Introduction

CE-477: Machine Learning - CS-828: Theory of Machine Learning
Sharif University of Technology
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References of the lecture are mentioned in the last slide

Course info

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- Course website: On Quera
  - Tentative schedule, slides and notes
  - Discussions
  - Policies and rules
  - HWs & solutions

Prerequisites

- Programming skills
  - Python
- Probability and statistics
- Basic linear algebra

Grading policy

- Two midterm exams: 4 + 4
- Final exam: 5 + (1 extra point)
- Homeworks (Theory & practical): 6
- Project: 1 + (0.5 extra point)
- Presentations (Extra point): 1

Text books

- Pattern Recognition and Machine Learning, C. Bishop, Springer, 2006.
- Machine Learning, T. Mitchell, MIT Press, 1998.

- Other books:
  - The elements of statistical learning, T. Hastie, R. Tibshirani, J. Friedman, Second Edition, 2008.
  - Machine Learning: A Probabilistic Perspective, K. Murphy, MIT Press, 2012.
  - Richard Sutton and Andrew Barto, Reinforcement Learning: An introduction. MIT Press, Second edition, 2017.

Outline of the course

- The learning problem? — What is learning?
- Basic supervised learning models — How to do it?
  - Linear regression
  - Linear and probabilistic classifiers
- Generalization and regularization — Can we learn?
- Computational learning theory — Can we learn?
- Supervised learning — How to do it? — Paradigms in machine learning
  - SVM
  - Neural nets
  - Decision trees
  - Instance based learning
  - Ensemble learning
- Unsupervised learning
  - Clustering – EM – GMM
  - Dimensionality reduction
- Reinforcement Learning
- Interpretability — What did we learn?

Today: the learning problem

- Example of machine learning problem
- Component of learning
- A simple model
- Paradigms in machine learning

