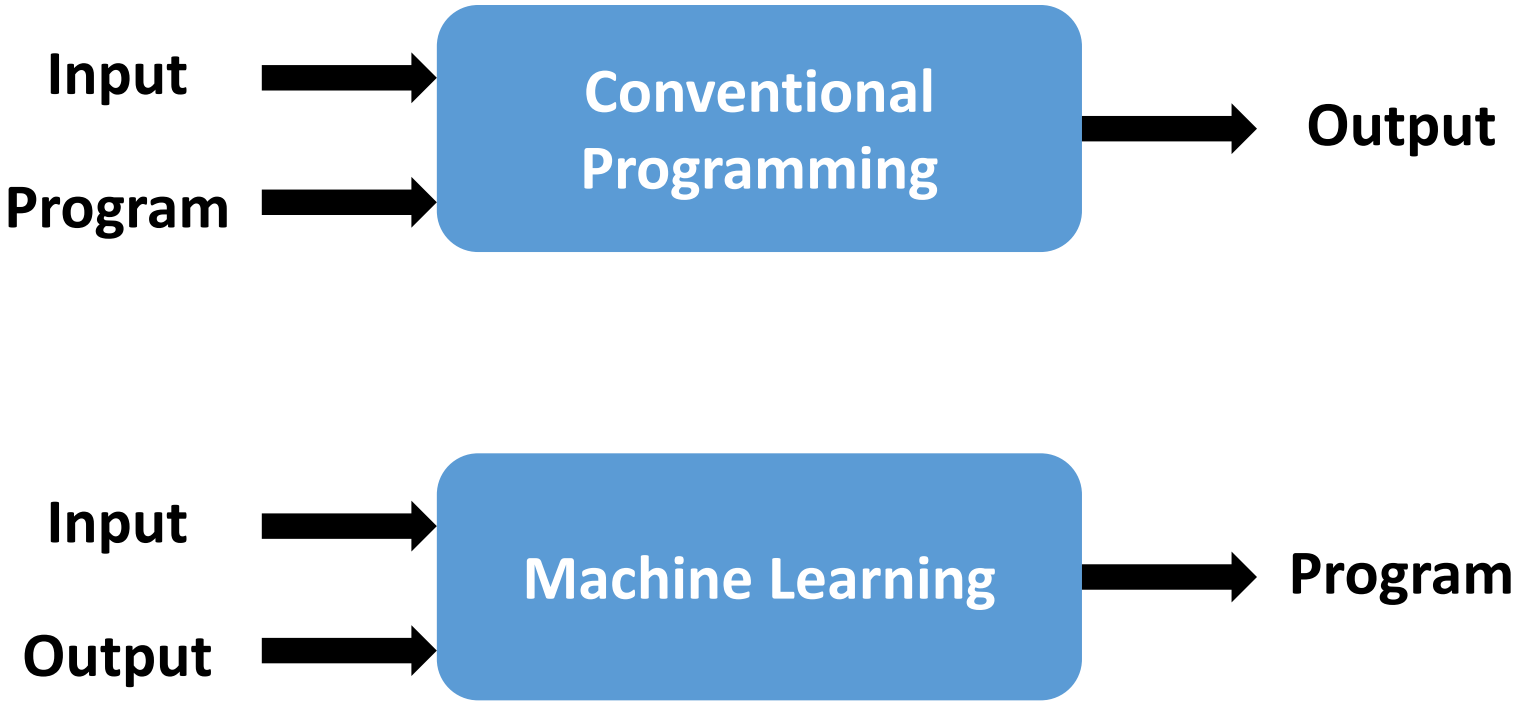


(0, 1), (1, 2), (2, 4), …



$$f(x) = 1.5x + 0.8$$

Conventional vs. Machine Learning



Types of Machine Learning

	With Teacher	Without Teacher
Direct feedback	Supervised Learning	Unsupervised Learning
Indirect feedback	Reinforcement Learning	

Types of Machine Learning

- **Consider observing a set of input data $X = \{\mathbf{x}^1, \mathbf{x}^2, \dots, \mathbf{x}^n\}$**
  - **Supervised Learning**
    - We are also given **target outputs** (**labels**, **responses**): $\boldsymbol{y^1}, \boldsymbol{y^2}, \dots, \boldsymbol{y^n}$
    - The goal is to **predict correct output given a new input**.
  - **Unsupervised Learning**
    - We only have a set of input data $\boldsymbol{X}$.
    - The goal is to **discover hidden representation of data**.
  - **Reinforcement Learning**
    - Given a **state** $\boldsymbol{s} \in \boldsymbol{S}$, the model (agent) produces a set of **actions**, $\boldsymbol{a_1}, \boldsymbol{a_2}, \dots, \boldsymbol{a_k}$ that affect the next state $\boldsymbol{s'} \in \boldsymbol{S}$ and **rewards** $\boldsymbol{r_1}, \boldsymbol{r_2}, \dots, \boldsymbol{r_k}$.
    - The goal is to **learn actions in an environment to maximize cumulative rewards**.
  - **Semi-supervised Learning**
    - Only a limited amount of labels, and lots of unlabeled data.

Types of Machine Learning

- **Supervised Learning (icing)**
  - Predict label $\boldsymbol{y}$ corresponding to observation $\mathbf{x}$

$$\boldsymbol{y} = f(\mathbf{x})$$

- **Unsupervised Learning (cake)**
  - Estimate the distribution of observation $\mathbf{x}$

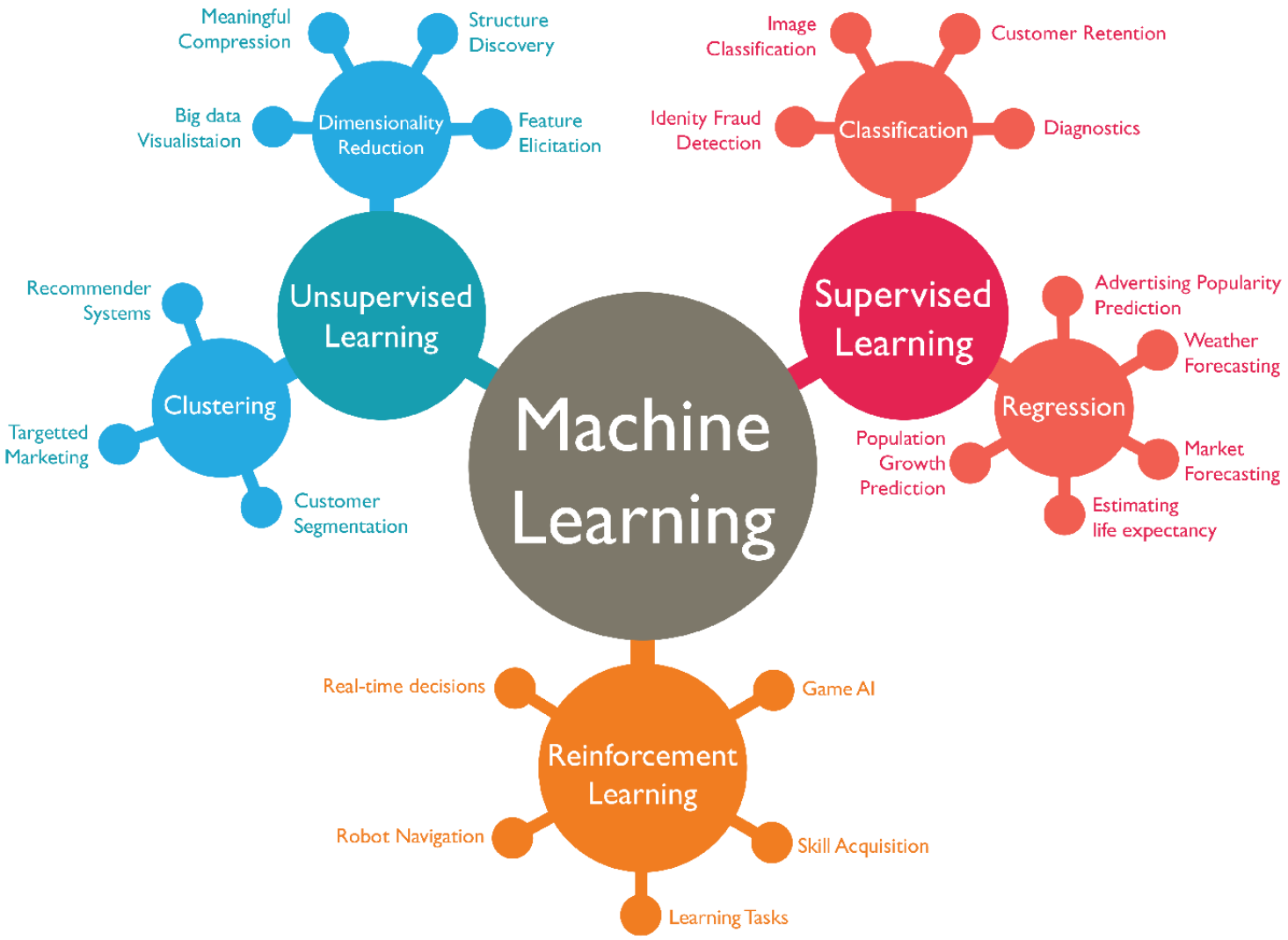
$$f(\mathbf{x})$$

- **"Pure" Reinforcement Learning (cherry)**
  - Predict action $\boldsymbol{y}$ based on observation $\mathbf{x}$ to maximize a future reward $\boldsymbol{r}$.

