Machine Learning

Introduction

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Sri City, Chittoor

Today's Agenda

- What is learning?
- Why learning?
- Machine Learning Paradigms
  - Supervised Learning
  - Unsupervised Learning
  - Reinforcement Learning
- What is classification problem?
- What is regression problem?

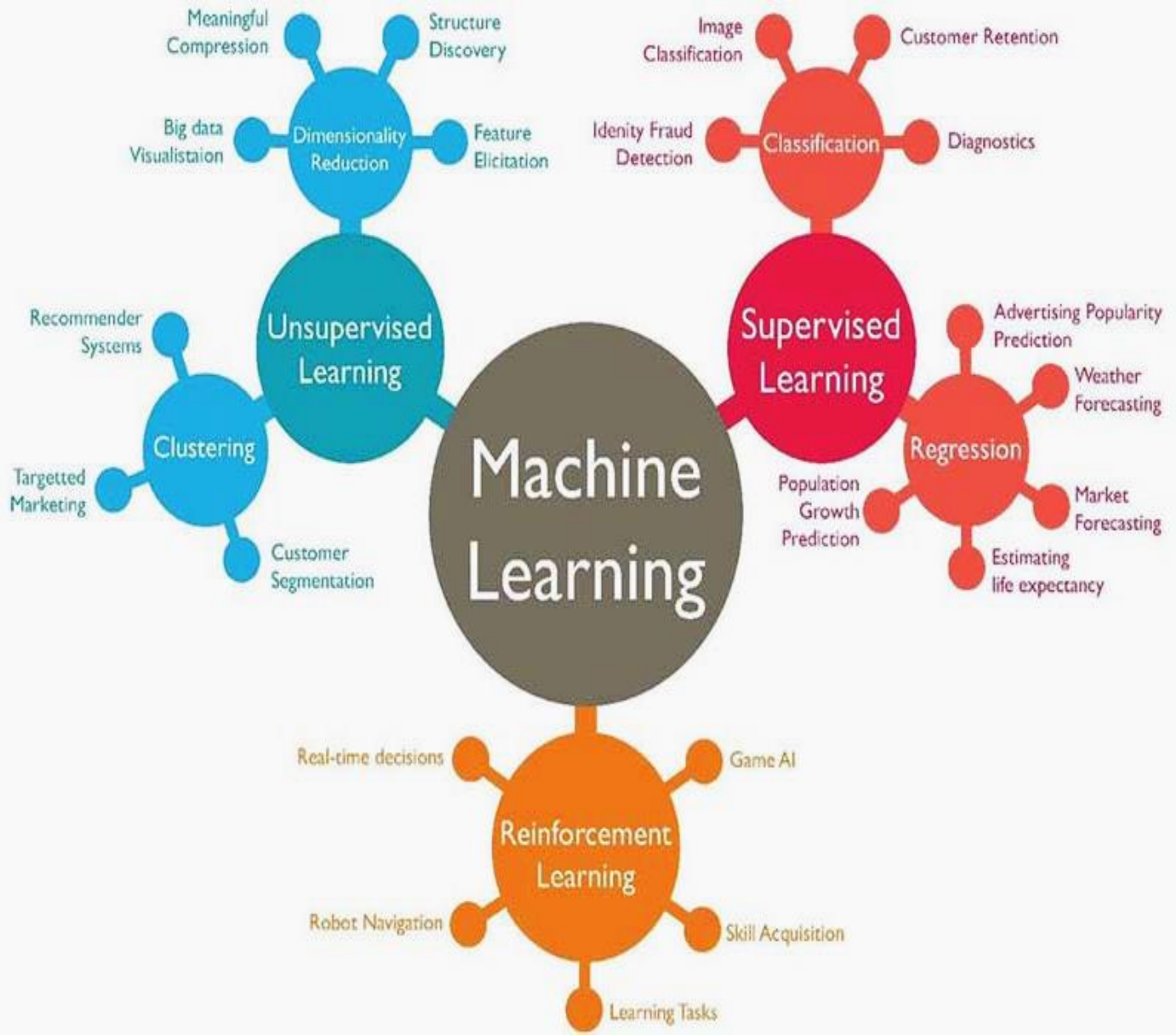
What is learning?

- **Learning** is a computational process for improving performance based on experience.
- We will see again in classification.

Why learning?

- *Instead of trying to produce a programme to simulate the adult mind, why not rather try to produce one which simulates the child's? If this were then subjected to an appropriate course of education one would obtain the adult brain. Presumably the child brain is something like a notebook as one buys it from the stationer's. Rather little mechanism, and lots of blank sheets.*
  - [Alan Turing, 1950]
- Learning is *essential* for unknown environments.

Different Machine Learning Paradigms



Supervised Learning

- To learn an unknown *target function* f
- Input: a *training set* of *labeled examples* (x_j, y_j) where $y_j = f(x_j)$
  - E.g., x_j is an image, $f(x_j)$ is the label "giraffe"
- Output: *hypothesis* h that is "close" to f, i.e., predicts well on unseen examples ("*test set*")
- Many possible hypothesis families for h
  - Linear models, logistic regression, neural networks, decision trees, examples (nearest-neighbor) etc.