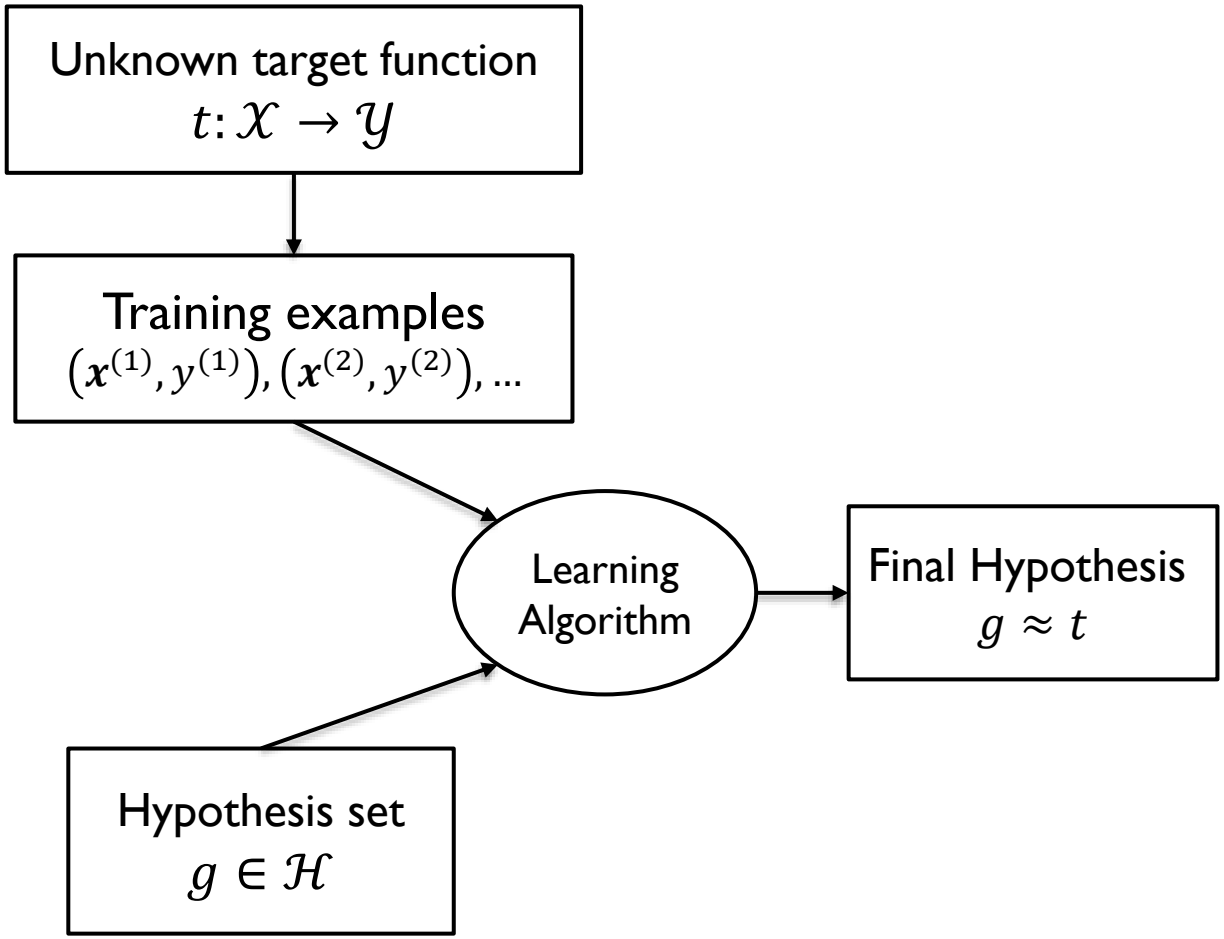
Example

- Predicting the risk of heart attack
  - Is this a risky person for heart attack? (yes or no)

age	59
gender	Female
diabetes	Yes
weight	90
…	…

- The essence of machine learning
  - A pattern exist
  - We do not know it mathematically
  - We have data on it

Components of learning

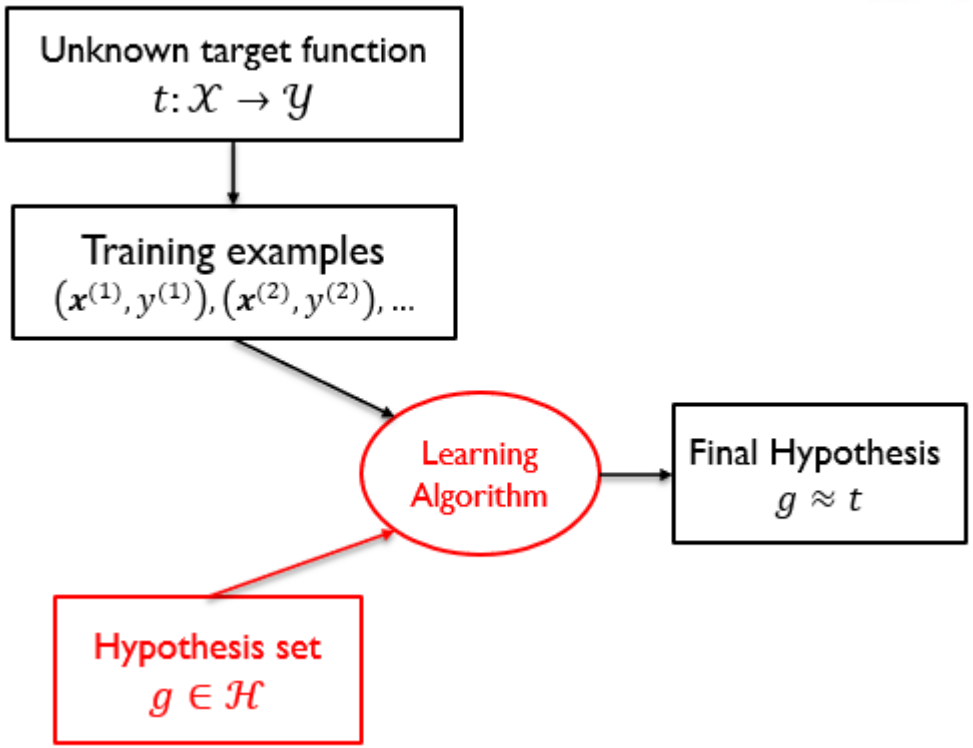


Solution component

- The learning model:
  - The hypothesis set

$$\mathcal{H} = \{h\} \qquad g \in \mathcal{H}$$

  - The learning algorithm
    - Search the hypothesis set to find the best estimate of the target function