$$\boldsymbol{y} = f(\mathbf{x}) \text{ that maximizes } \boldsymbol{r}$$

Yann LeCun's Cake Analogy

Types of Machine Learning

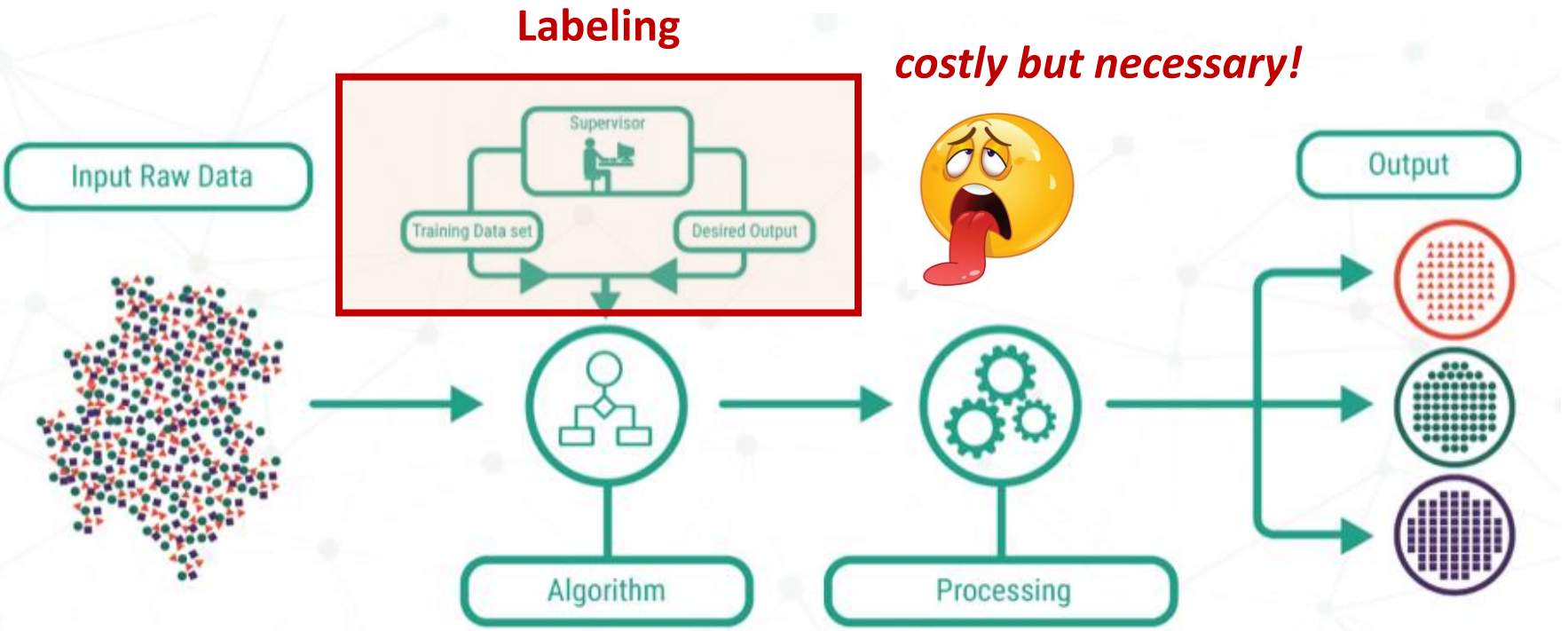


https://towardsdatascience.com/machine-learning-algorithms-in-laymans-terms-part-1-d0368d769a7b

Supervised Learning

What is Supervised Learning?

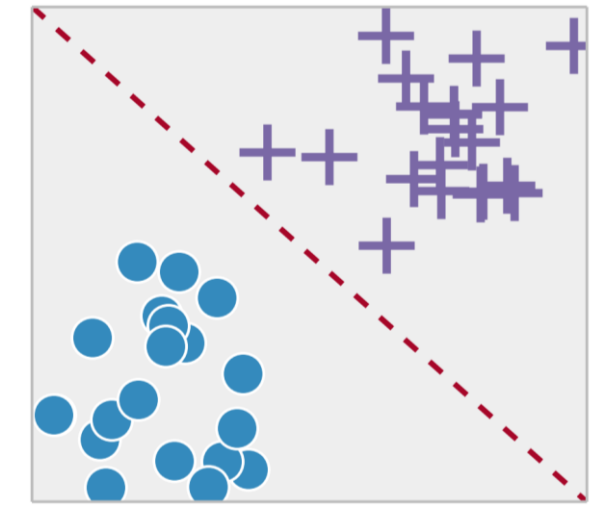
- **Data consist of input-output pairs.**
  - **Input**: covariates, predictors, and features
  - **Output**: variates, targets, labels
- **Let computers learn with many (input, output) pairs.**

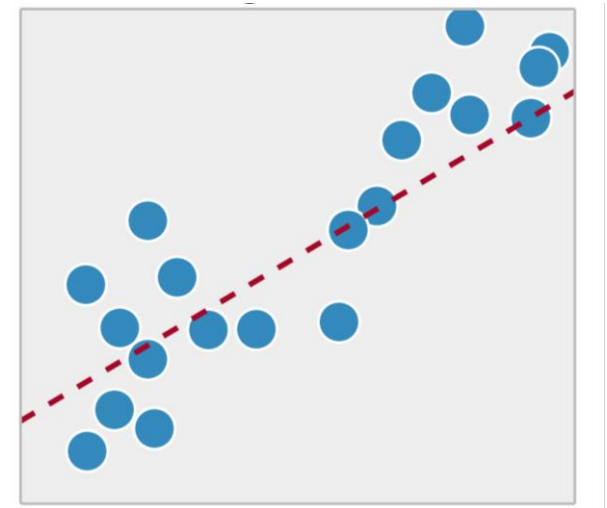


What is Supervised Learning?

- **Let computers learn with many (input, output) pairs.**
  - The output are **direct feedback** for given input.

- **Regression vs. Classification**
  - **Regression**: Labels are **continuous**.
  - **Classification**: Labels are **discrete**.

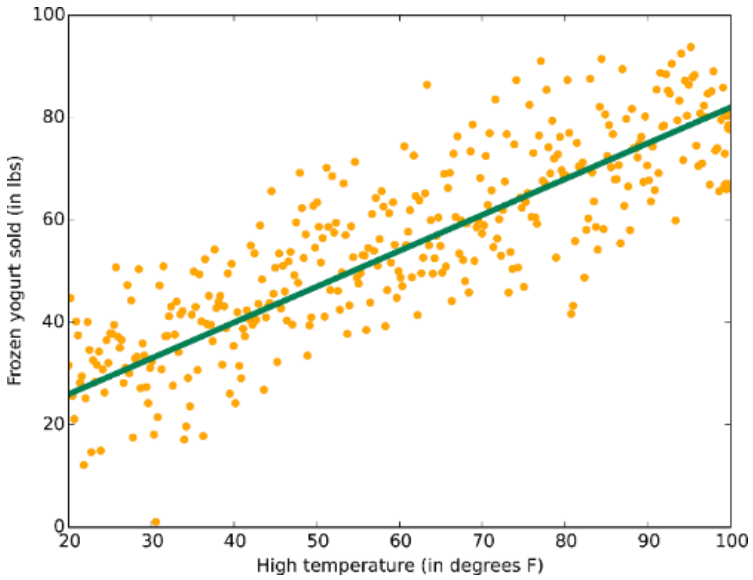


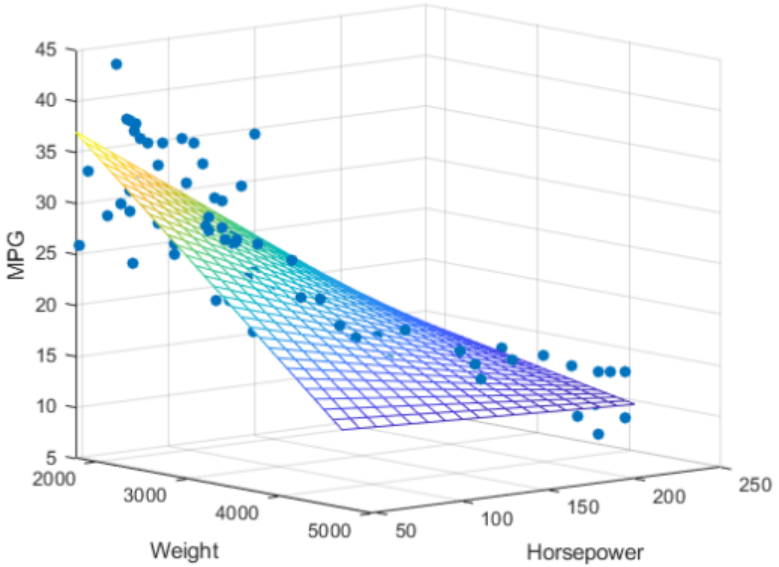


Supervised Learning: Regression

- **Predicting real values (i.e., continuous labels)**

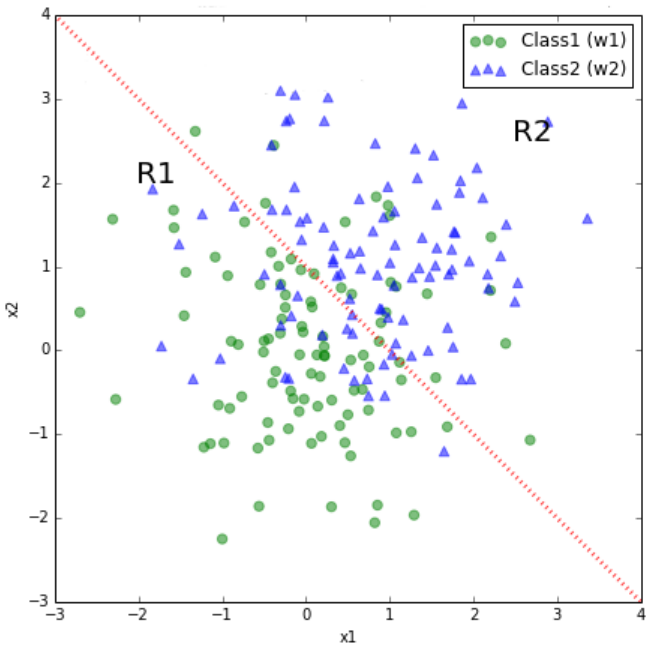
- **Examples**
  - Linear regression
  - Polynomial regression

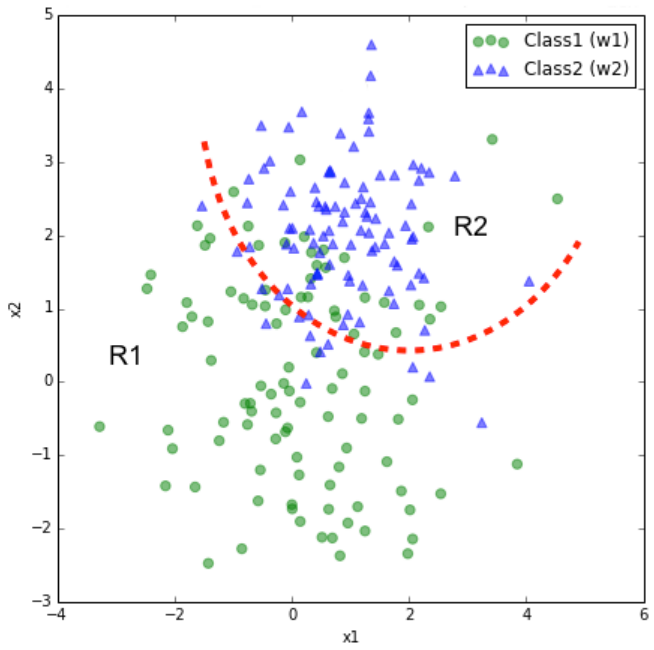




Supervised Learning: Classification

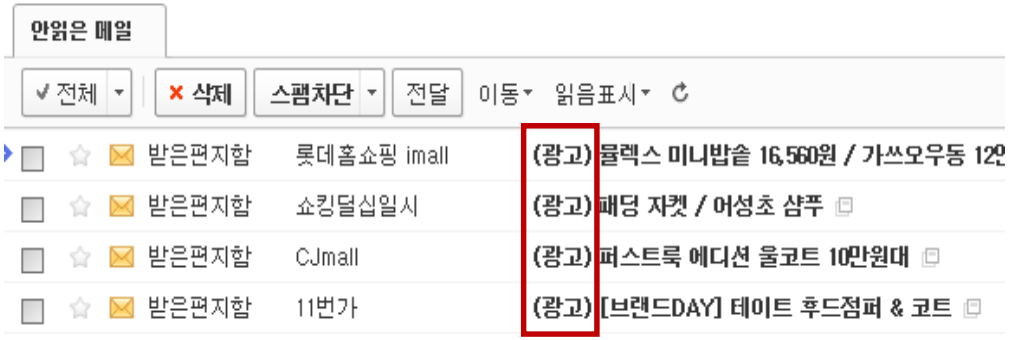
- **Predicting categorical values (i.e., discrete labels)**
  - It learns **decision boundaries** for data with different labels.
- **Examples**
  - Logistic regression, Support vector machines (SVM)
  - Neural Networks: Perceptron, Multilayer perceptron (MLP)
  - Decision trees, Naïve Bayes, K-nearest neighbors (k-NN)





