DS-GA 3001.007 Introduction to Machine Learning

Lecture 2

Agenda

- Review
  - What are the different types of ML?
  - How to use ML for data science?
  - What are the components of ML?
- Lesson
  - Perceptron Algorithm
- Demo
  - Churn analysis

Reminders

- Section
  - Section 008 Thursdays 2:25-3:15 pm (60th 5th Avenue, Room 115)
  - Access to https://iml-f19.jupyter.hpc.nyu.edu
- Homework 1
  - Due September 18 11:59pm on Gradescope
- NYU Classes
  - Lessons
  - Demos
  - Labs

Types of Machine Learning

- Supervised Learning
  - Classification
  - Regression

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- Supervised Learning
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  - Regression
- Unsupervised Learning
  - Clustering
  - Dimension Reduction

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- Supervised Learning
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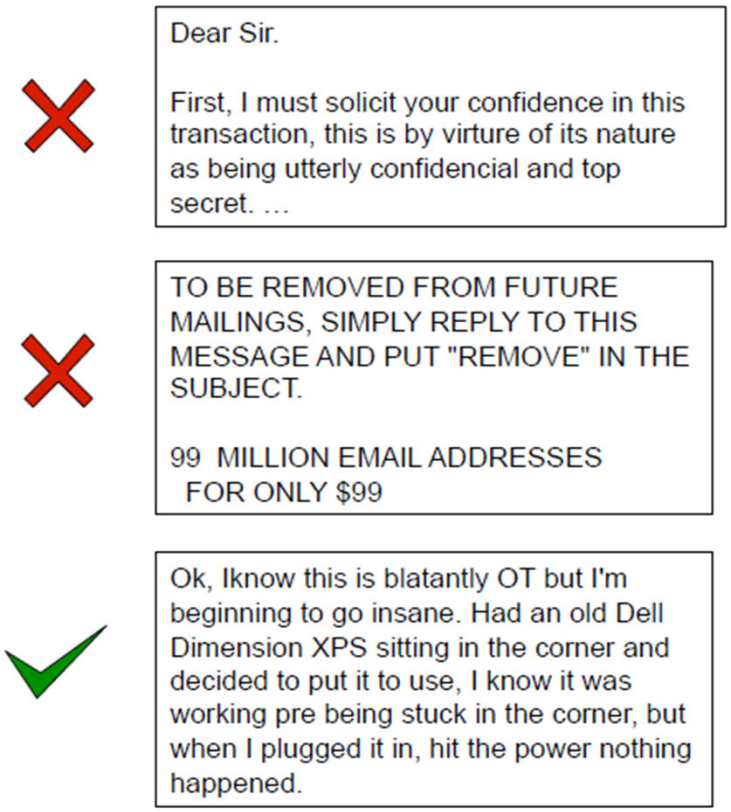
  - Regression
- Unsupervised Learning
  - Clustering
  - Dimension Reduction
- Reinforcement Learning

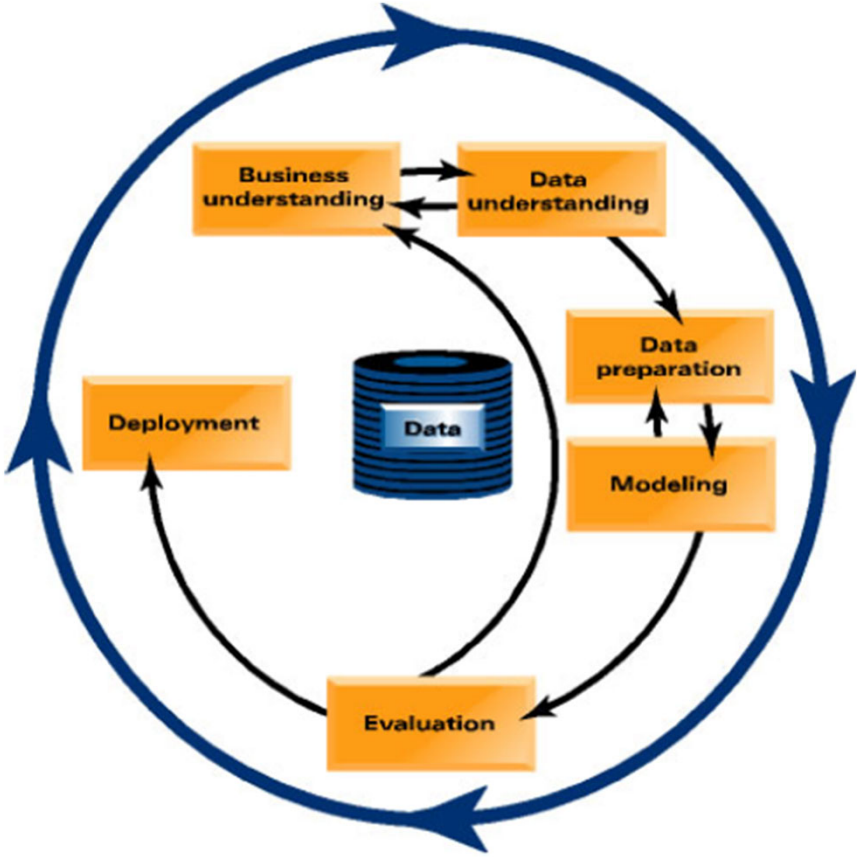
Types of Machine Learning



How to use machine learning for data science?

