CS 480 – Introduction to Artificial Intelligence

Topic: Learning – Intro

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LEARNING

- What's learning?
- Intro to Chapter 19: *"In which we describe agents that can improve their behavior through diligent study of past experiences and predictions about the future."*
- We do not make any philosophical statements about whether the agent is *truly* learning
- *"An agent is learning if it improves its performance after making observations about the world."*

Why Learn and not program directly?

- We cannot anticipate all possible situations that the agent might find itself in
- Time/location/context changes knowledge and rules
- We might not know the solution crisp enough to program it
- We might not have time to encode all the knowledge

What to learn?

- Which action to take in a state (state $\rightarrow$ action)
- Outcomes of our actions (action $\rightarrow$ state)
- Mapping percepts to world states (percept $\rightarrow$ state)
- Utility of the states (state $\rightarrow$ utility)
- and more…

FEEDBACK

1. Unsupervised learning
   - No feedback; the agent discovers patterns in the data
   - E.g., clustering, dimensionality reduction, outlier detection
2. Supervised learning
   - Feedback: input-output pairs
   - E.g., classification, regression, ranking
3. Reinforcement learning
   - Feedback: rewards

Episodic vs Sequential

- Supervised and unsupervised learning are often episodic
  - E.g., speech recognition, medical diagnosis, credit score prediction, …
- Reinforcement learning is often sequential
  - E.g., game playing

1. Unsupervised Learning

- Given a set of objects: X
- Density estimation, P(X)
  - E.g., Bayesian networks
- Clustering
  - E.g., K-Means, Expectation Maximization (EM), Latent Dirichlet allocation (LDA), DBScan, …
- Dimensionality reduction
  - Principal component analysis (PCA), independent component analysis (ICA), …

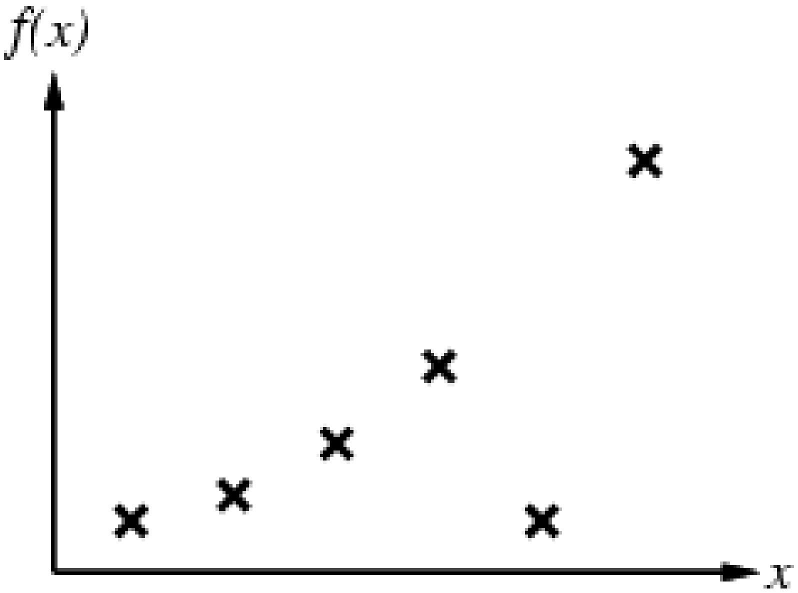
2. Supervised learning

- Given objects with their labels, <X,Y>
- Learn a function f that maps objects, X, to labels, Y
- We want f to perform well on unseen objects
- Several applications
  - Face recognition, speech recognition, medical diagnosis, fraud detection, credit scoring, home value prediction, temperature prediction, …
- If Y is
  - Discrete, the task is called classification
  - Continuous, the task is called regression