Document Classification

- Classifying a document into one or more categories



ham vs. spam

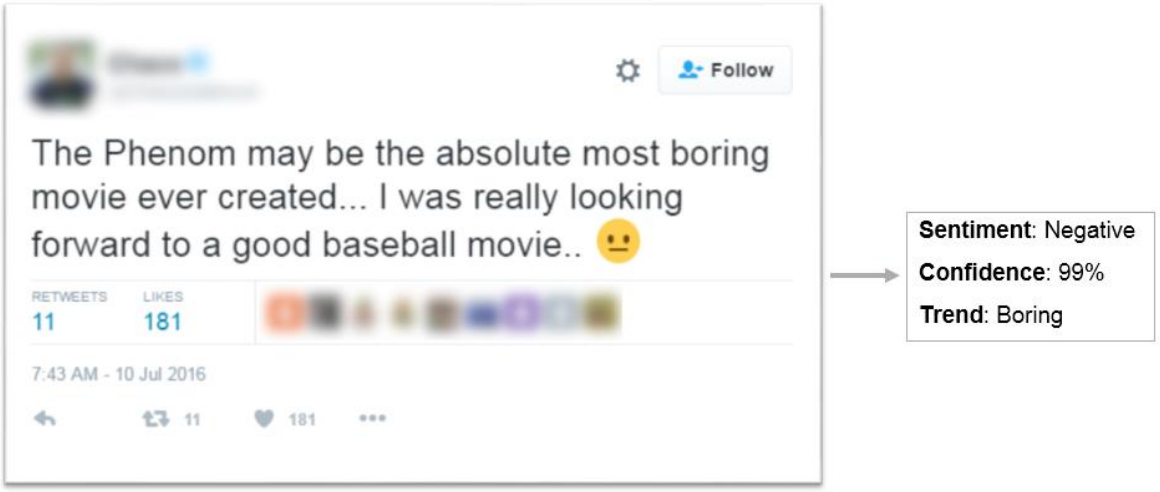
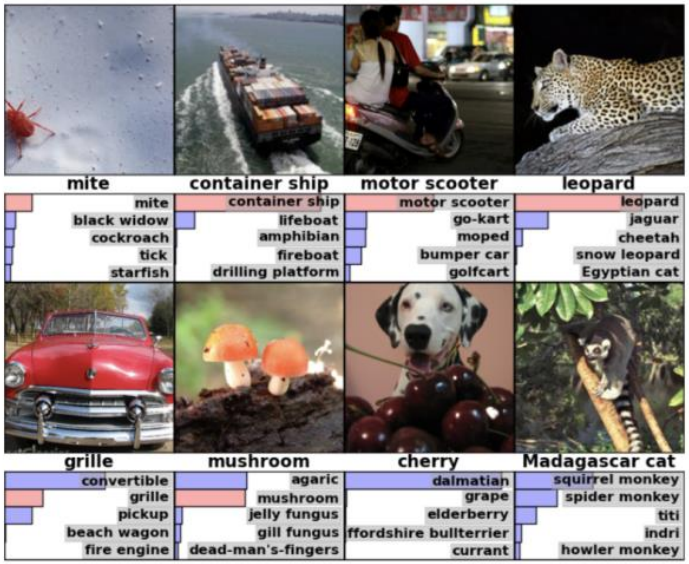


Image Classification

- **ImageNet Large Scale Visual Recognition Competition (ILSVRC)**
  - 1.2M training, 100k test, 1000 object classes (categories)



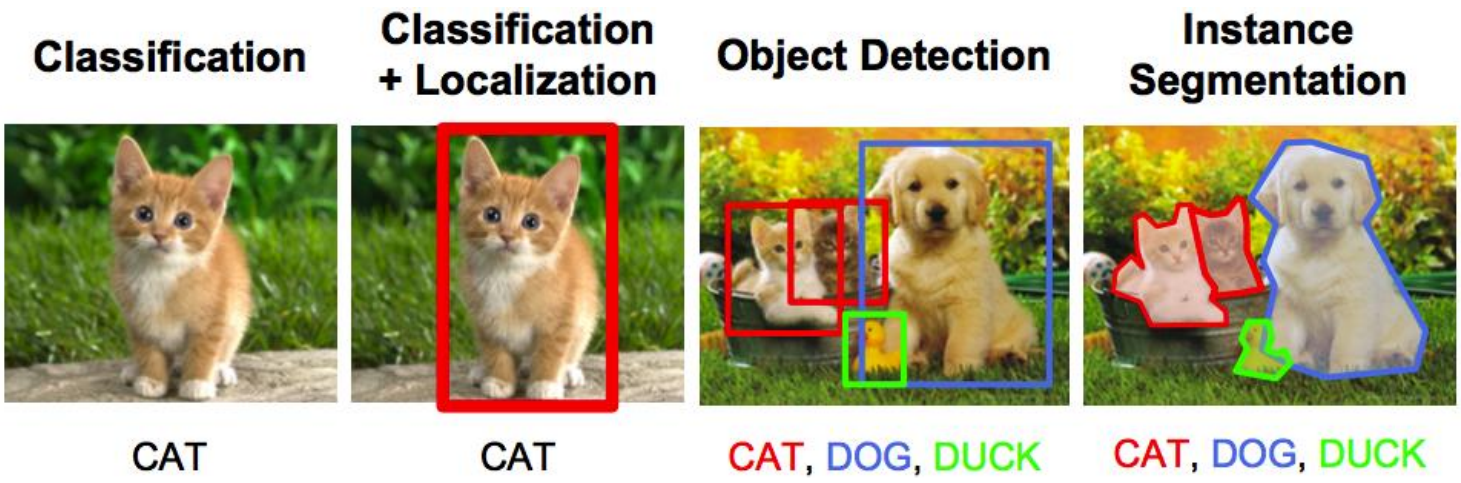
t-SNE visualization of CNN codes: https://cs.stanford.edu/people/karpathy/cnnembed/

Video Classification

- **Large-scale Video Classification with Convolutional Neural Networks, CVPR 2014**