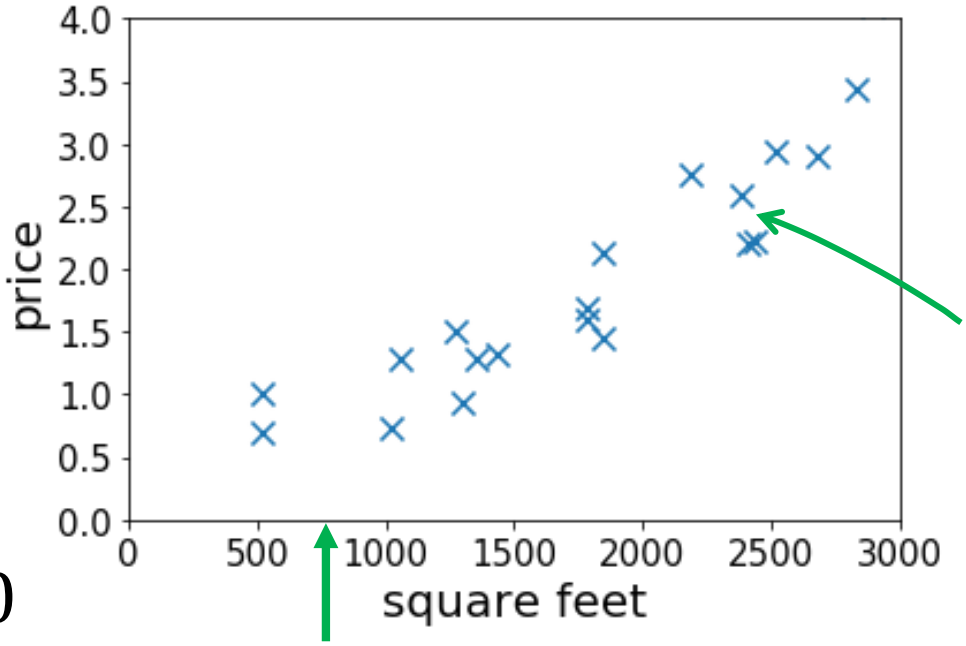
Slide Adapted from **Stuart Russell**

Housing Price Prediction

- Given: a dataset that contains n samples

$$\left(x^{(1)}, y^{(1)}\right), \ldots \left(x^{(n)}, y^{(n)}\right)$$

- Task: If a residence has x square feet, predict its price?



15th sample $(x^{(15)}, y^{(15)})$

$x = 800$

$y = ?$

Housing Price Prediction

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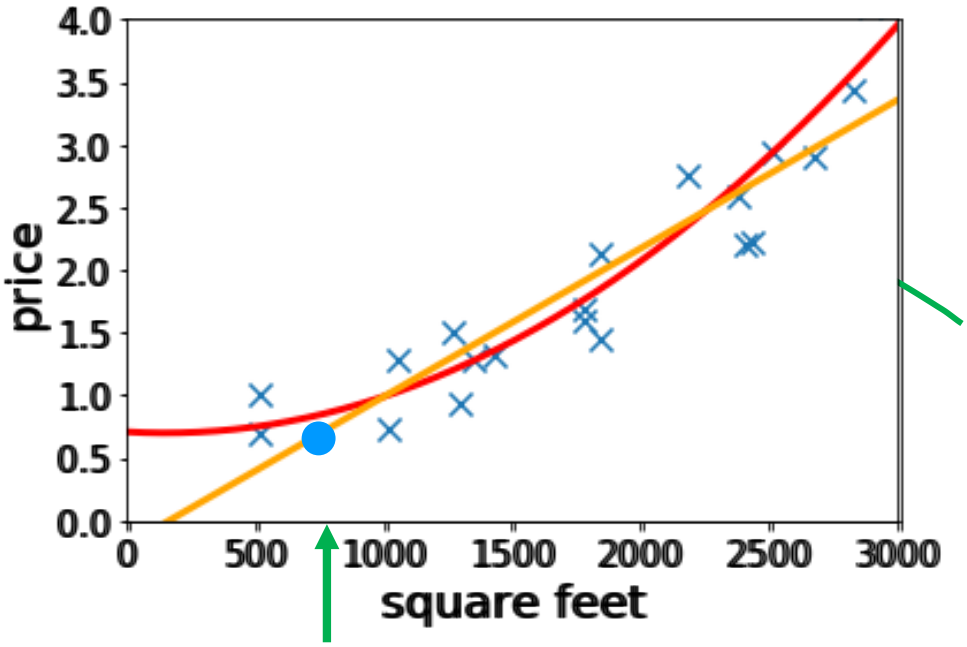

15th sample $(x^{(15)}, y^{(15)})$

$x = 800$

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- Solution: fitting linear/quadratic functions to the dataset.