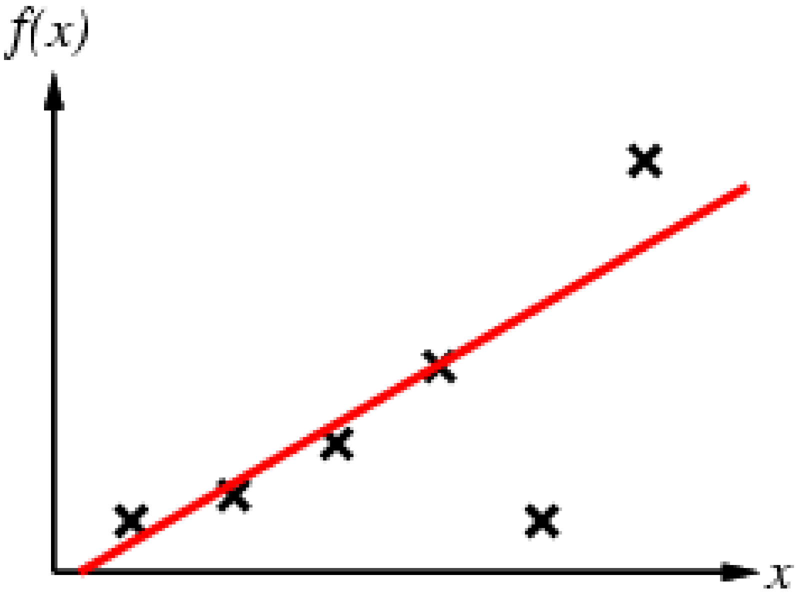
Function Fitting?

- Isn't classification/regression simply "function fitting?"
- Yes and No
- The purpose is to generalize and perform well on unseen data
- We don't want to underfit or overfit to the training data