A simple hypothesis set

- Predicting the risk of heart attack
  - Is this a risky person for heart attack? (yes (+1) or no (-1))
- For input vector $\boldsymbol{x} = [x_1, \ldots, x_d]$, a person attributes

x_1:	age	59
x_2:	gender	Female
x_3:	diabetes	Yes
x_4:	weight	90
…		…

- A simple hypothesis set: The perceptron

A simple hypothesis set

- A case with a high risk of heart attack

$$A\ risky\ person\text{:}\ \ if \sum_{i=1}^{d} w_i x_i > threshold$$

- Our hypothesis set:

$$h(\boldsymbol{x}) = sign\ (\sum_{i=1}^{d} w_i x_i\ - threshold)$$

A learning algorithm for perceptron

$$h(\boldsymbol{x}) = sign\left(\sum_{i=1}^{d} w_i x_i - w_0\right)$$

- Considering $x_0 = 1$,

$$h(\boldsymbol{x}) = sign\left(\boldsymbol{w}^T \boldsymbol{x}\right)$$

- Given a training set: $\left(\boldsymbol{x}^{(1)}, y^{(1)}\right)$, $\left(\boldsymbol{x}^{(2)}, y^{(2)}\right)$, …
  - Attributes of a set of normal or case of heart attack persons

A learning algorithm for perceptron

Repeat

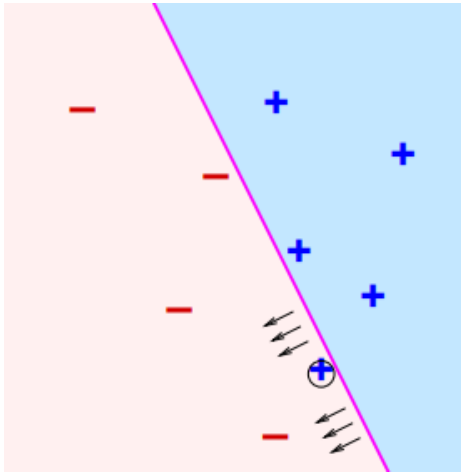
Pick a misclassified point $\left(\boldsymbol{x}^{(i)}, y^{(i)}\right)$ from training data

$$sign\left(\boldsymbol{w}^T \boldsymbol{x}^{(i)}\right) \neq y^{(i)}$$

Update $\boldsymbol{w}$:

$$\boldsymbol{w} = \boldsymbol{w} + y^{(i)} \boldsymbol{x}^{(i)}$$

Until all training data points are correctly classified by g



[1]

Generalization

- We don’t intend to memorize data but want to distinguish the pattern.

- A core objective of learning is to generalize from the experience.
  - Generalization: ability of a learning algorithm to perform accurately on new, unseen examples after having experienced?

Experience in ML

- Basic premise of learning:
  - Using a set of observations to uncover an underlying process

- We have different types of (getting) observations in different types or paradigms of ML methods

A definition of ML

- Tom Mitchell (1998):
  - A computer program is said to learn a **task** from **experience** if its **performance** improves with experience

- Using the observed data to make better decisions
  - Generalizing from the observed data

Paradigms of machine learning

- Supervised learning

  (input, correct output)
- Unsupervised learning

  (input, ?)
- Reinforcement learning

  (input, some output, grade for this output)