https://www.youtube.com/watch?v=qrzQ_AB1DZk

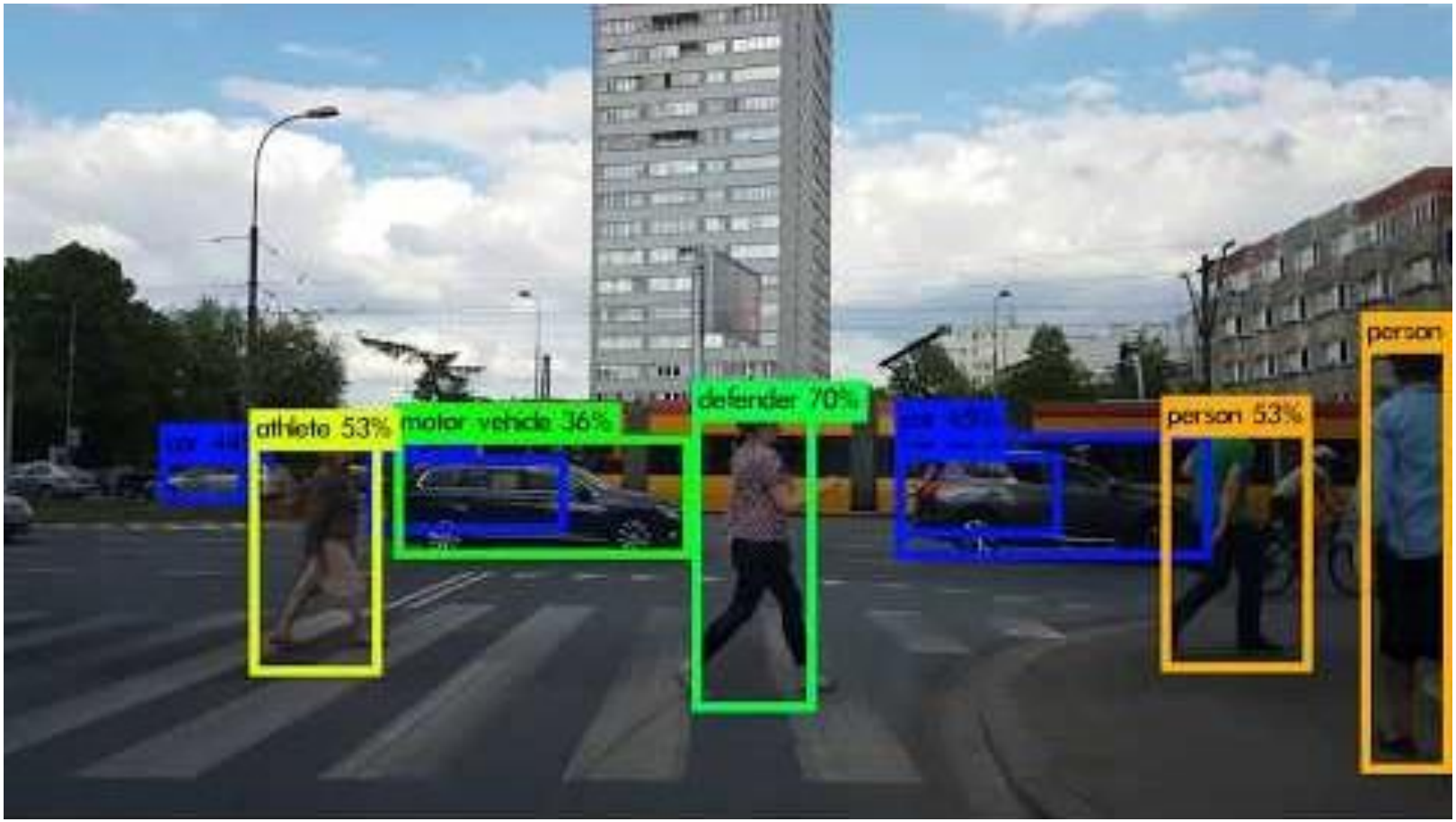
Object Detection



https://mlwhiz.com/blog/2018/09/22/object_detection/

Object Detection

- **YOLO: Real-Time Object Detection**
  - https://pjreddie.com/darknet/yolo/

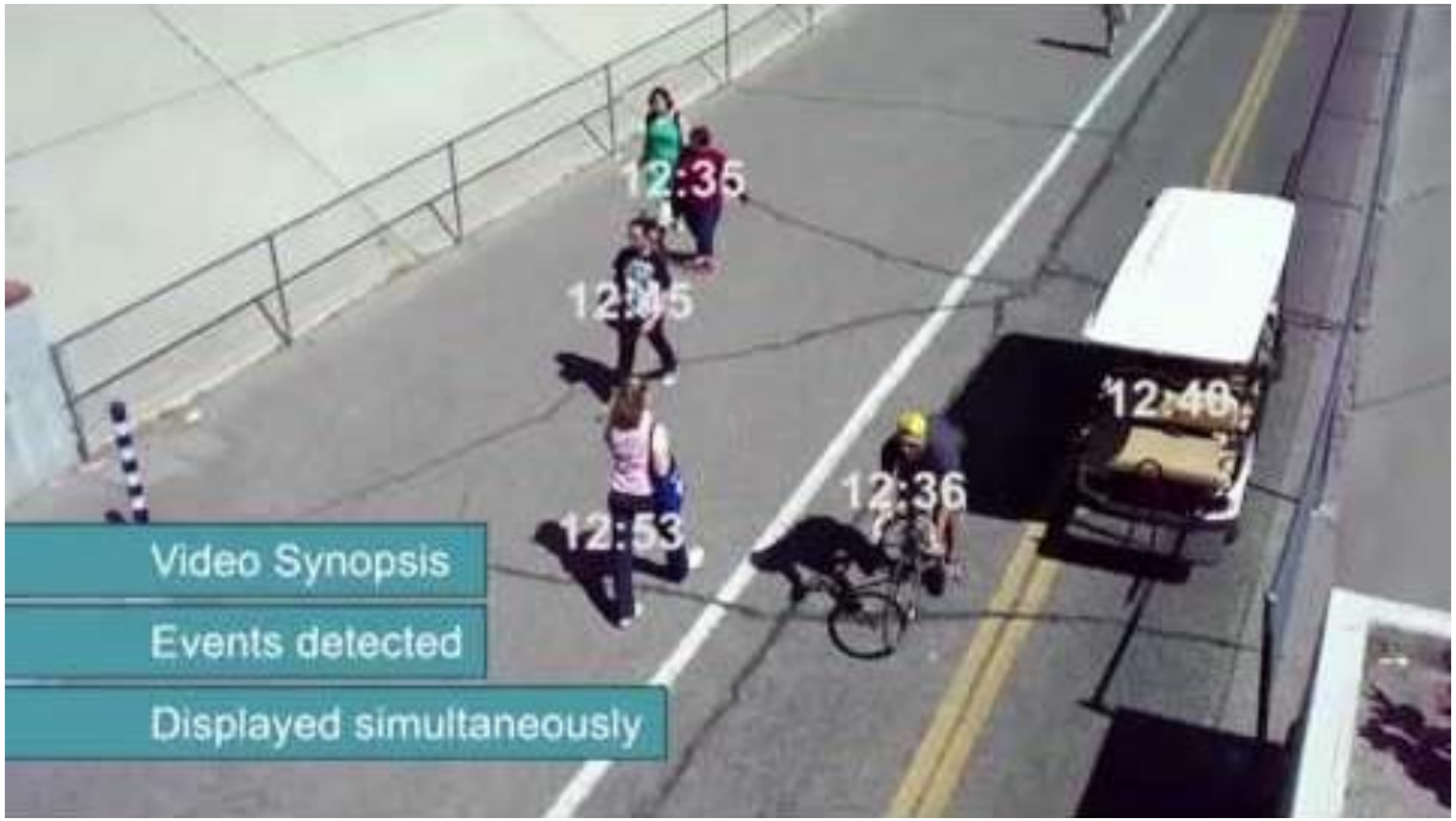


https://www.youtube.com/watch?v=_kxX09i4fds

Video Summarization

BriefCam

- **Video synopsis is the simultaneous presentation of objects, events and activities that occurred at different times.**



https://www.youtube.com/watch?v=fISfDd35sXU

Speech Recognition

➢ Converting speech into text

Voice Model:

Korean broadband model (16KHz)

Keywords to spot:

네 명,숙박,호텔,싱글룸,두개,예약,정오,입금 완료,당일 배송,몇 시

Detect multiple speakers (Not supported on current model)

Record Audio | Upload Audio File | Play Sample 1 | Play Sample 2

Text | Word Timings and Alternatives | Keywords (4/10) | JSON

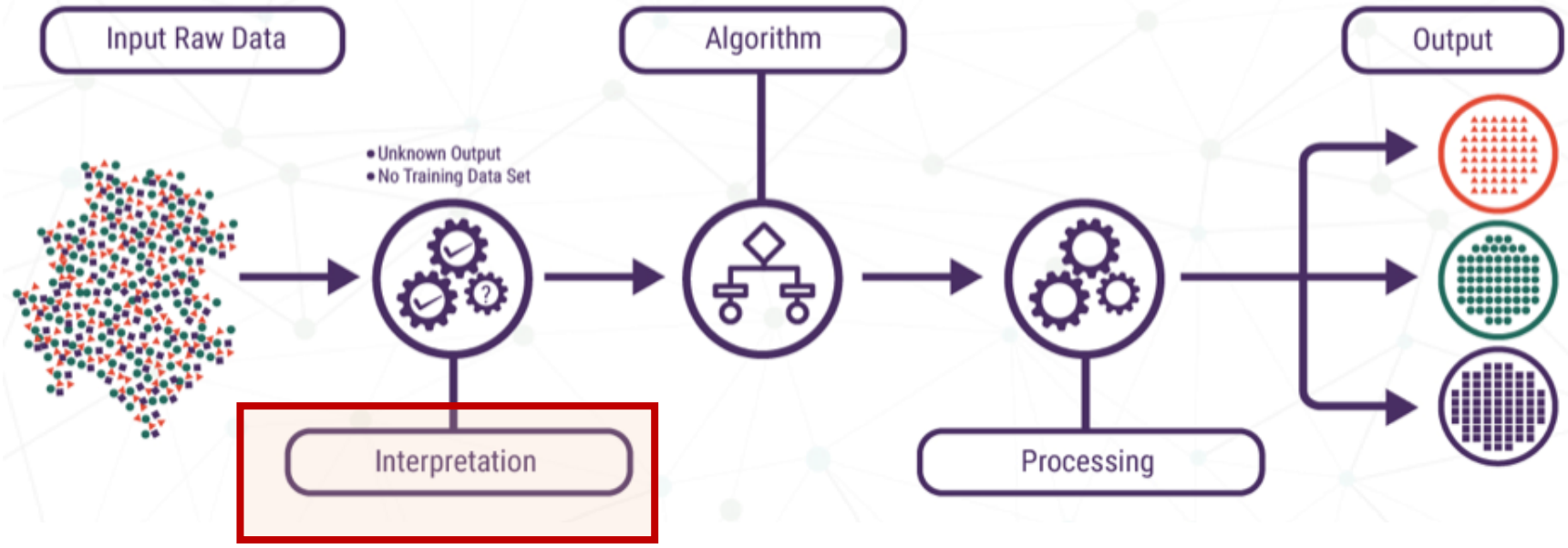
네 명 숙박 할 건데 호텔 디럭스 룸은 다 찼다고 하셔서 그런데 혹시 싱글룸 두개로 예약은 가능한가요.

https://speech-to-text-demo.ng.bluemix.net/

Unsupervised Learning

What is Unsupervised Learning?

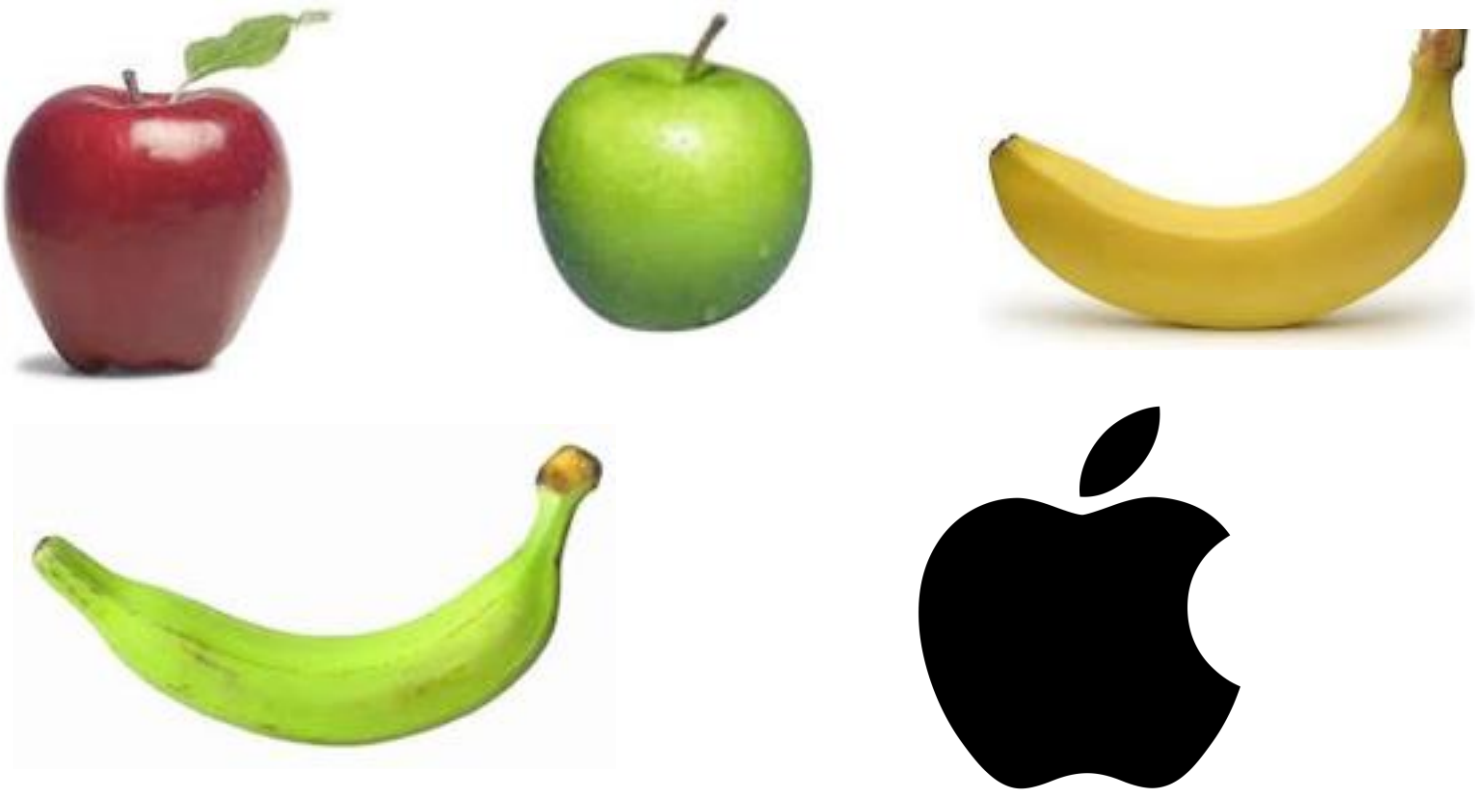
- Finding **hidden patterns** in a dataset with **no labels** and with a minimum of human supervision



Data representation

What is Unsupervised Learning?