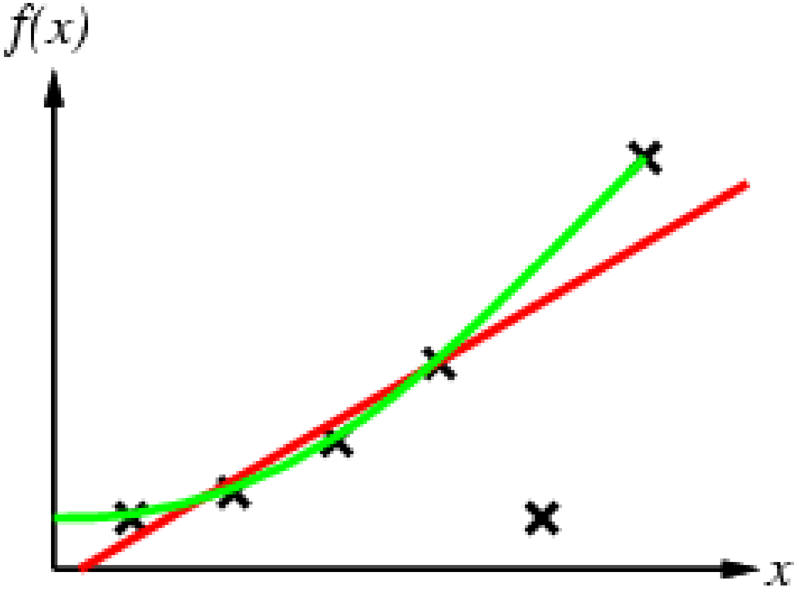
Curve Fitting



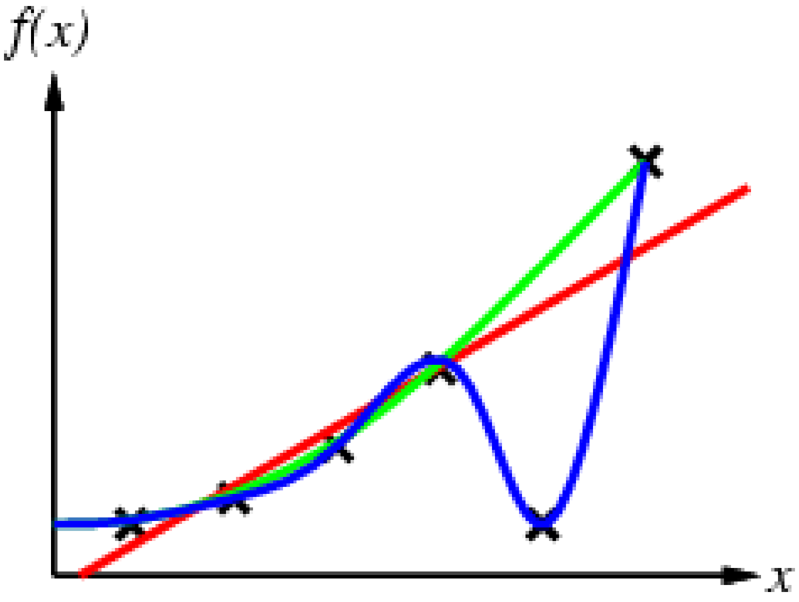
Curve Fitting



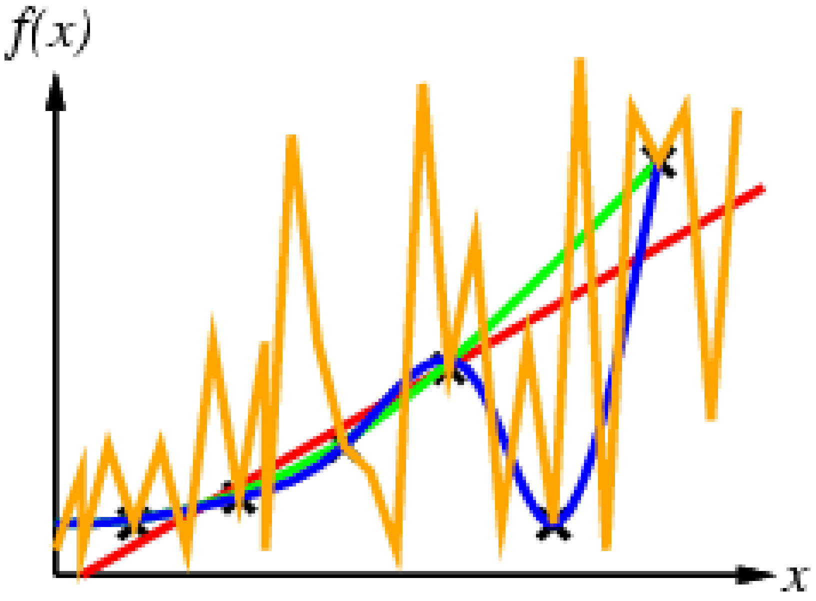
Curve Fitting