- Components of Data Science
  - Formulate a problem
  - Gather data
  - Explore data
  - Determine a model for prediction and inference
  - Evaluate findings

How to use machine learning for data science?



Components of Machine Learning Application

- Sampling data
  - Train Sample
  - Validation Sample
  - Testing Sample

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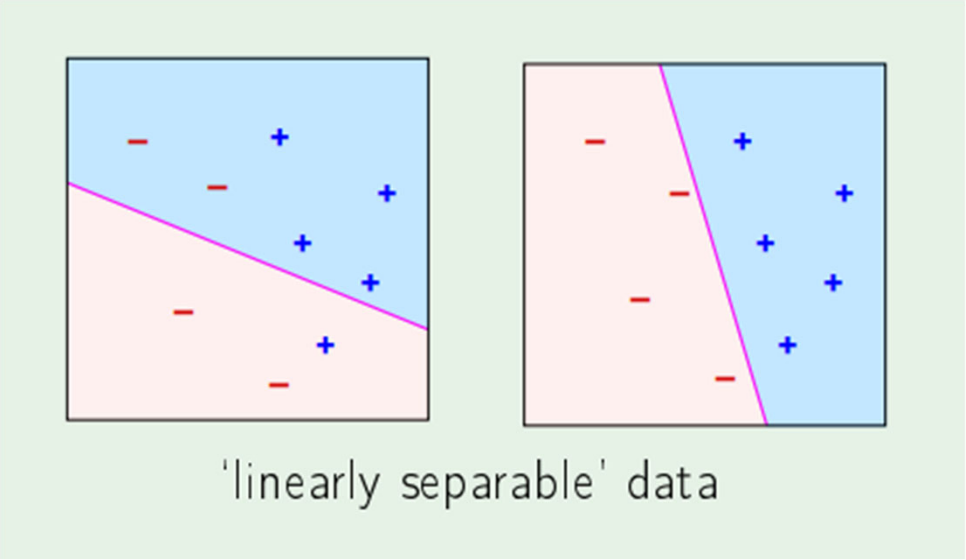
  - Hyperparameters
- Error Analysis
  - Metrics

Components of Machine Learning Application



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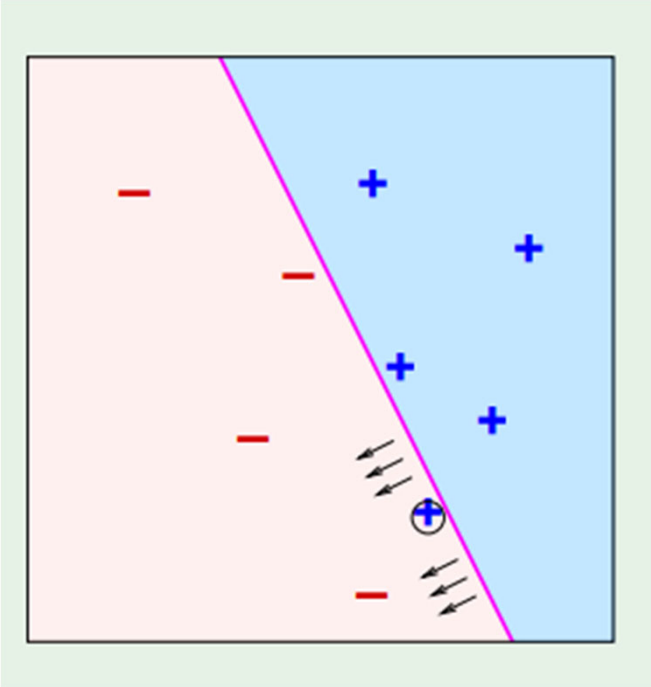
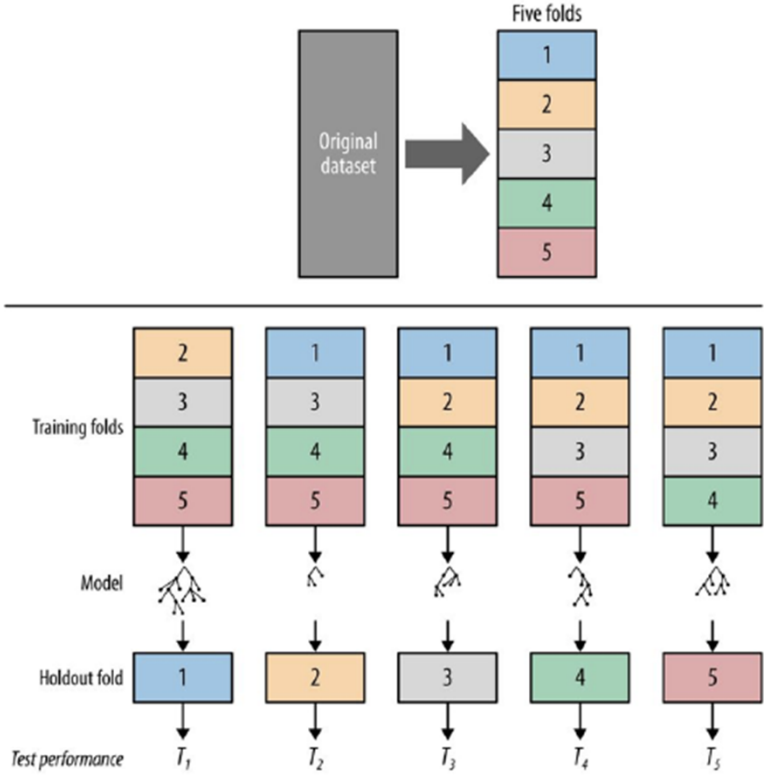