- Given a dataset with no labels, how to classify them?



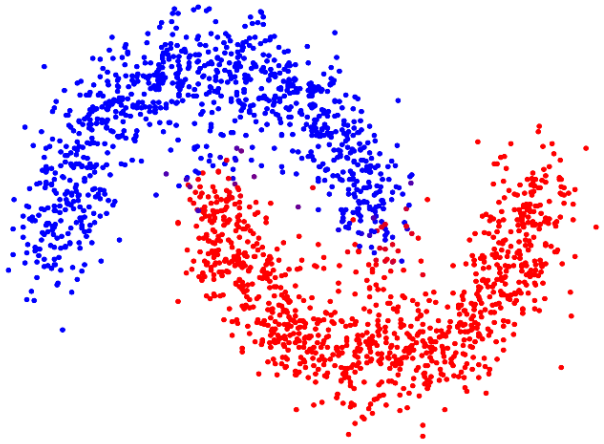
What is Unsupervised Learning?

- **Finding hidden meaningful representations of data**
  - **Clustering**: discover groups of similar examples within the data.
    - E.g., K-means clustering
  - **Dimensionality reduction**: project the data from a high-dimensional space to a lower dimension space.
    - E.g., Principle Component Analysis (PCA)
  - **Density estimation**: determine the distribution of data within the input space.
    - E.g., Gaussian Mixture Model (GMM)

Clustering

- **Grouping similar data tuples into clusters**
  - Defining the **similarities** between data according to the characteristics found in the data

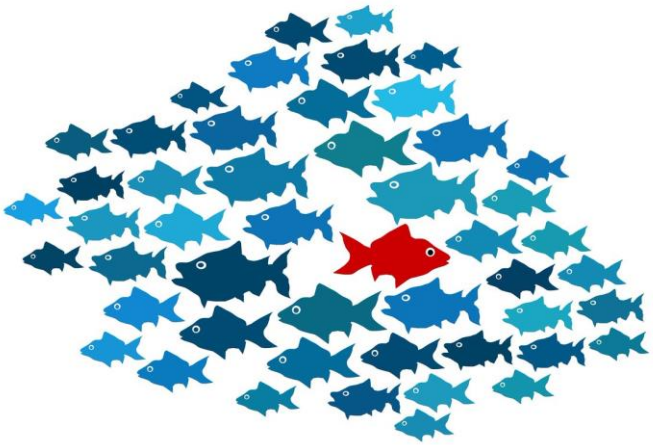
- **Cluster: A group of data instances**
  - **Similar** (or related) to one another within the same group
  - **Dissimilar** (or unrelated) to the tuples in other groups

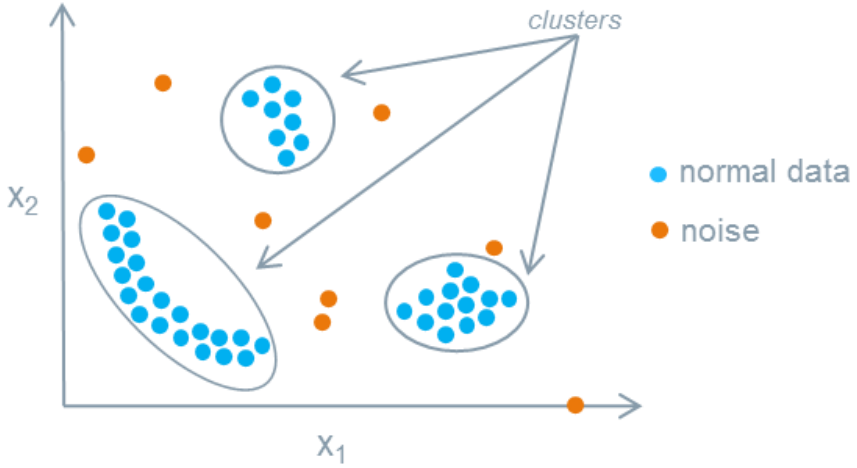


Outlier Detection

- **Finding a data point that does not comply with the general behavior of the data**
  - Noise or exception?

- **Useful in fraud detection, rare events analysis**

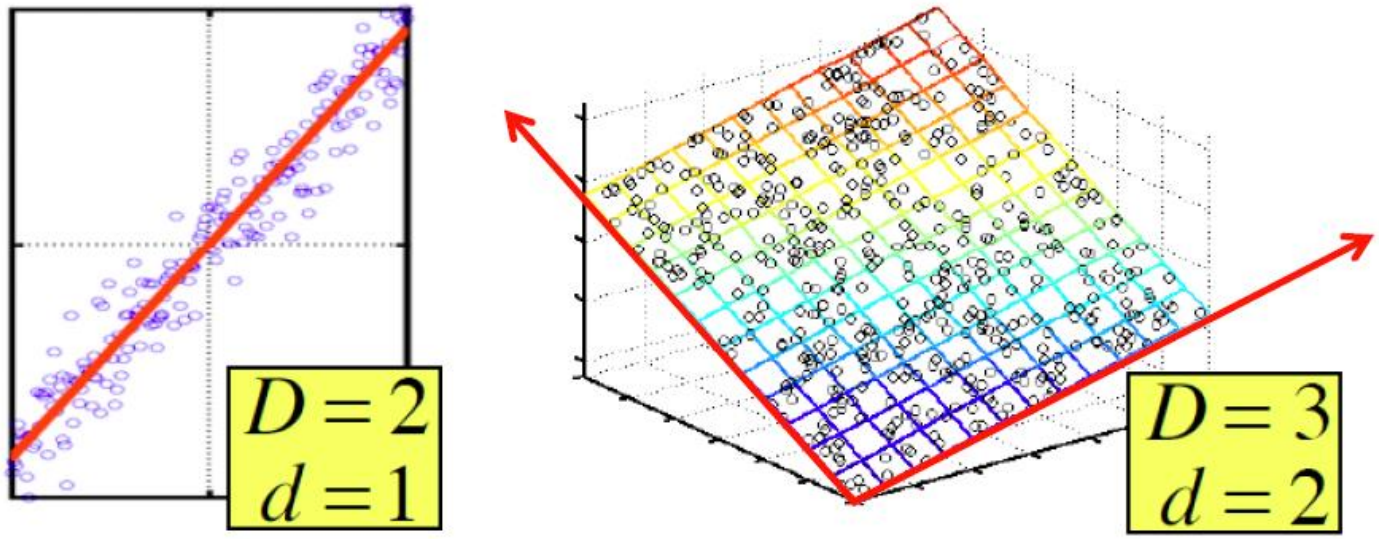




Dimensionality Reduction

- Assume that a **D-dimensional data** lie on or near a ***d*-dimensional subspace**.

- How to represent the axes of subspace effectively?



Dimensionality Reduction

- **How to reduce dimensionality without loss of information?**
  - With different axis **[2 3 0 0 0]** and **[0 0 2 4 2]**, all rows are rearranged.

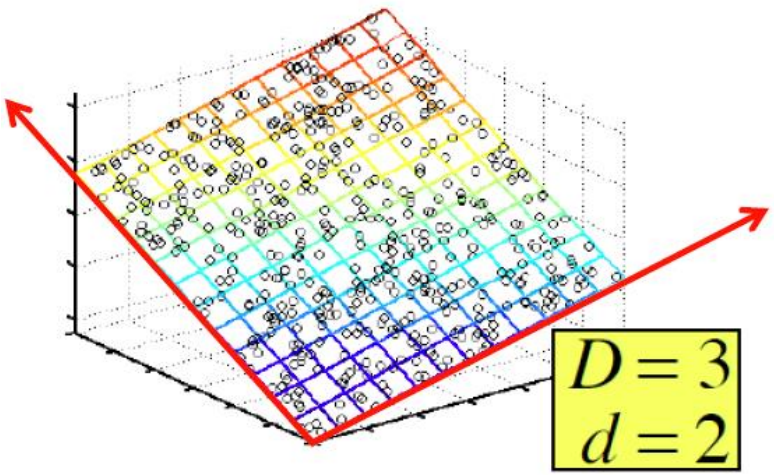
	Mon	Tue	Wed	Thu	Fri
Alice	2	3	0	0	0
Bob	4	6	0	0	0
Carol	6	9	0	0	0
David	0	0	2	4	2
Eve	0	0	3	6	3
Frank	0	0	1	2	1

	F1	F2
Alice	1	0
Bob	2	0
Carol	3	0
David	0	1
Eve	0	1.5
Frank	0	0.5

- **Data can be represented by two-dimensional space.**

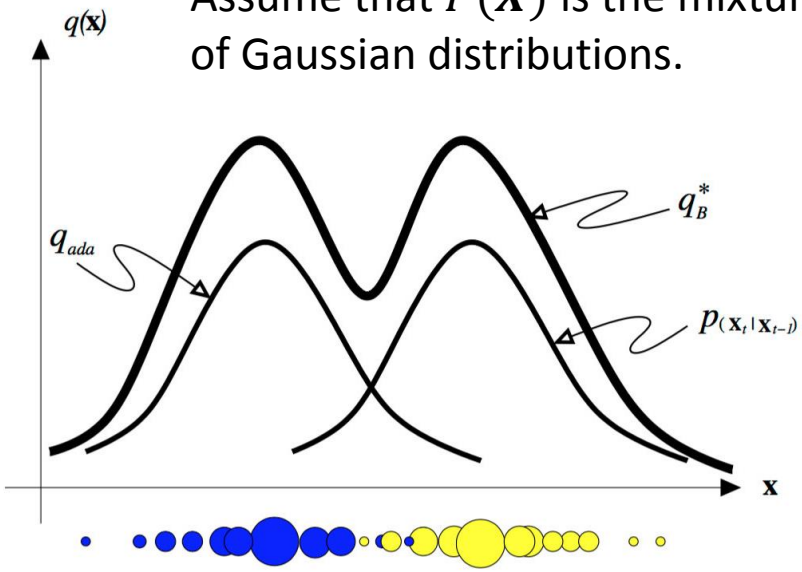
Why Reduce Dimensions?