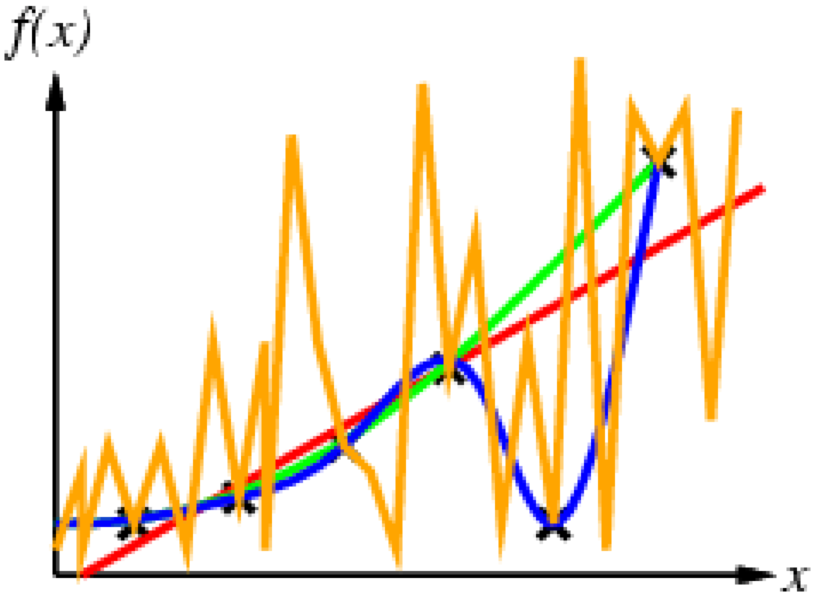
CURVE FITTING



Curve Fitting



CURVE FITTING

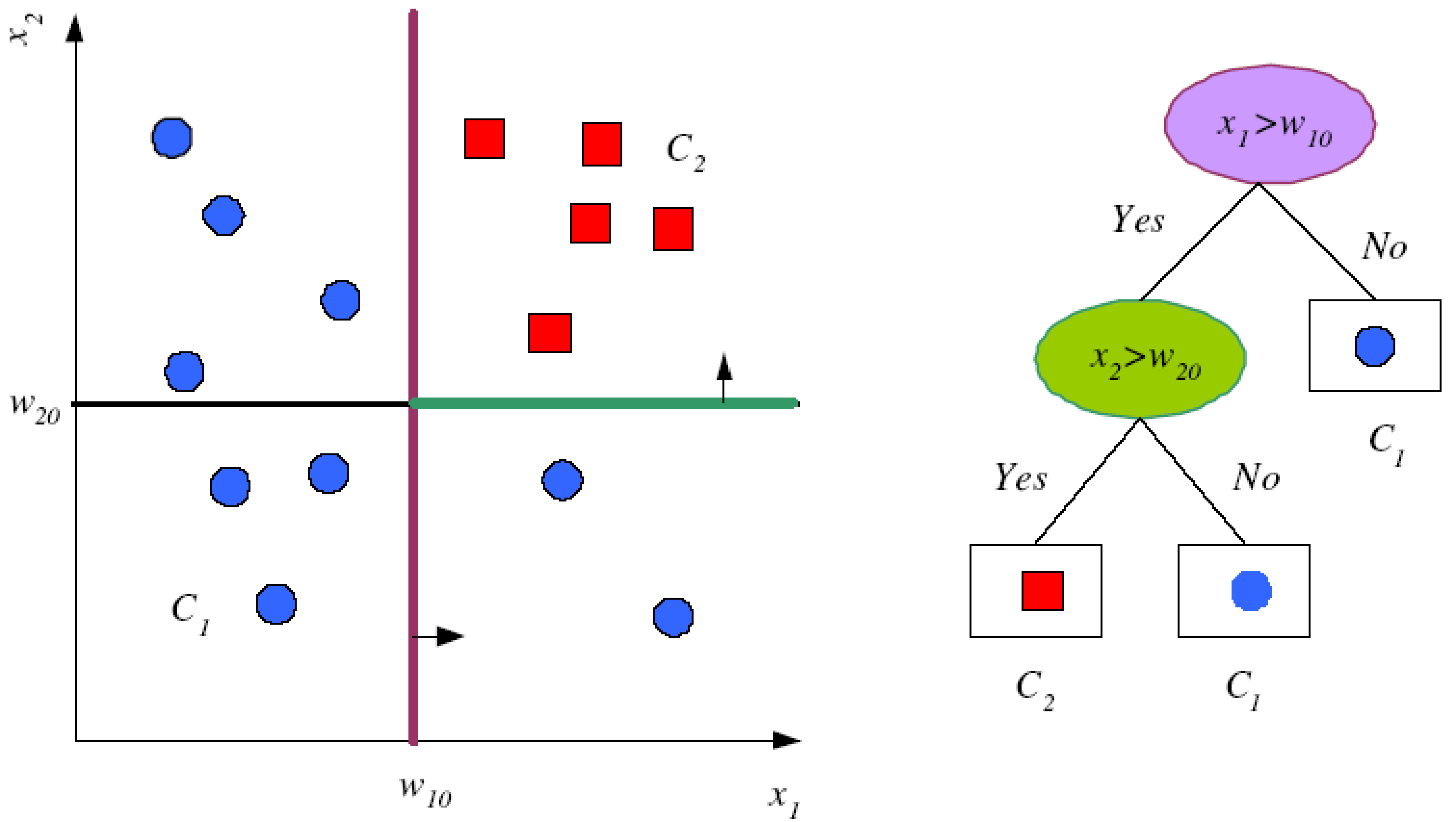


So, which function is the "right" one?