High-dimensional Features

- $x \in \mathbb{R}^d$ for large d
- E.g.,

$$x = \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ \vdots \\ \vdots \\ \vdots \\ x_d \end{bmatrix}$$

--- living size
--- lot size
--- # floors
--- condition
--- zip code
⋮

$\longrightarrow$ y --- price

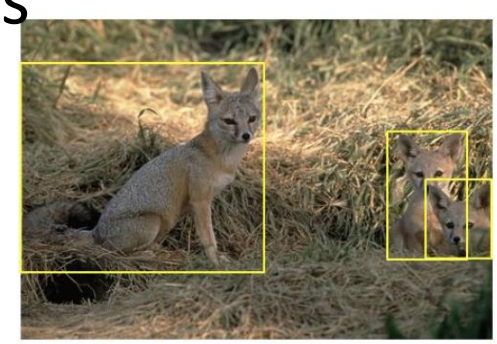
Supervised Learning in CV

- Image Classification
  - $x =$ raw pixels of the image, $y =$ the main object

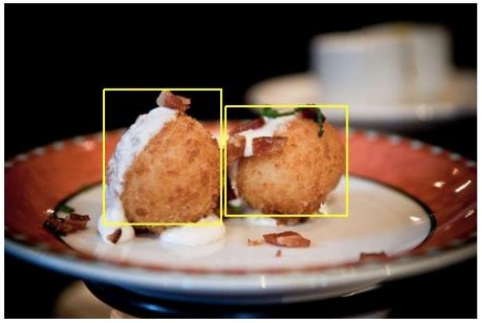
ImageNet Large Scale Visual Recognition Challenge. Russakovsky et al.'2015

Supervised Learning in CV

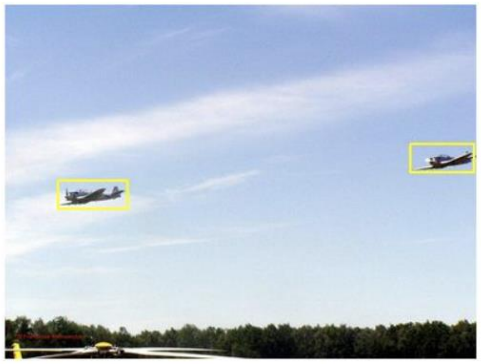
- Object localization and detection
  - $x =$ raw pixels of the image, $y =$ the bounding boxes



kit fox



croquette



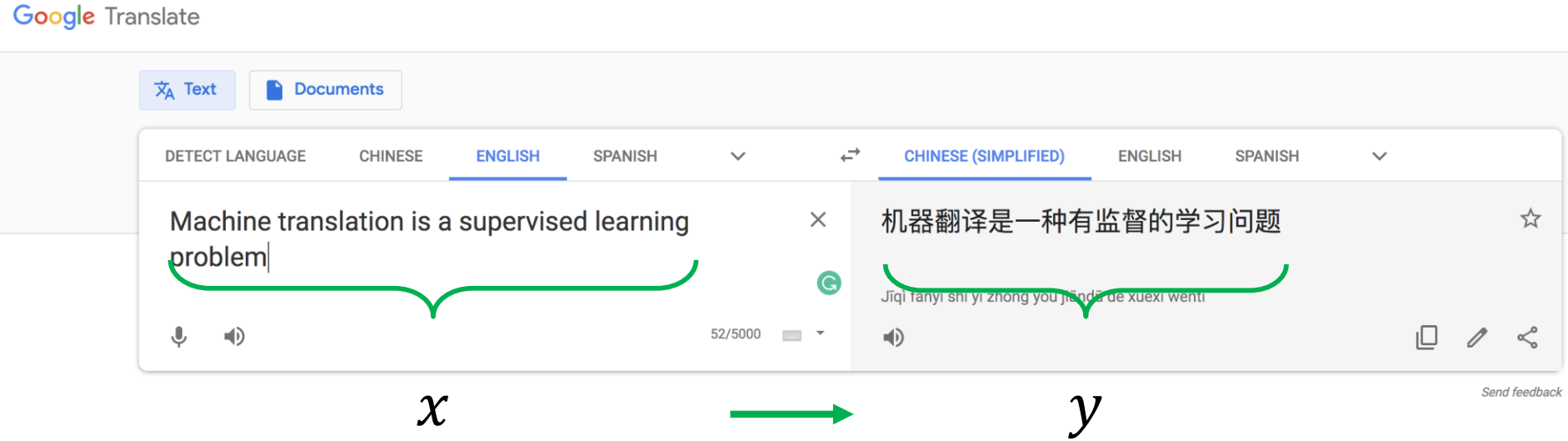
airplane

frog

ImageNet Large Scale Visual Recognition Challenge. Russakovsky et al.'2015

Supervised Learning in Natural Language Processing

- Machine translation



x → y

- Note: This course only covers the basic and fundamental techniques of supervised learning (which are not enough for solving hard vision or NLP problems.)

Supervised Learning

Advantage

- You have full control over what the machine is learning.