Train, Validate, Test



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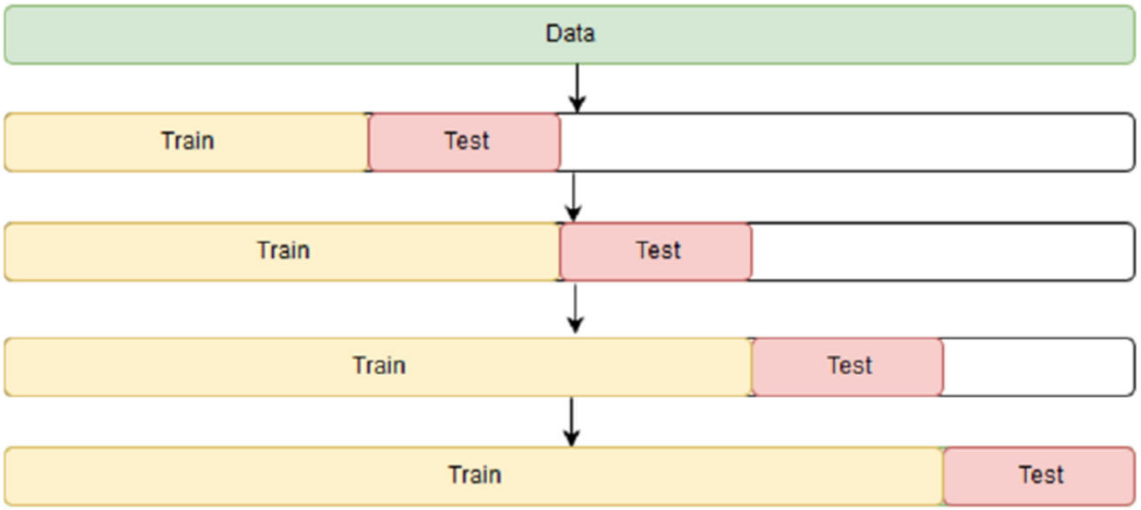
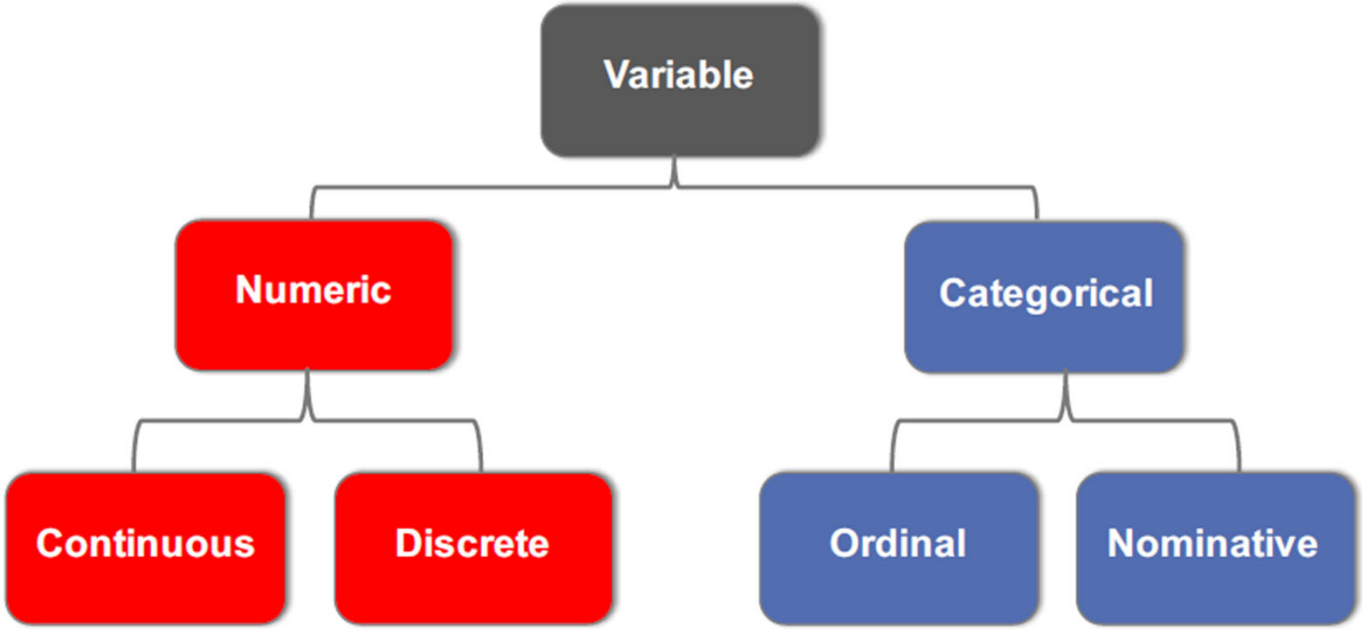