Classification

- Decision trees
- Nearest neighbors
- Naïve Bayes
- Logistic regression
  - Note: it's called regression, but it is a classification model
- Support vector machines
- Neural networks

DECISION TREES



Learning: how do you learn a small tree that generalizes to unseen data?

Image credit: Ethem Alpaydin. Introduction to Machine Learning. 3rd Edition. http://www.cmpe.boun.edu.tr/~ethem/i2ml3e

Naïve Bayes

- Given $X_1, X_2, \ldots, X_n$, and class Y
- Assume $X_i \perp X_j \mid Y$

$$P(Y|X_1, X_2, \ldots, X_n) = \frac{P(X_1, X_2, \ldots, X_n|Y)P(Y)}{P(X_1, X_2, \ldots, X_n)} = \frac{P(Y)\prod_{i=1}^{n} P(X_i|Y)}{P(X_1, X_2, \ldots, X_n)}$$

We need to estimate $P(Y)$ and $P(X_i \mid Y)$

Logistic Regression

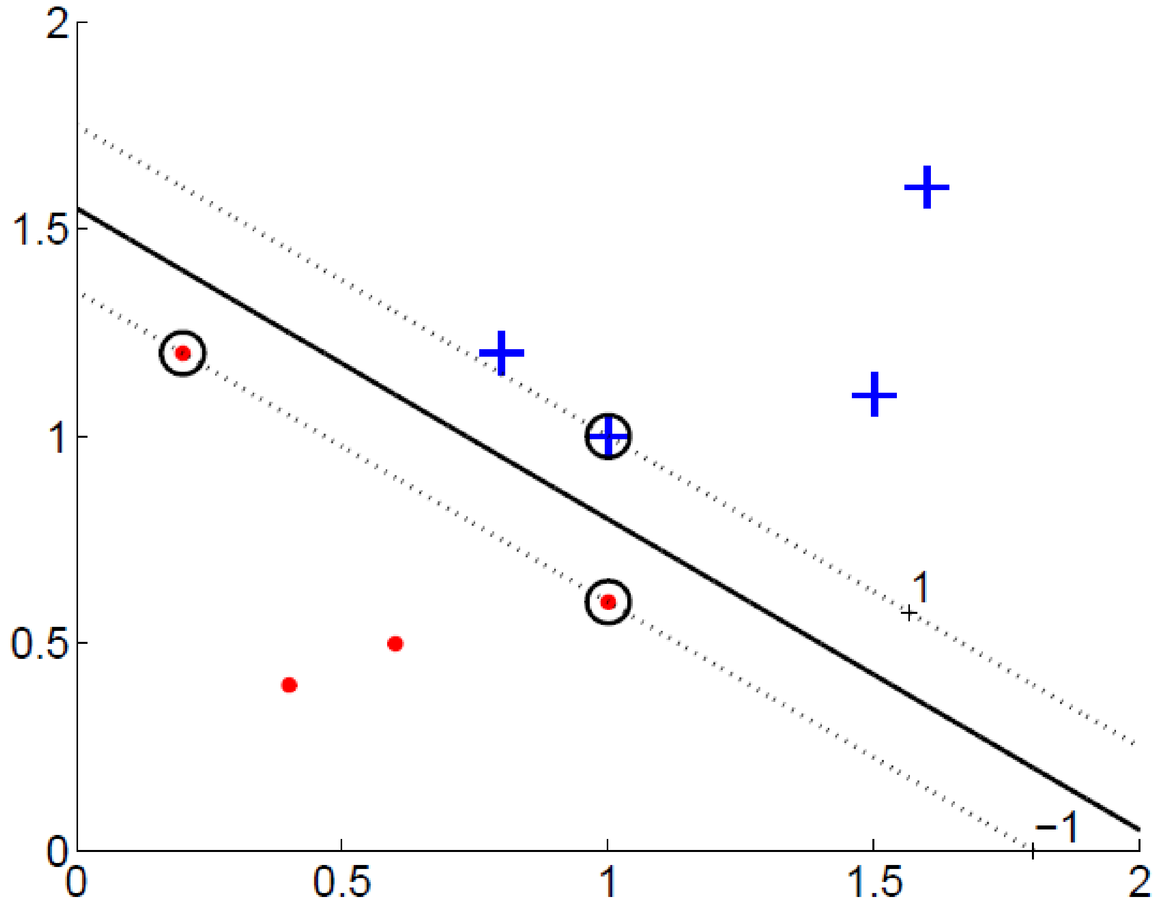
- Learns $P(Y|\boldsymbol{X})$ directly, without going through $P(\boldsymbol{X}|Y)$ and $P(Y)$
- Assumes $P(Y|\boldsymbol{X})$ follows the logistic function