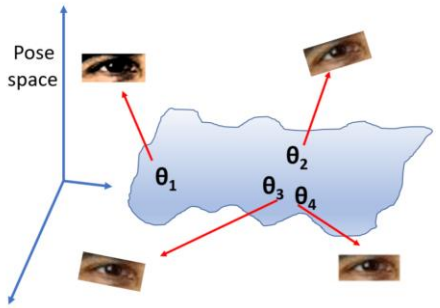
- Discovering hidden correlations of features
- Removing redundant and noisy features
- Easier storage and processing of the data
- Interpretation and visualization

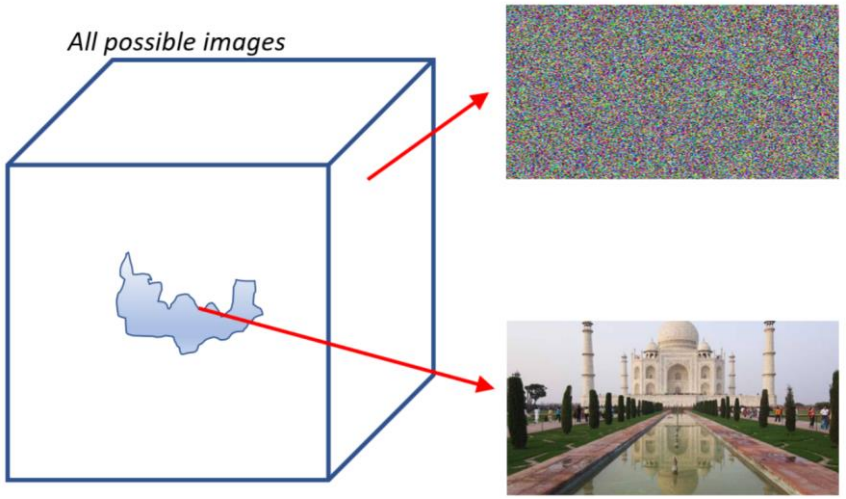


Density Estimation

- Given input data $\mathbf{x}_1, \mathbf{x}_2, \ldots, \mathbf{x}_n$ sampled by an unknown distribution $P(X)$, estimate z associated with $P(X)$.







Manifold hypothesis: Real data are on highly curved **manifolds**.

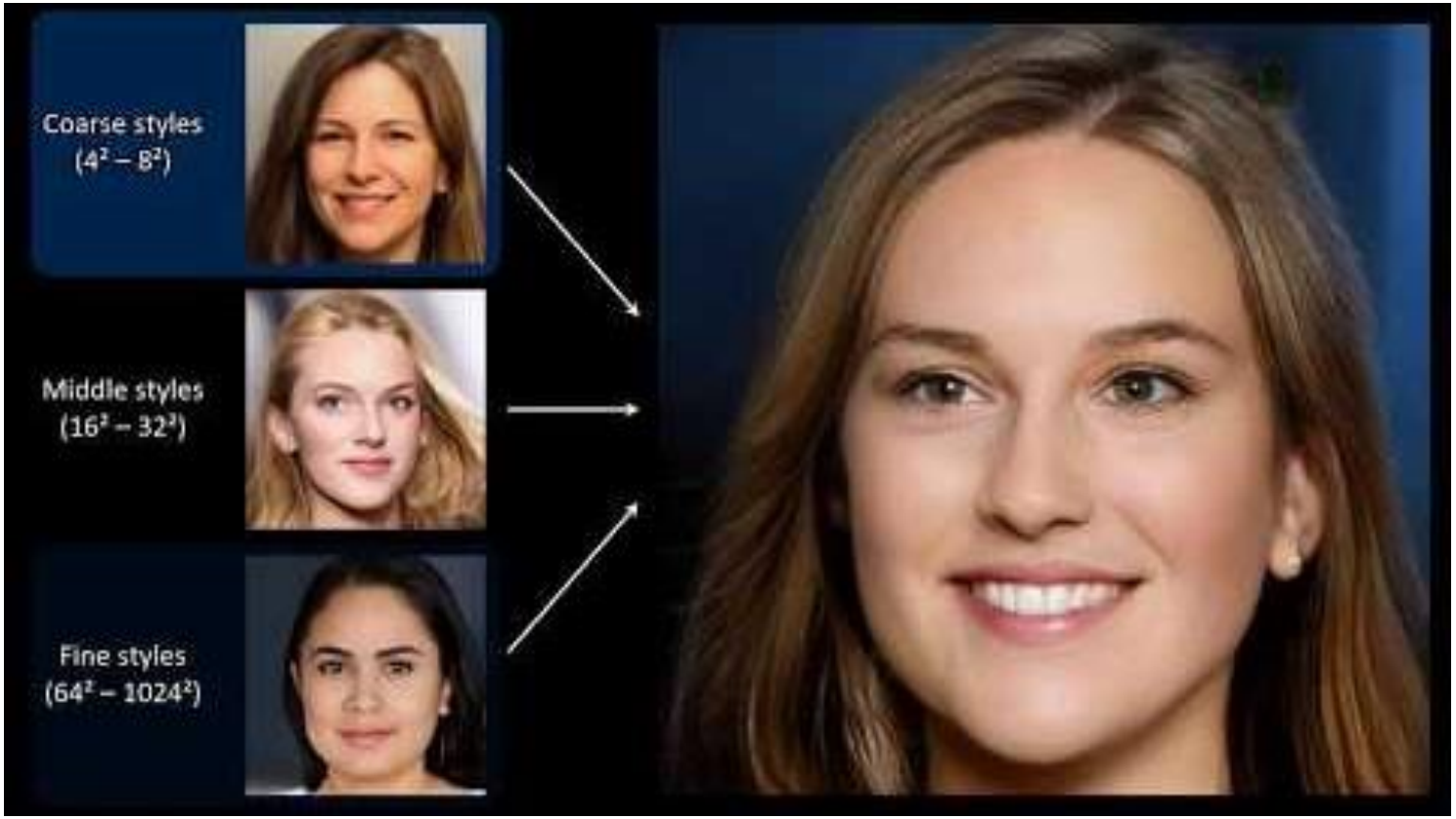
Generative Adversarial Nets (GAN)

- Learning to **generate new data** with the same statistics as the training set

https://www.youtube.com/watch?v=G06dEcZ-QTg

Style-Based GAN

- **Analyzing and Improving the Image Quality of StyleGAN**
  - https://arxiv.org/abs/1912.04958



https://www.youtube.com/watch?v=kSLJriaOumA

Video-to-Video Synthesis

- **Everybody Dance Now**

https://www.youtube.com/watch?v=PCBTZh41Ris

https://www.youtube.com/watch?v=cEBgi6QYDhQ

Reinforcement Learning

Nature of Learning

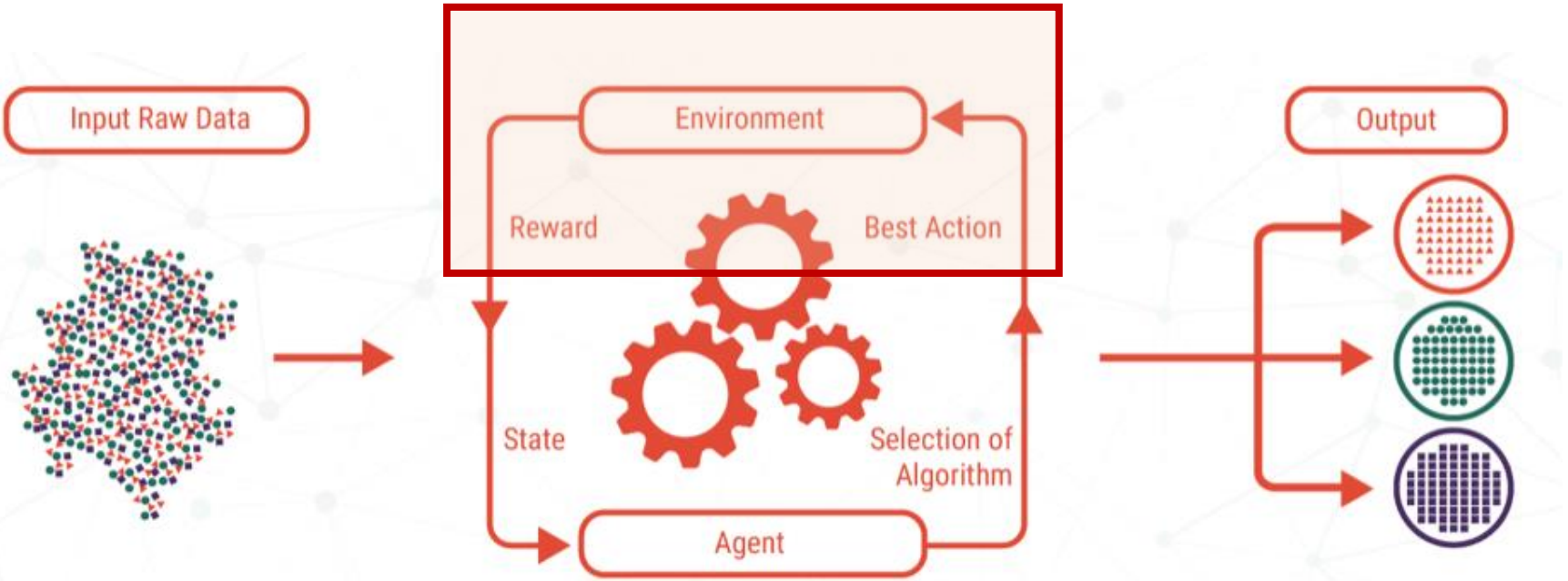
- **We learn from past experiences.**
  - When an infant plays, waves its arms, or looks about,
  - She has no explicit teacher but does have **direct interaction** to **the environment**.

- **Positive compliments vs. negative criticism**

What is Reinforcement Learning?

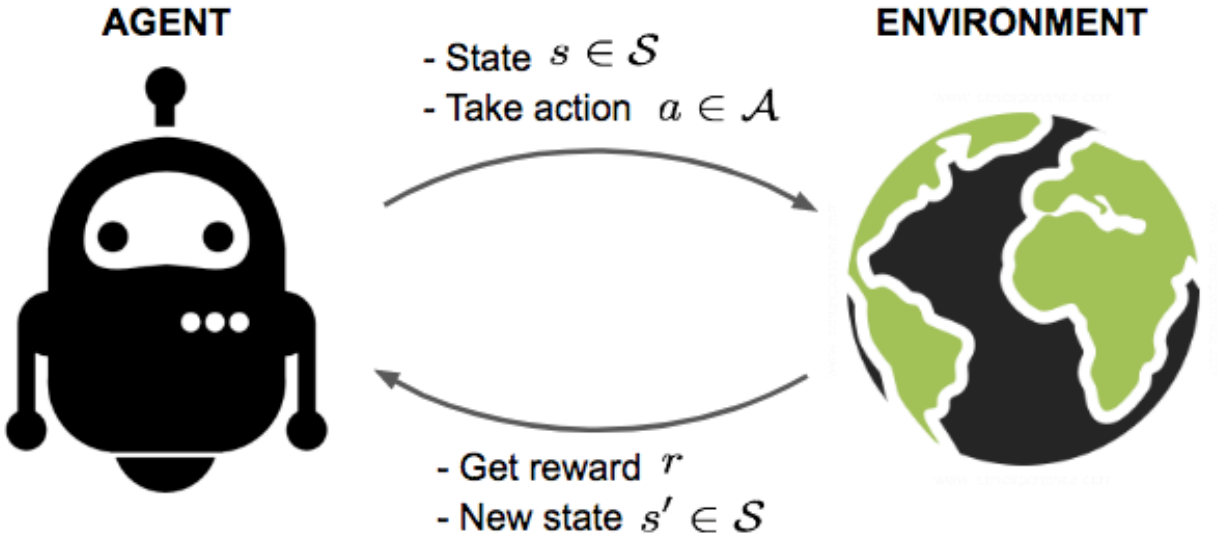
- Learning agents to **take actions** in an environment to **maximize cumulative rewards**.