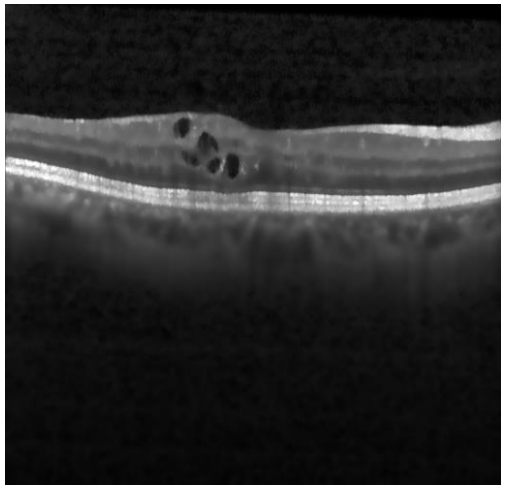
- You can easily test and debug your learning machine.
  - Since the labelled data is available you can easily inspect its output and find out what errors it's making on what type of input data.

Supervised Learning

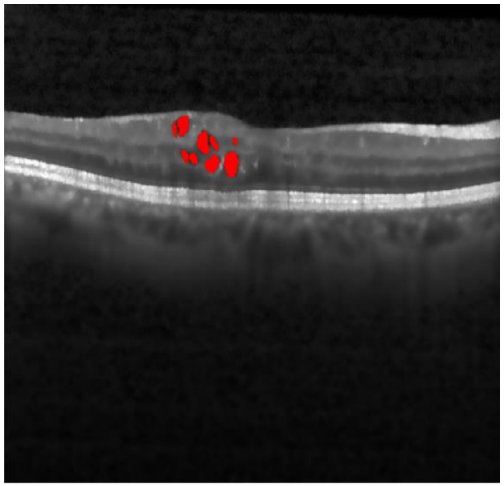
Disadvantage

- Collecting and labelling data is expensive and time-consuming.

  Example: Speech Recognition, Medical Image Analysis, etc.



Original Retinal Scan



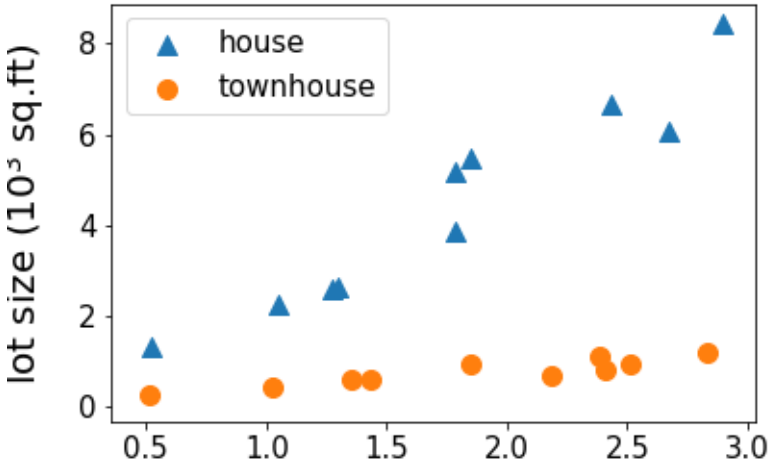
Intra-retinal cysts annotated scan

- Errors in your training data might confuse your algorithm and lower its accuracy. Garbage-in -> Garbage-out

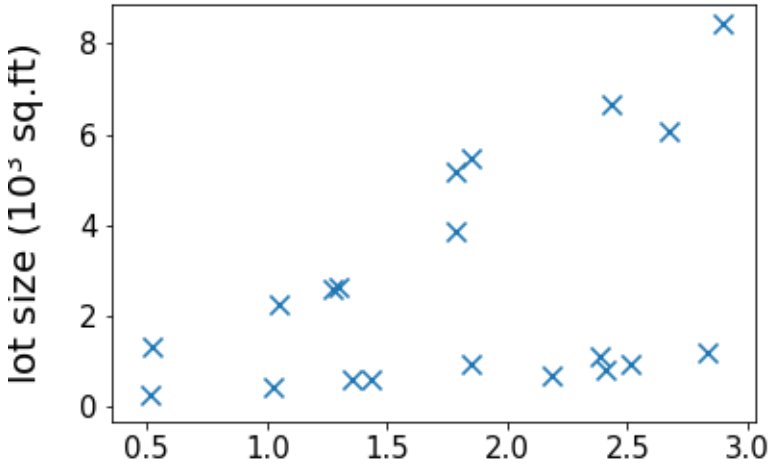
Unsupervised Learning

- Dataset contains no labels: $x^{(1)}, \ldots x^{(n)}$
- Goal (vaguely-posed): to find interesting structures in the data