$$P(Y = false \mid X_1, X_2, \cdots, X_n) = \frac{1}{1 + e^{w_0 + \sum_{i=1}^{n} w_i X_i}}$$

$$P(Y = true \mid X_1, X_2, \cdots, X_n) = \frac{e^{w_0 + \sum_{i=1}^{n} w_i X_i}}{1 + e^{w_0 + \sum_{i=1}^{n} w_i X_i}}$$

- Learning: estimate the weights $w_0, w_1, \ldots, w_n$

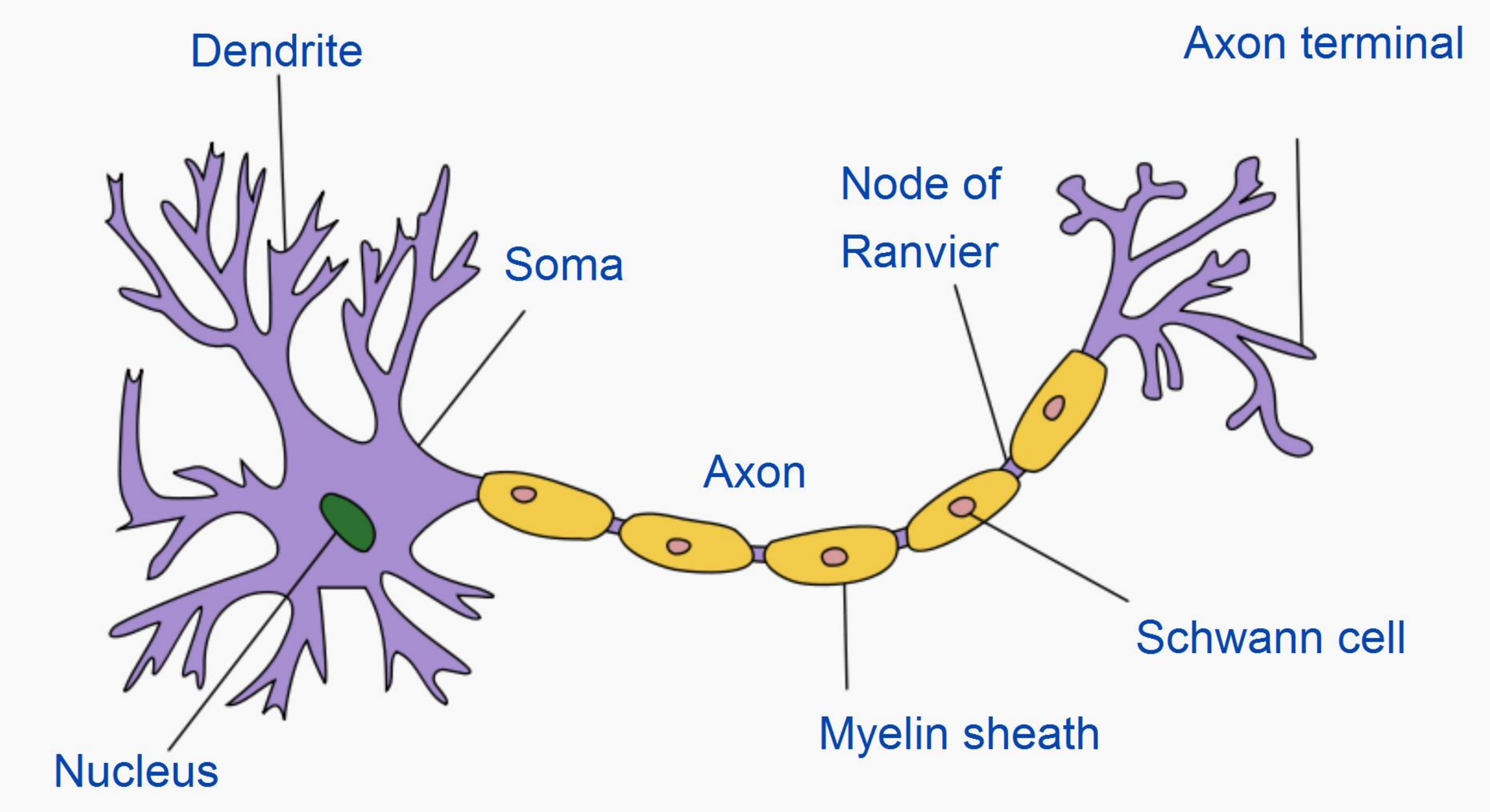
Support Vector Machines



$$\min \frac{1}{2} w^T w \text{ subject to } y^{(d)}\left(w^T x^{(d)} + b\right) \geq +1$$

Image credit: Ethem Alpaydin. Introduction to Machine Learning. 3rd Edition. http://www.cmpe.boun.edu.tr/~ethem/i2ml3e

Neuron


Dendrite
Axon terminal
Node of
Ranvier
Soma
Axon
Schwann cell
Myelin sheath
Nucleus

WHAT AN ARTIFICIAL NEURON DOES

- Takes a weighted sum of its inputs
  - $w_0 + \sum_{i=1}^{k} w_i x_i$
  - Assume that there is always a constant input 1, that is, $x_0 = 1$. Then,
  - $\sum_{i=0}^{k} w_i x_i$
- Passes this sum through its activation function
  - $f\left(\sum_{i=0}^{k} w_i x_i\right)$

MULTILAYER NEURAL NETWORKS

- An input layer
- One or more hidden layers
- An output layer

- Learning: estimate the weights

Regression

- Linear regression
- Ridge
- Lasso
- Support vector machines
- Decision trees
- Nearest neighbors
- Gaussian processes

3. Reinforcement Learning

- Agent interacts with the environment and receives rewards
  - E.g., play a game and receives a reward (which could be negative) after the game is over
- Goal: learn to maximize future rewards
- Might not receive a reward for each action
  - E.g., in the game of chess, the agent does not receive feedback for each move
  - Providing a reward at the end is easier to specify than providing feedback on each move
- Might need to learn the transition model (from one state to another) and/or the reward function
- Has to balance between exploration and exploitation

We'll Cover

- Unsupervised learning
  - Maximum likelihood estimation for density estimation in Bayesian networks
- Supervised learning
  - Naïve Bayes
- How related courses touch on ML
  - CS 584 – Machine Learning
    - All three types of ML; focuses on unsupervised and supervised learning
  - CS 577 – Deep learning
  - CS 422/522 – Data mining
    - Decision trees, random forests, support vector machines with a focus on data
  - CS 581 – Advanced AI
    - Reinforcement learning (and of course other advanced AI topics)

SCIKIT-LEARN

- An open-source Python package for primarily unsupervised and supervised learning
- https://scikit-learn.org/stable/
  - Preprocessing
  - Classification
  - Regression
  - Clustering
  - Dimensionality reduction