Features and Labels



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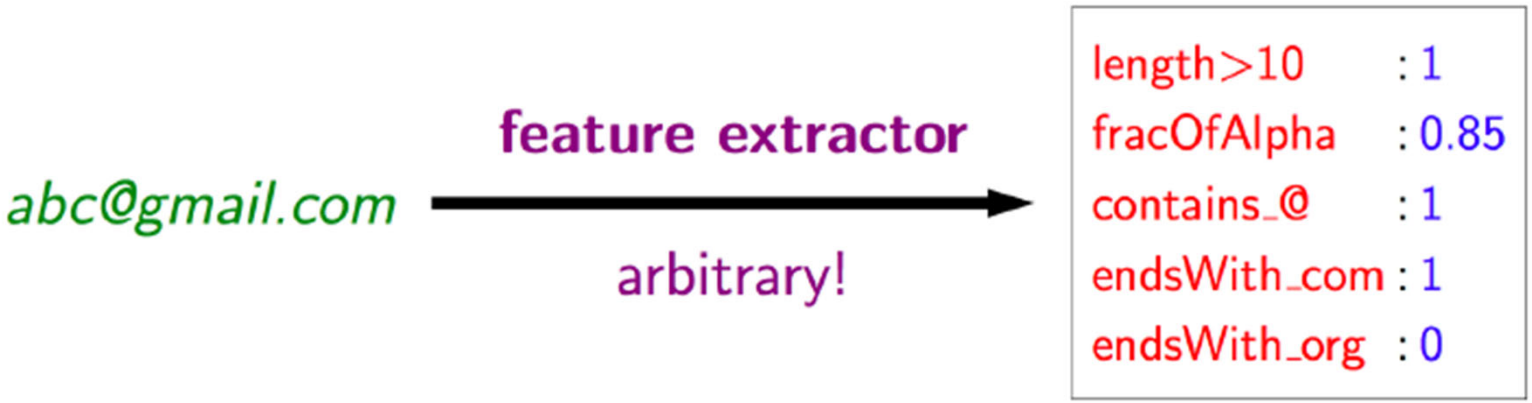

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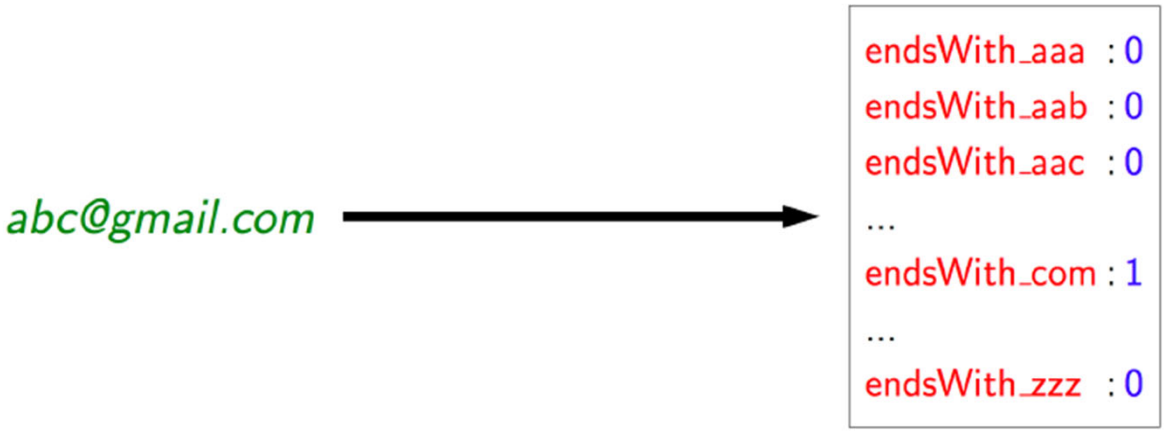