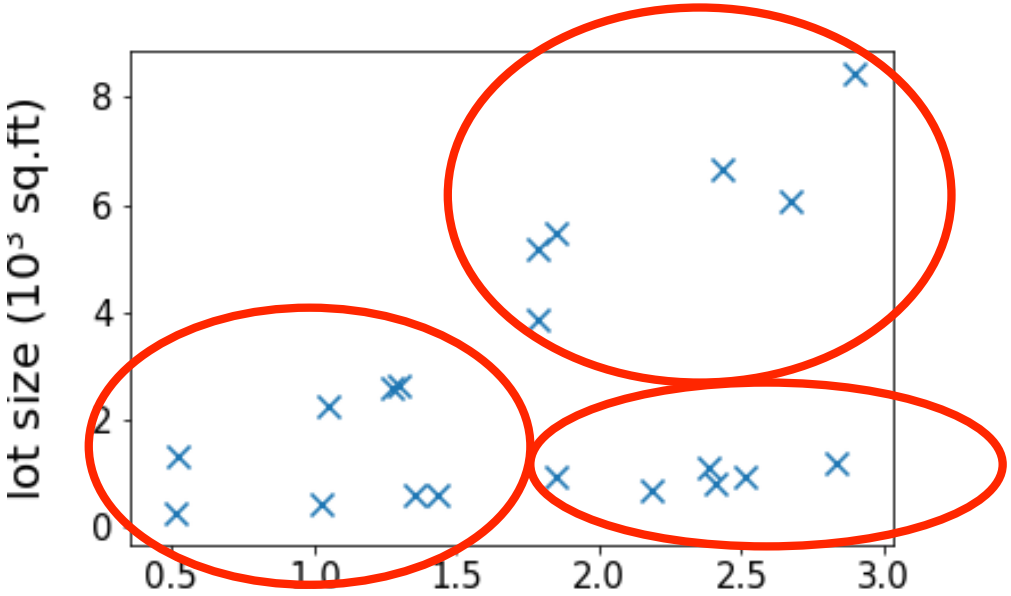
supervised



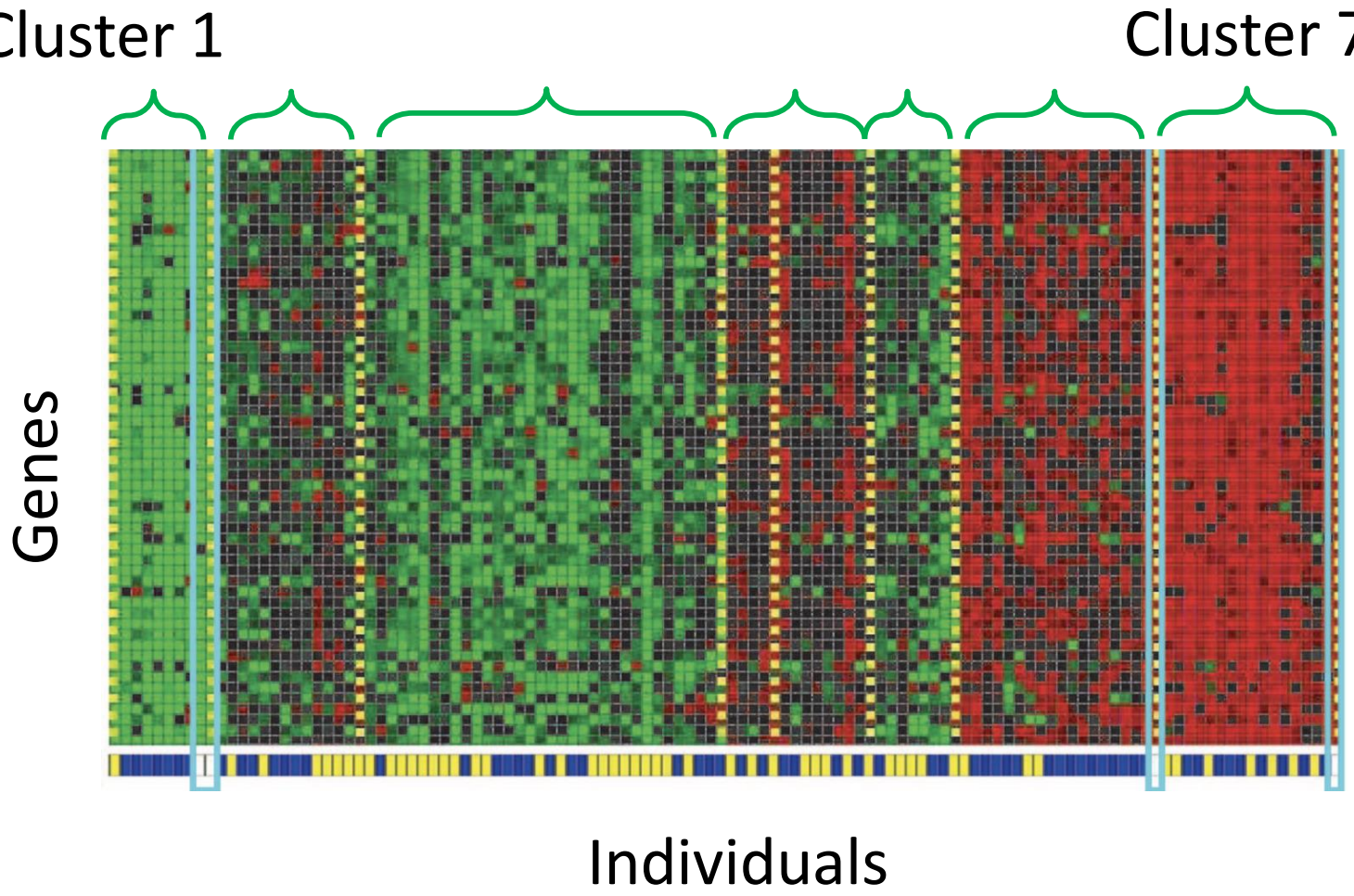
unsupervised



Clustering



Clustering Genes



Identifying Regulatory Mechanisms using Individual Variation Reveals Key Role for Chromatin Modification. [Su-In Lee, Dana Pe'er, Aimee M. Dudley, George M. Church and Daphne Koller. ’06]