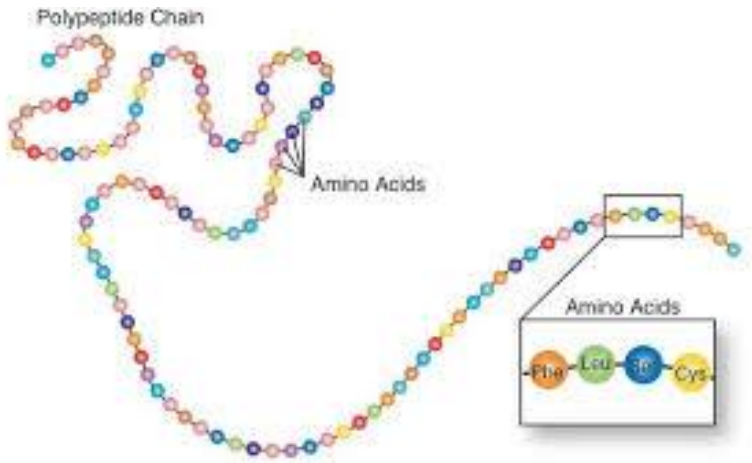
- Other paradigms: semi-supervised learning, online learning, active learning, etc

Supervised learning

- Supervised learning

  (input, correct output)

  - Our risky heart attack identifier
  - Predicting the function of protein sequences



[https://medium.com]

Supervised learning

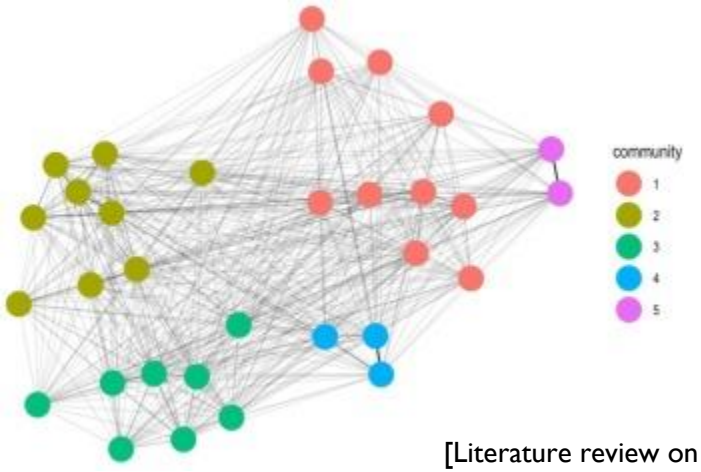
- Extract useful information as features
  - Represent a protein sequence in a vectorized format
    - Proteins with a length of 1000 amino-acids
    - Each amino-acid is represented as a one hot vector

x_1	x_2	…	x_{999}	x_{1000}
I	0		0	0
0	I		I	0
…	…		…	…
0	0		0	0
0	0		0	I

Unsupervised learning

- Revealing structure in the observed data

  (input, ?)
  - Clustering: partitioning of data into groups of similar data points.
    - Customer segmentation in marketing
    - Community detection in social networks
      - Users are represented with the



[Literature review on data analytics for social microblogging platforms]

Reinforcement learning

- Partial (indirect) feedback, no explicit guidance
  (input, some output, grade for this output)
  - AlphaZero
    - DeeepMind chess player
  - Autonomous driving

Relation to other fields

- **Statistics**
  - The goal is the understanding of the data at hand
- **Artificial Intelligence**
  - The goal is to build an intelligent agent
- **Data Mining**
  - The goal is to extract patterns from largescale data
- **Data Science**
  - The science encompassing collection, analysis, and interpretation of data

- The goal of **machine learning** is the underlying mechanisms and algorithms that allow improving our knowledge with more data

Some Learning Application Areas

- Computer Vision (Photo tagging, face recognition,…)
- Natural language processing (e.g., machine translation)
- Robotics
- Speech recognition
- Autonomous vehicles
- Social network analysis
- Web search engines
- Medical outcomes analysis
- Marketing (stock prediction)
- Computational biology
- Self-customizing programs (recommender systems)

Top conferences for ML

- Neural information processing systems (NeurIPS)
- International conferences on learning representations(ICLR)
- International conference on machine learning (ICML)
- Computer vision and pattern recognition (CVPR)
- AAAI Conference on Artificial Intelligence
- …

References

- [1]: Yaser Abu-Mostafa, Learning from data, Caltech
- [2]: Mahdieh Soleymani, Machine learning, Sharif university of technology
- [3]: Pradeep Ravikumar, Machine learning, CMU