Features and Labels

Array representation (good for dense features):

```
[0.85, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0]
```

Map representation (good for sparse features):

```
{"fracOfAlpha": 0.85, "contains_@": 1}
```

Features and Labels

> Anyone knows how much it costs to host a web portal ?
> Well, it depends on how many visitors youre expecting. This can be anywhere from less than 10 bucks a month to a couple of $100. You should checkout http://www.rackspace.com/ or perhaps Amazon EC2 if youre running something big..

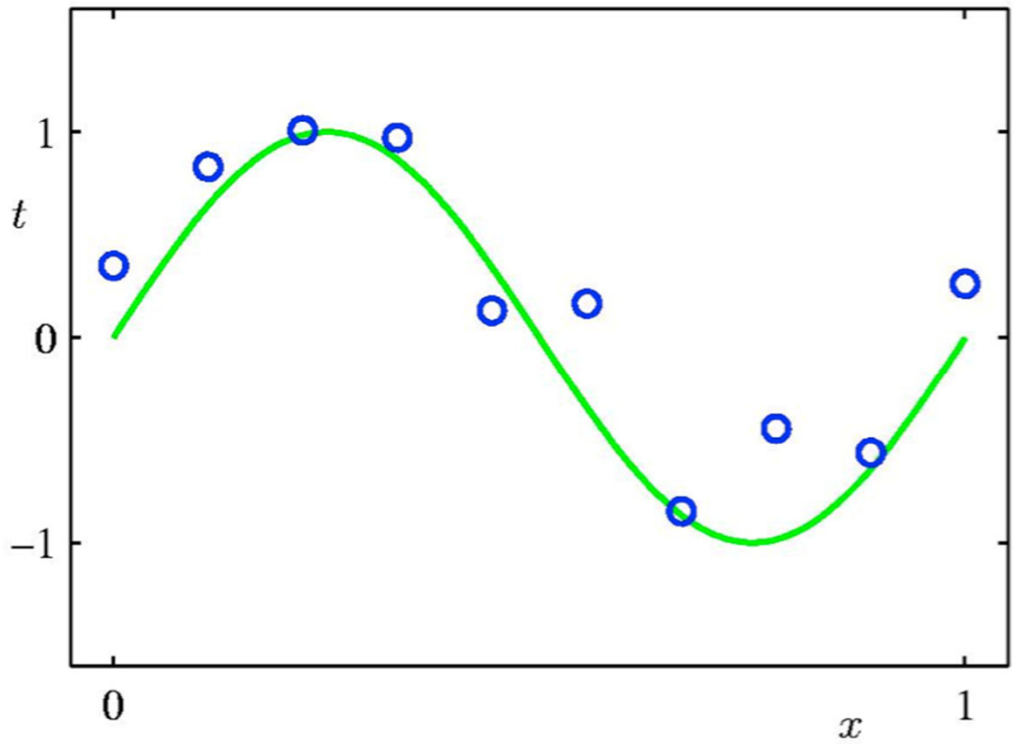
To unsubscribe yourself from this mailing list, send an email to: groupname-unsubscribe@egroups.com

Figure 1: Sample e-mail in SpamAssassin corpus before pre-processing.

anyon know how much it cost to host a web portal well it depend on how mani visitor your expect thi can be anywher from less than number buck a month to a coupl of dollarnumb you should checkout httpaddr or perhap amazon ecnumb if your run someth big to unsubscrib yourself from thi mail list send an email to emailaddr

Figure 2: Pre-processed version of the sample e-mail from Figure 1.