Need for Unsupervised Learning

- Annotating large datasets is very costly and time consuming. Example: Speech Recognition, Medical Image Analysis, etc.

- There may be cases where we don’t know how many/what classes is the data divided into.

  Example: Data Mining, Sentimental Analysis.

- We may want to use clustering to gain some insight into the structure of the data before designing a classifier.

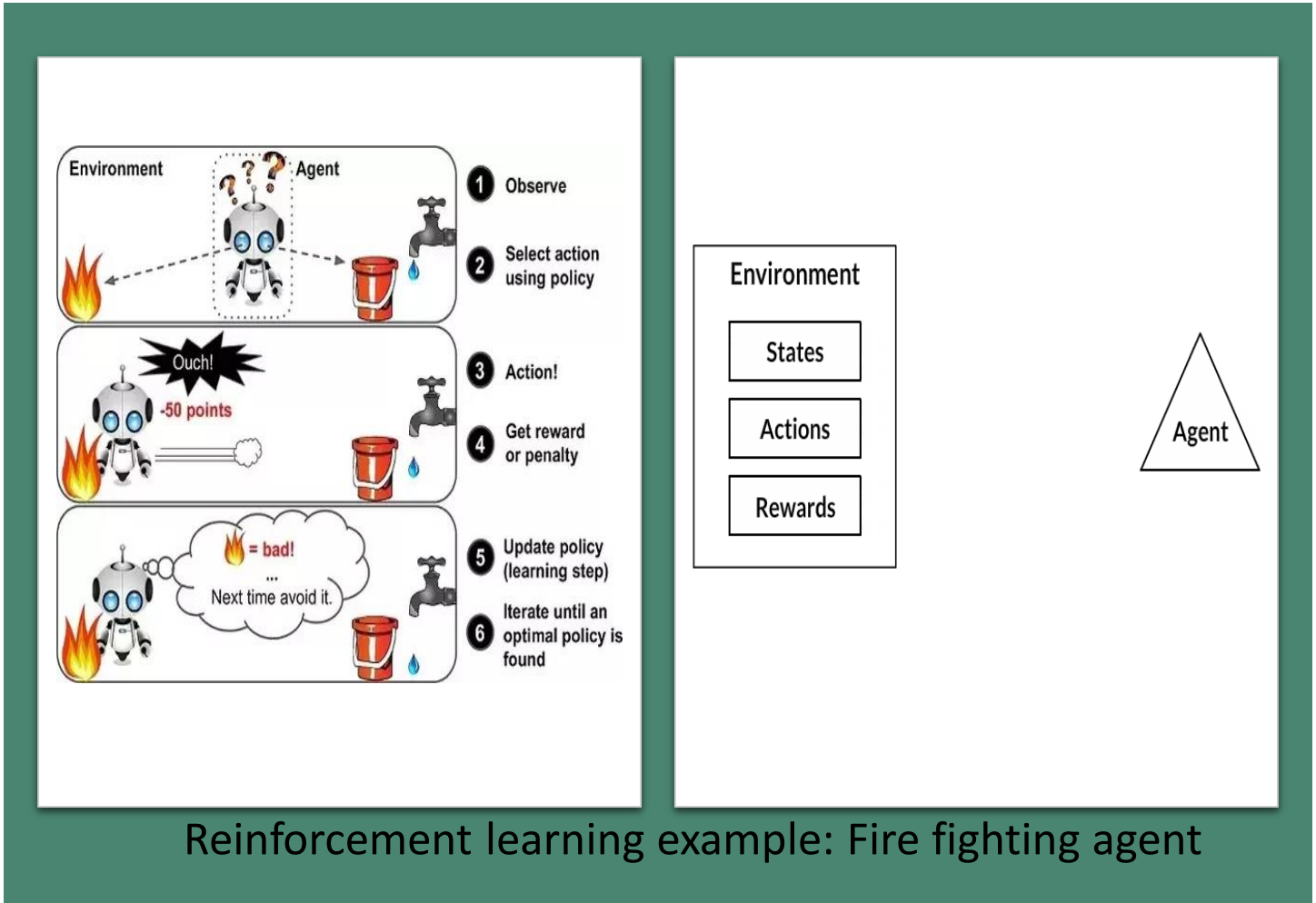
Disadvantages of Unsupervised Learning

- Unsupervised Learning is harder as compared to Supervised Learning. Since, making the inference is difficult due to unavailable labels.