Sequential actions with world



What is Reinforcement Learning?

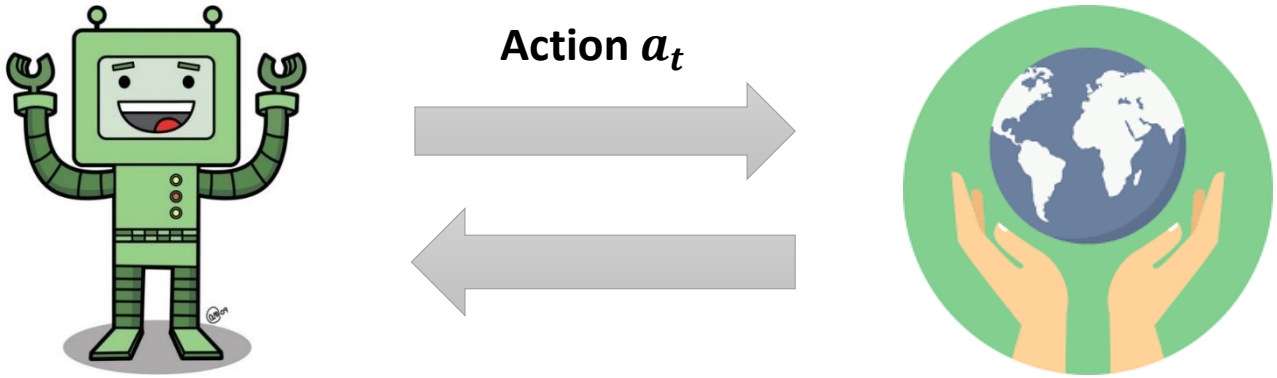
- **Computational approach to learning from interaction**
  - Learn to make **good sequences of decisions**.
  - **No supervisor**
  - **Feedback** is **delayed**.
  - **Actions** affect the **subsequent future rewards**.



Goal of Reinforcement Learning

Learn to make good sequences of decisions

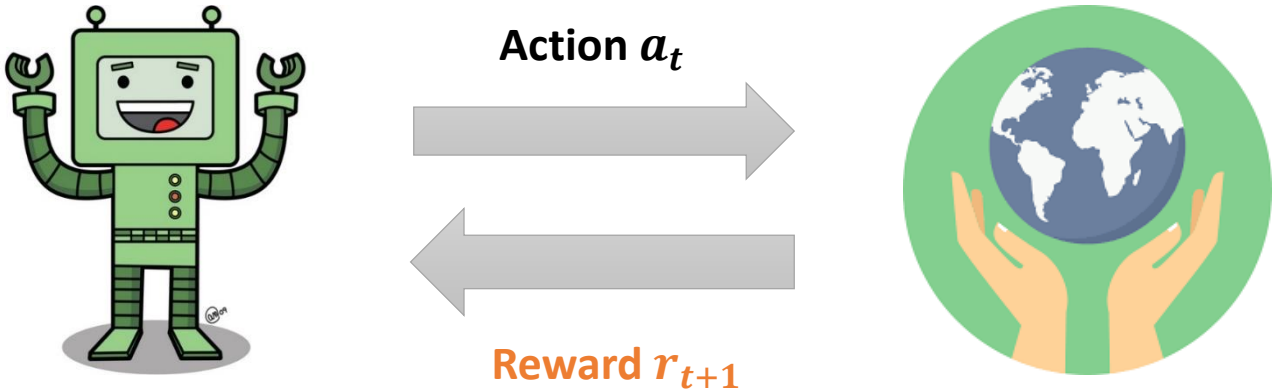
Repeated interactions with world



Goal of Reinforcement Learning

Learn to make good sequences of decisions

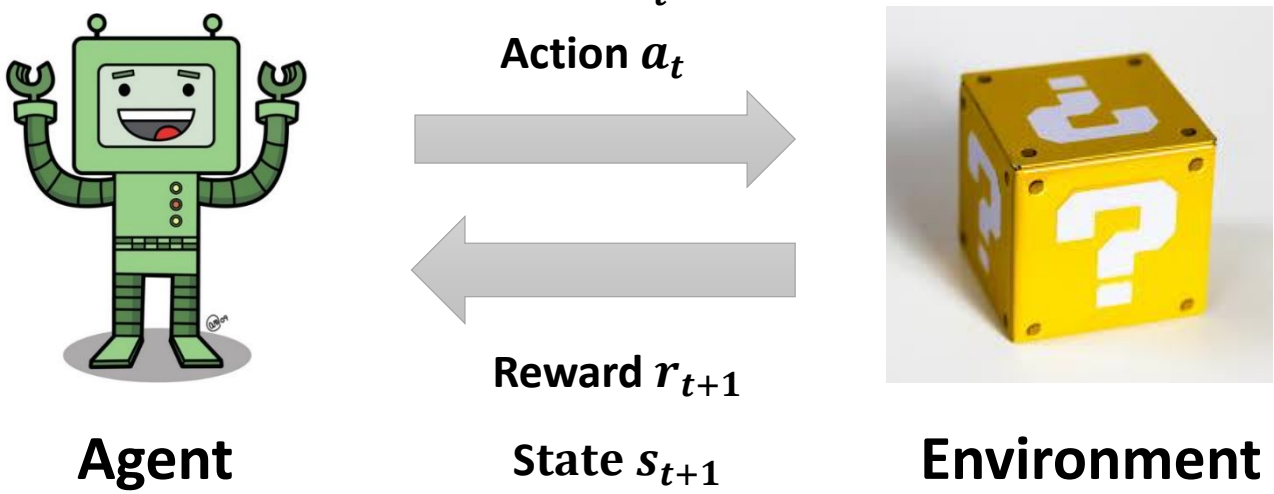
Rewards for sequences of decisions



Goal of Reinforcement Learning

Learn to make good sequences of decisions

Don’t know how the world works



Goal of Reinforcement Learning

Learn to make good sequences of decisions

The key challenge is to learn to make good decisions under uncertainty.

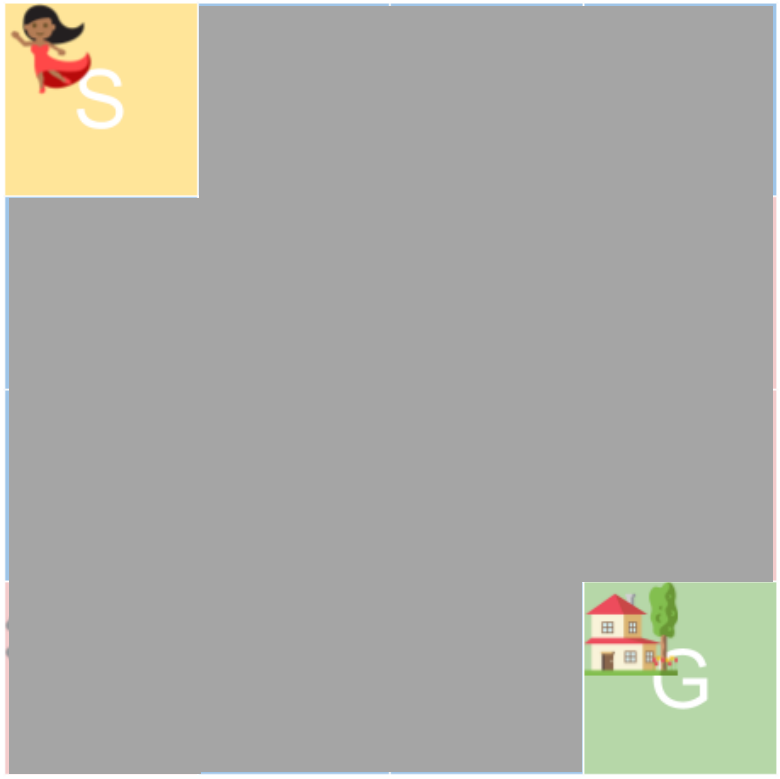
Example: Frozen Lake

➢ Rules

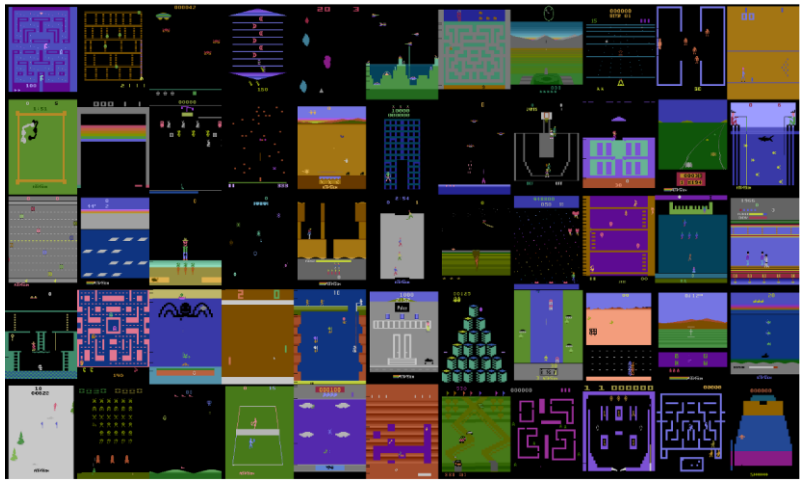
- You go from **Start** to **Goal** without falling into **Hole**.
- You **get reward of +1** for reaching the Goal; otherwise **you receive nothing**.
- Every time you can go **left**, **right**, **up** and, **down**.
- But you can't leave the grid.