Hypotheses and Hyperparameters



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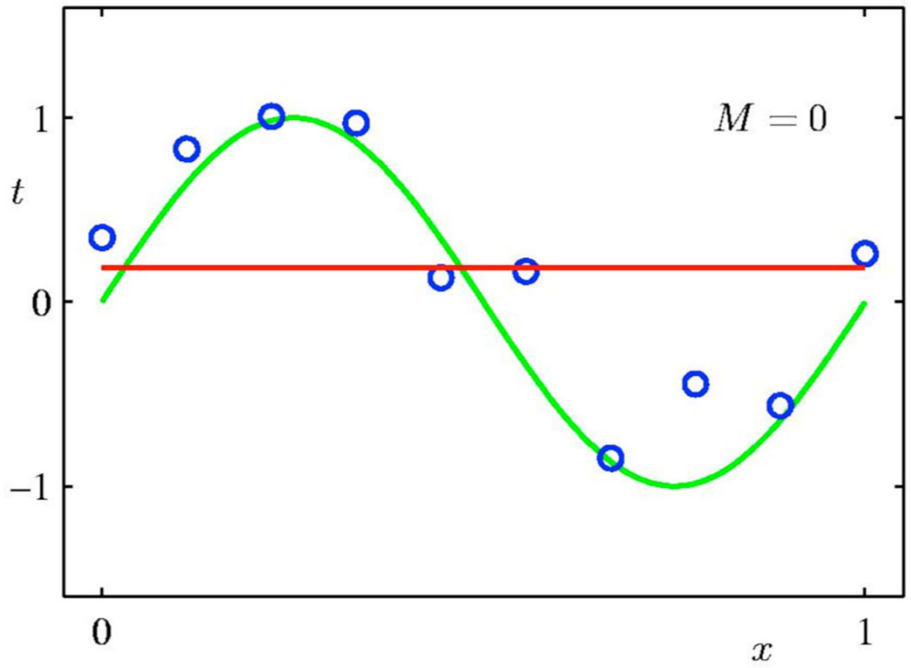

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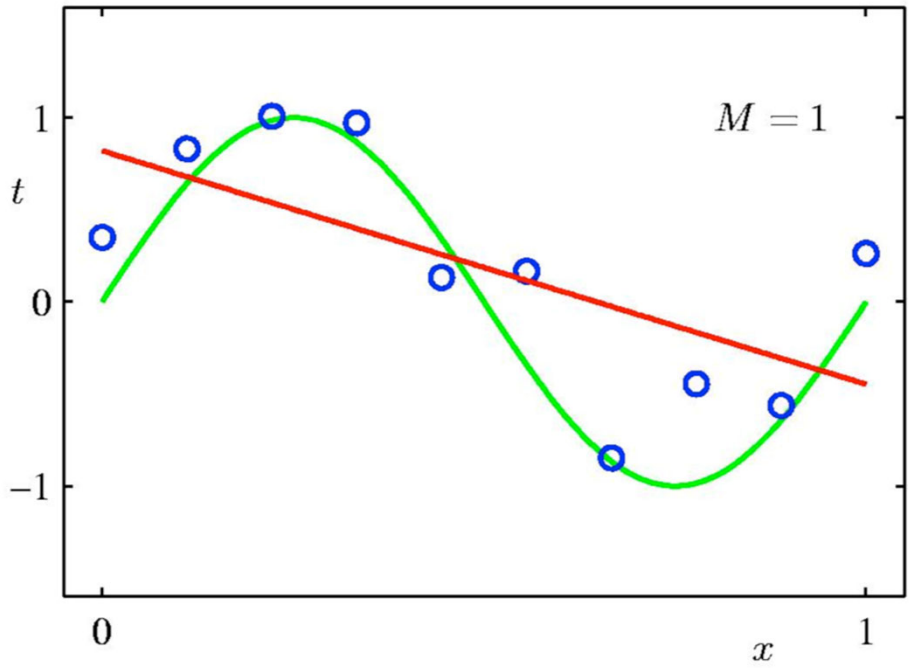

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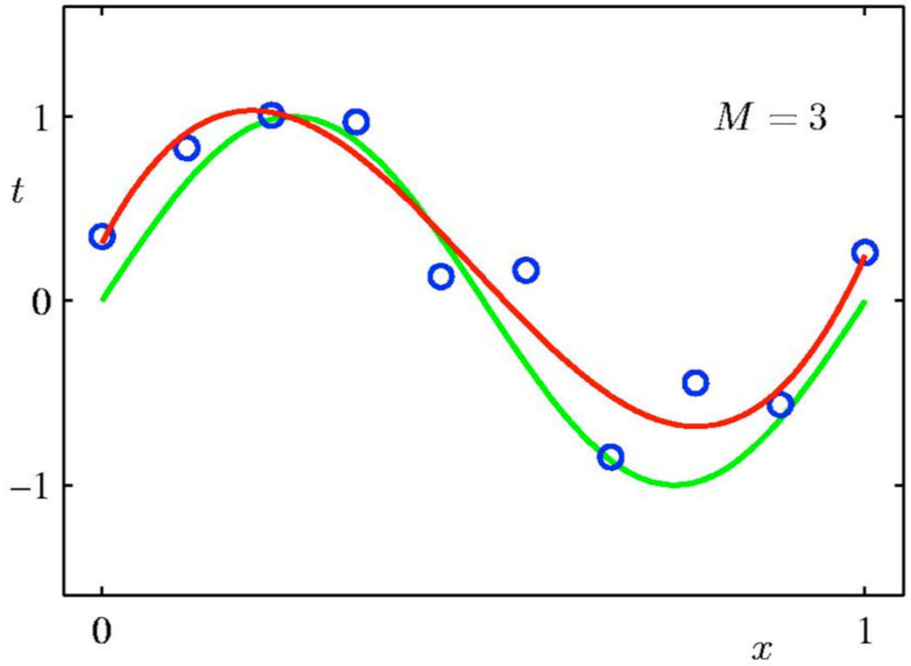