- How do we know if results are meaningful since it has unlabelled data?
  - External evaluation- Expert analysis.
  - Internal evaluation- Objective function.

Reinforcement Learning

A reinforcement learning algorithm, or agent, learns by interacting with its environment. The agent receives rewards by performing correctly and penalties for performing incorrectly.



Reinforcement learning example: Fire fighting agent

Need for Reinforcement Learning

- Reinforcement learning can be used to solve very complex problems that cannot be solved by conventional techniques.
- In the absence of a training dataset, it is bound to learn from its experience.
- Reinforcement learning models can outperform humans in many tasks and learning process is similar to human learning.
- DeepMind's AlphaGo program, a reinforcement learning model, beat the world champion *Lee Sedol* at the game of *Go* in March 2016.

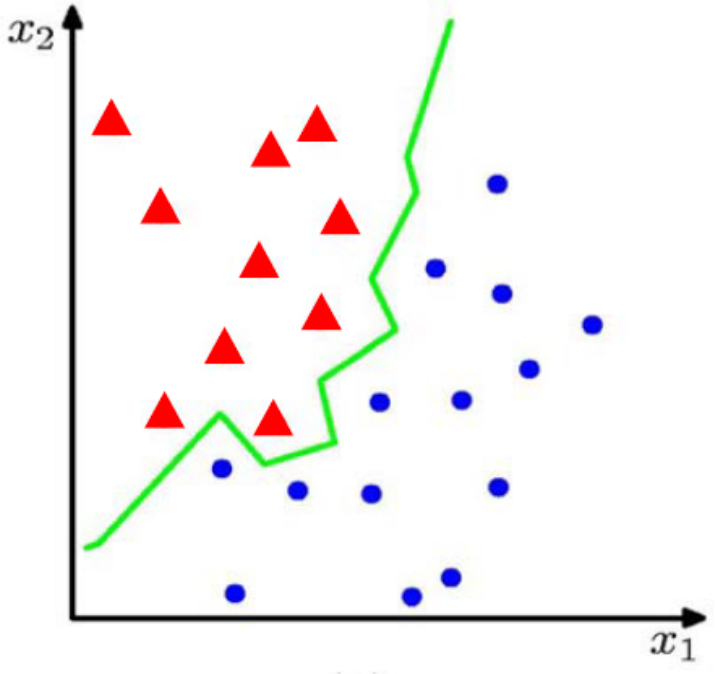
Disadvantages of Reinforcement Learning

- Reinforcement learning needs a lot of data and a lot of computation. It is data-hungry.
  - So for solving video games and puzzles it performs well.
- Reinforcement learning assumes the world is Markovian, which it is not.
  - The Markovian model describes a sequence of possible events in which the probability of each event depends only on the state attained in the previous event.

What is classification problem?

- Let there are two classes of objects.
  - Class 1: Set of dog pictures
  - Class 2: Set of cat pictures
- Problem is
  - Given a picture, you should say whether it is cat or dog.
  - For a human being it is easy…, but for a machine it is a non-trivial problem.

What is classification problem?



- Suppose we are given a training set of N observations

$$(x_1, \ldots, x_N) \text{ and } (y_1, \ldots, y_N), x_i \in \mathbb{R}^d, y_i \in \{-1, 1\}$$

- Classification problem is to estimate f(x) from this data such that

$$f(x_i) = y_i$$

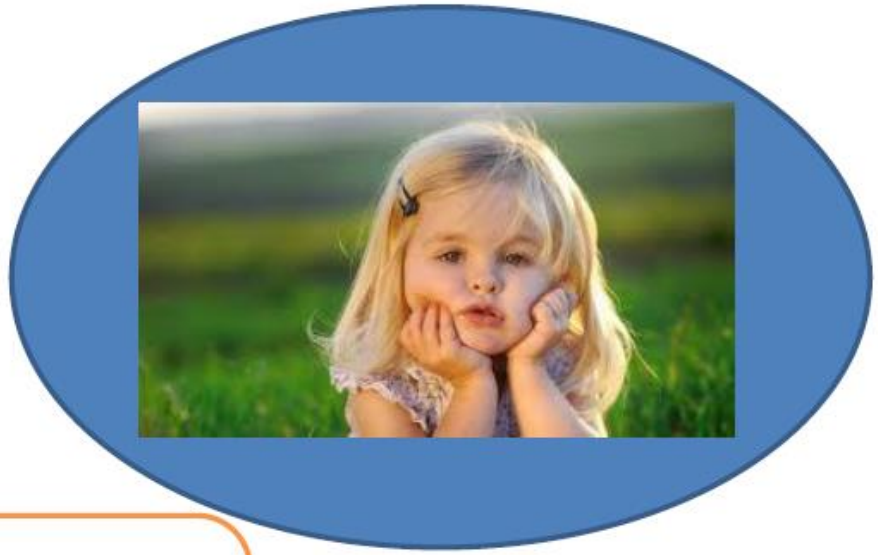
Classification: Supervised Learning

Training Phase

We have shown a set of dog pictures and a set of cat pictures to a child.