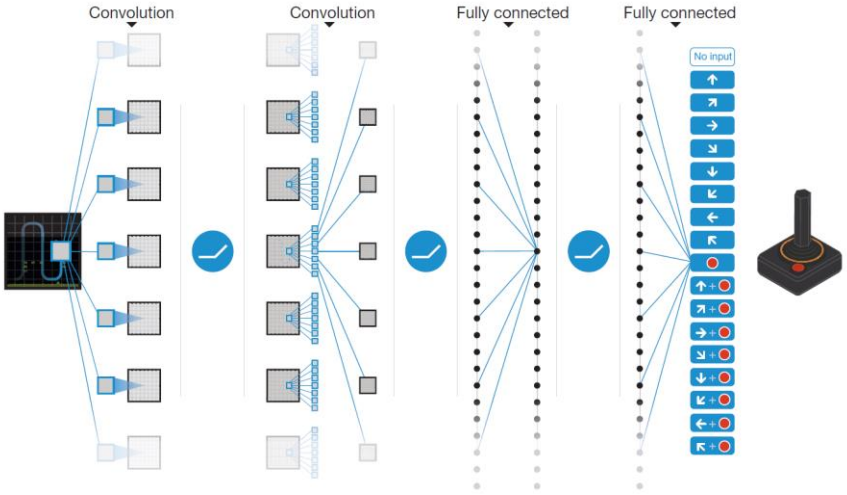
➢ Assumptions

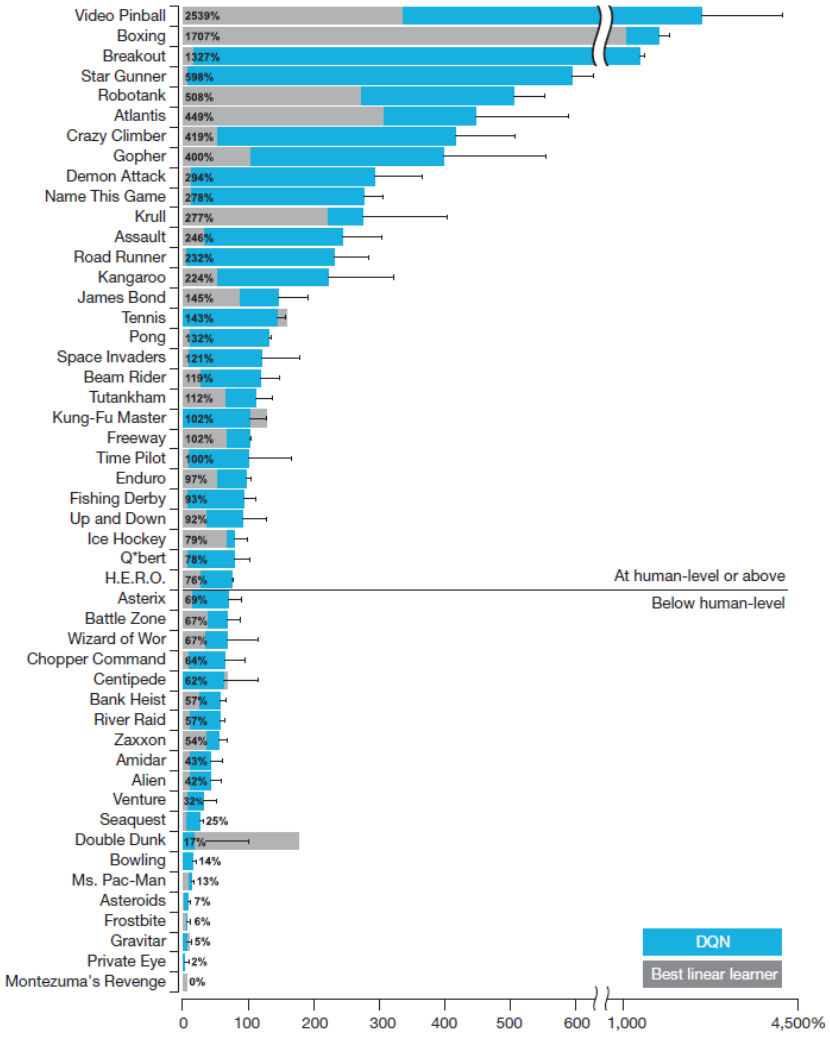
- Do not know where holes are.
- Move to another position with an unknown probability.



Atari Game with RL





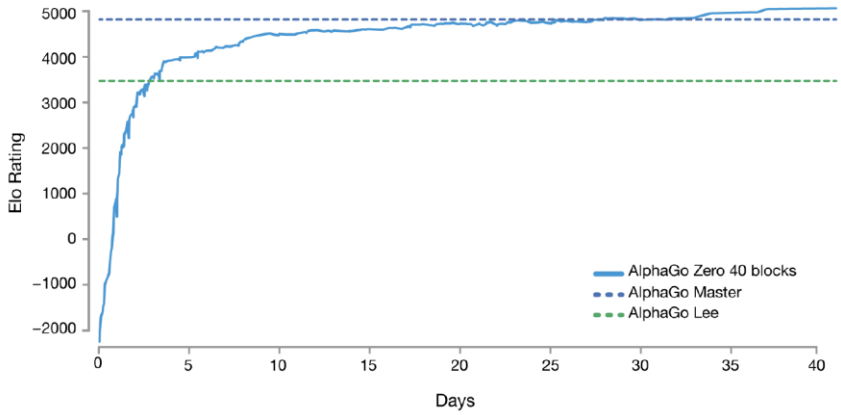


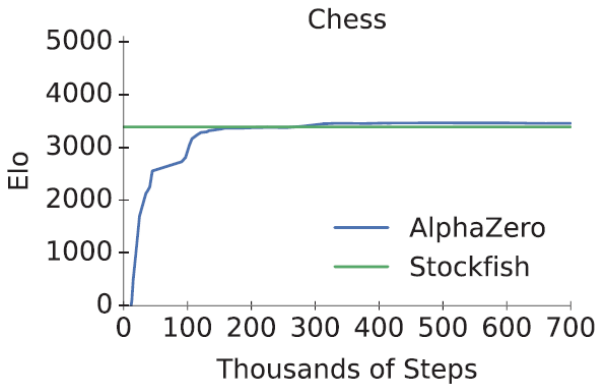
https://deepmind.com/research/publications/playing-atari-deep-reinforcement-learning/

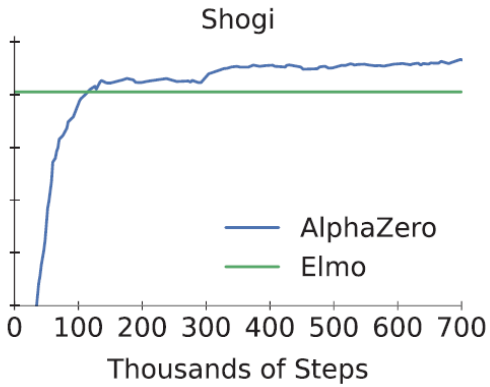
Atari Breakout

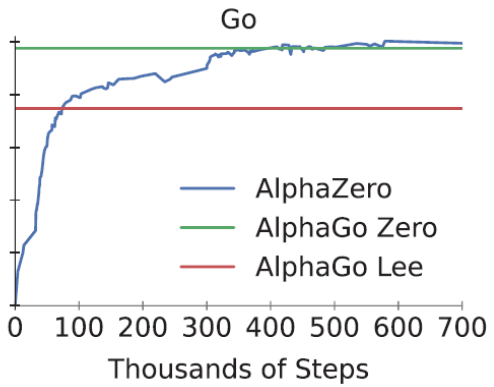
https://www.youtube.com/watch?v=V1eYniJ0Rnk

AlphaGo with RL

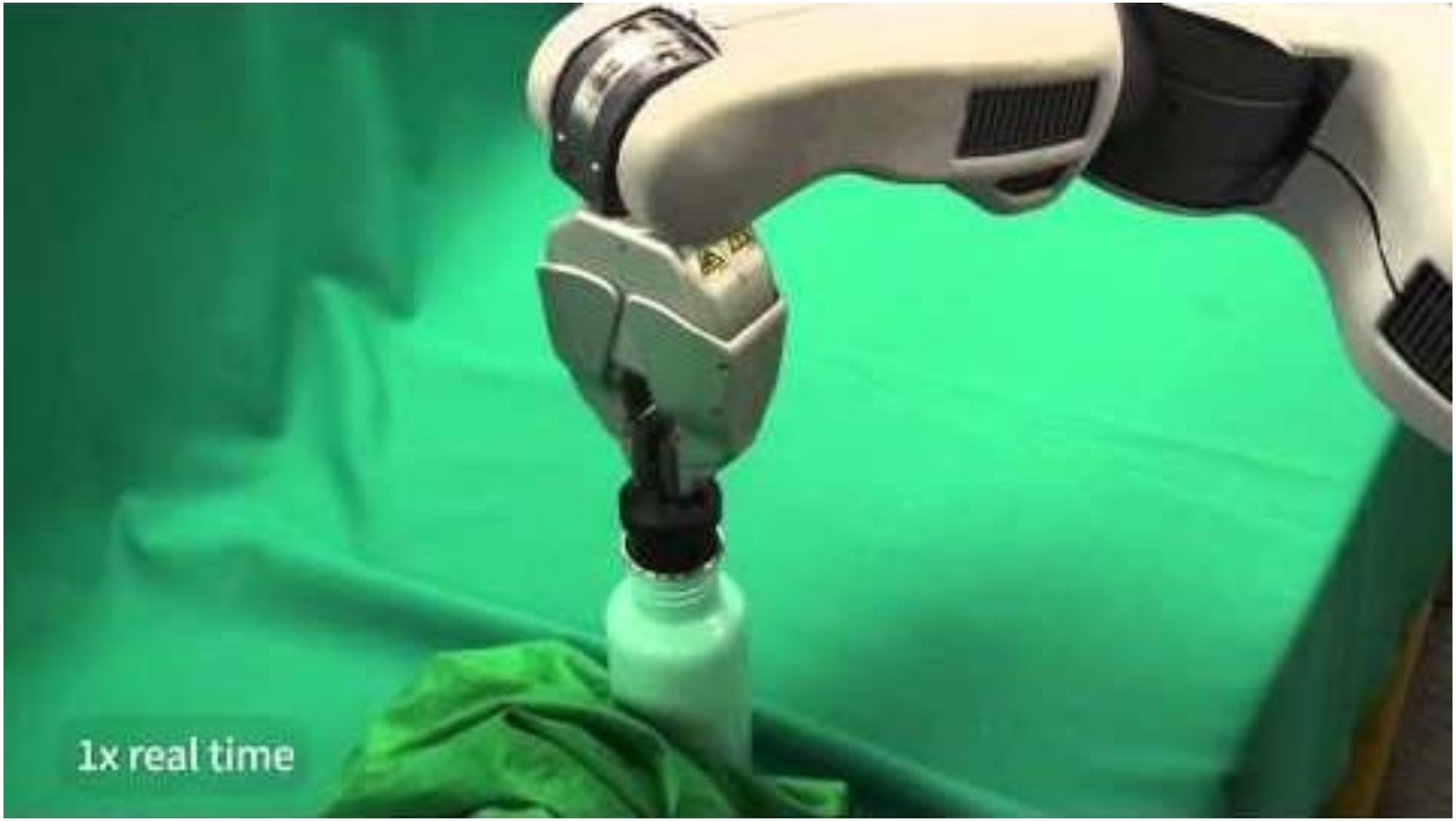








Sensorimotor Learning



https://www.youtube.com/watch?v=2hGngG64dNM

Q&A