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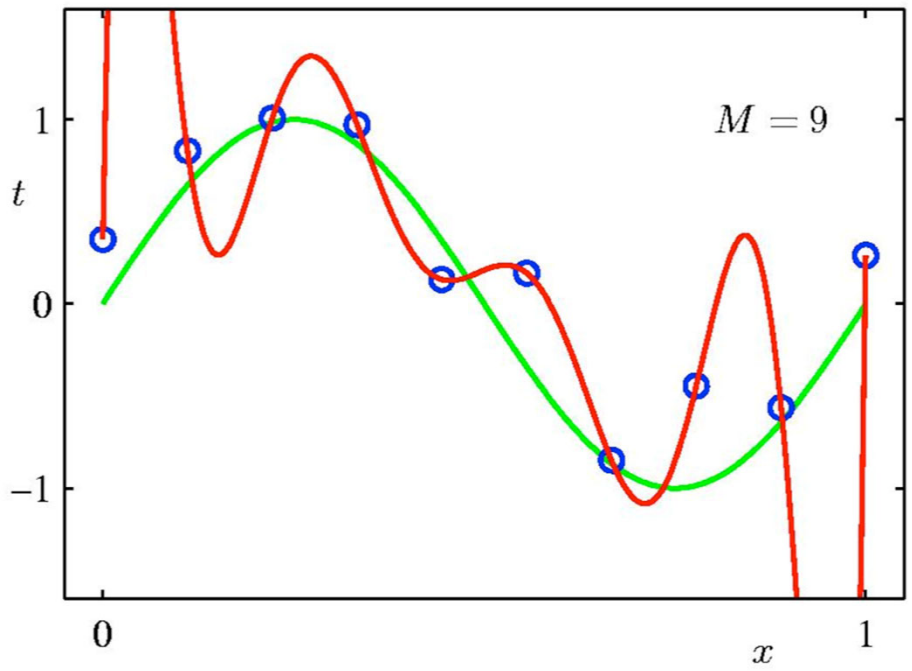

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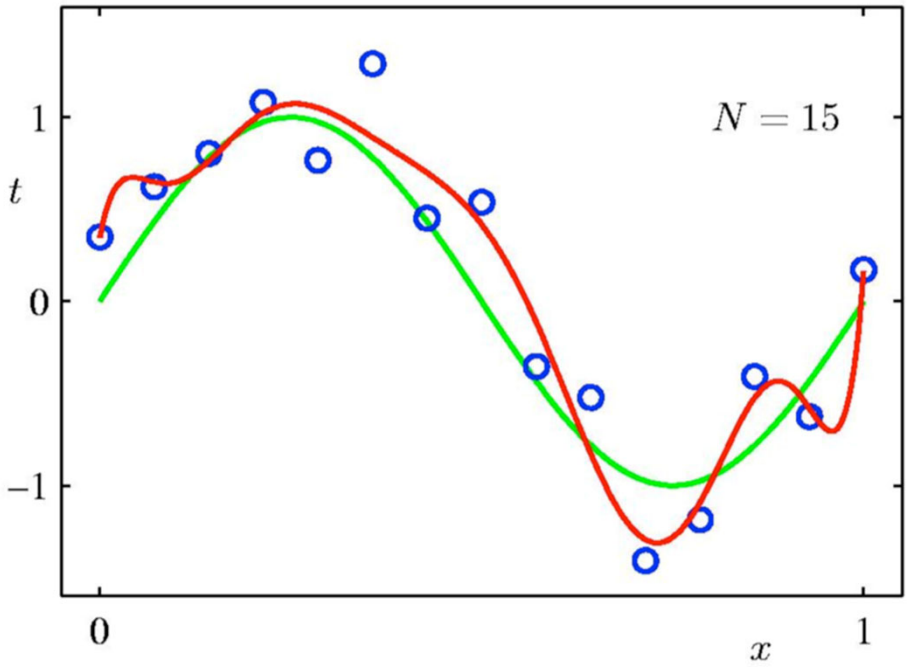