Classification: Supervised Learning

Testing Phase



DOG

This picture as it is may not be in the training set

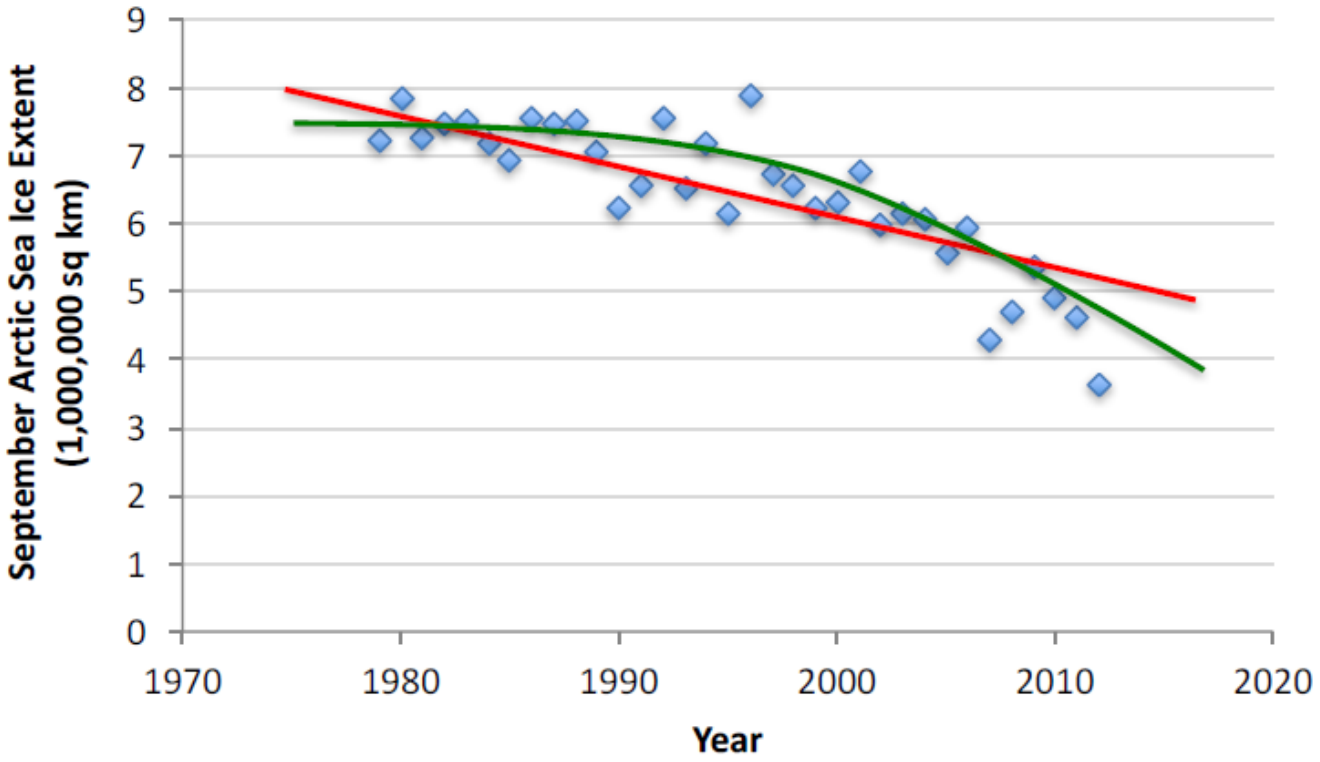
Child has done more than just remembering

What is Learning?

- Child has learnt what is it that is common among dogs … and, what is it that is common among cats… also, what are the distinguishing features/attributes.
- Child has learnt the pattern (regularity) behind all dogs and the pattern behind all cats.
- Child then recognized a test image as having a particular pattern that is unique to dogs.

What is Regression Problem?

- Given $(x_1, y_1), (x_2, y_2), \ldots, (x_n, y_n)$
- Learn a function $f(x)$ to predict y given x
  - y is real-valued == regression



Popular ML algorithms

Classification

- Linear Classifiers
- Support Vector Machines
- Decision Trees
- K-Nearest Neighbor
- Random Forest

Regression

- Linear Regression
- Logistic Regression
- Polynomial Regression

Resources: Journals

- Journal of Machine Learning Research www.jmlr.org
- Machine Learning
- IEEE Transactions on Neural Networks
- IEEE Transactions on Pattern Analysis and Machine Intelligence
- Annals of Statistics
- Journal of the American Statistical Association

Resources: Conferences

- International Conference on Machine learning (ICML)
- European Conference on Machine Learning (ECML)
- Neural Information Processing Systems (NIPS)
- Computational Learning
- International Joint Conference on Artificial Intelligence (IJCAI)
- ACM SIGKDD Conference on Knowledge Discovery and Data Mining (KDD)
- IEEE Int. Conf. on Data Mining (ICDM)

Thank You: Question?