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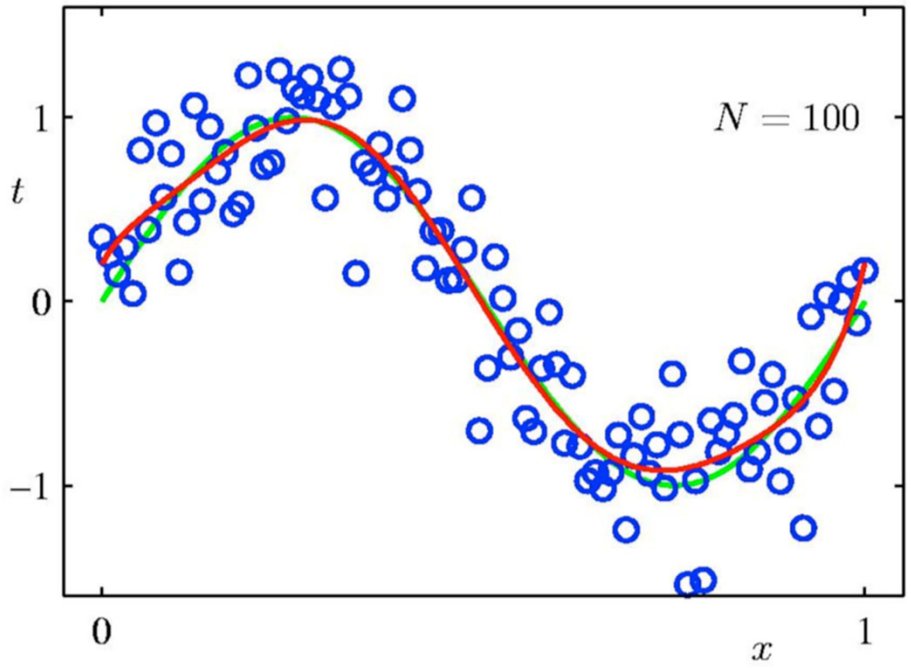

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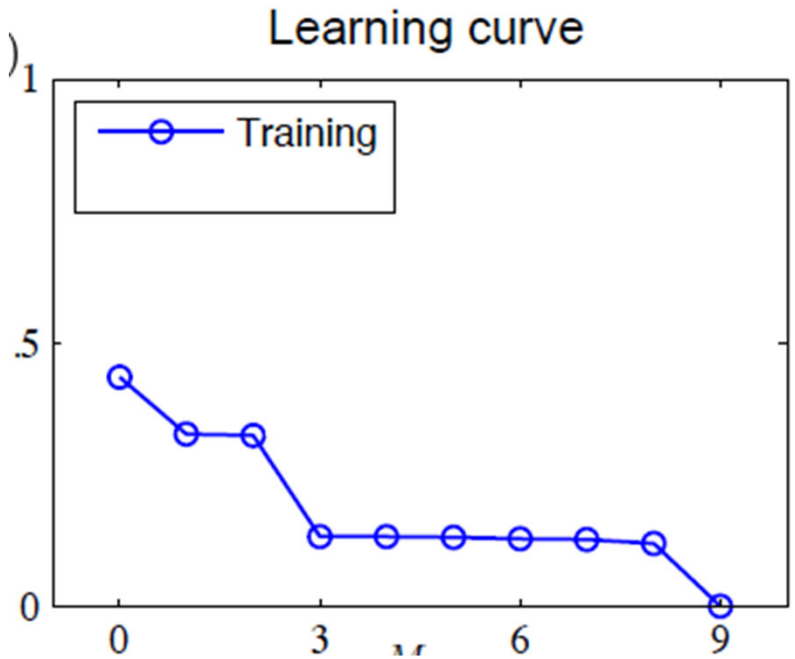

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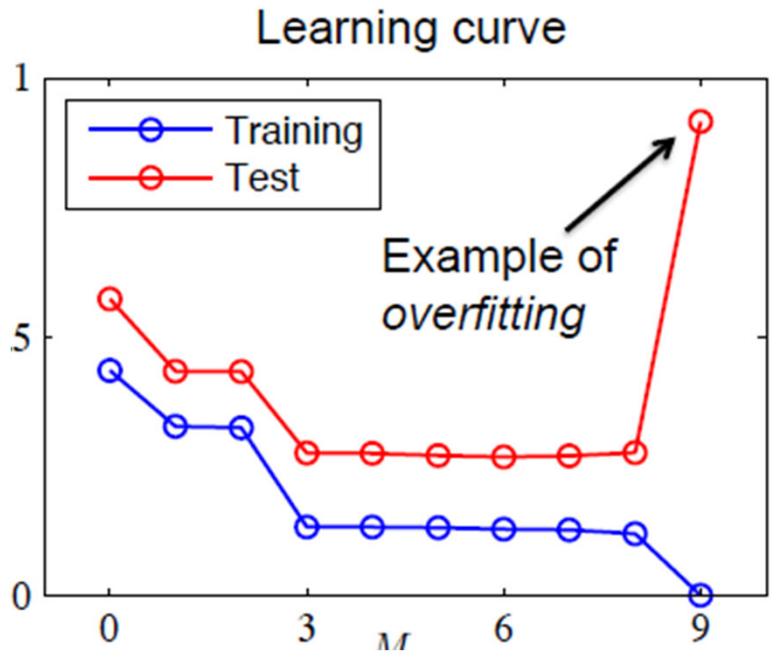
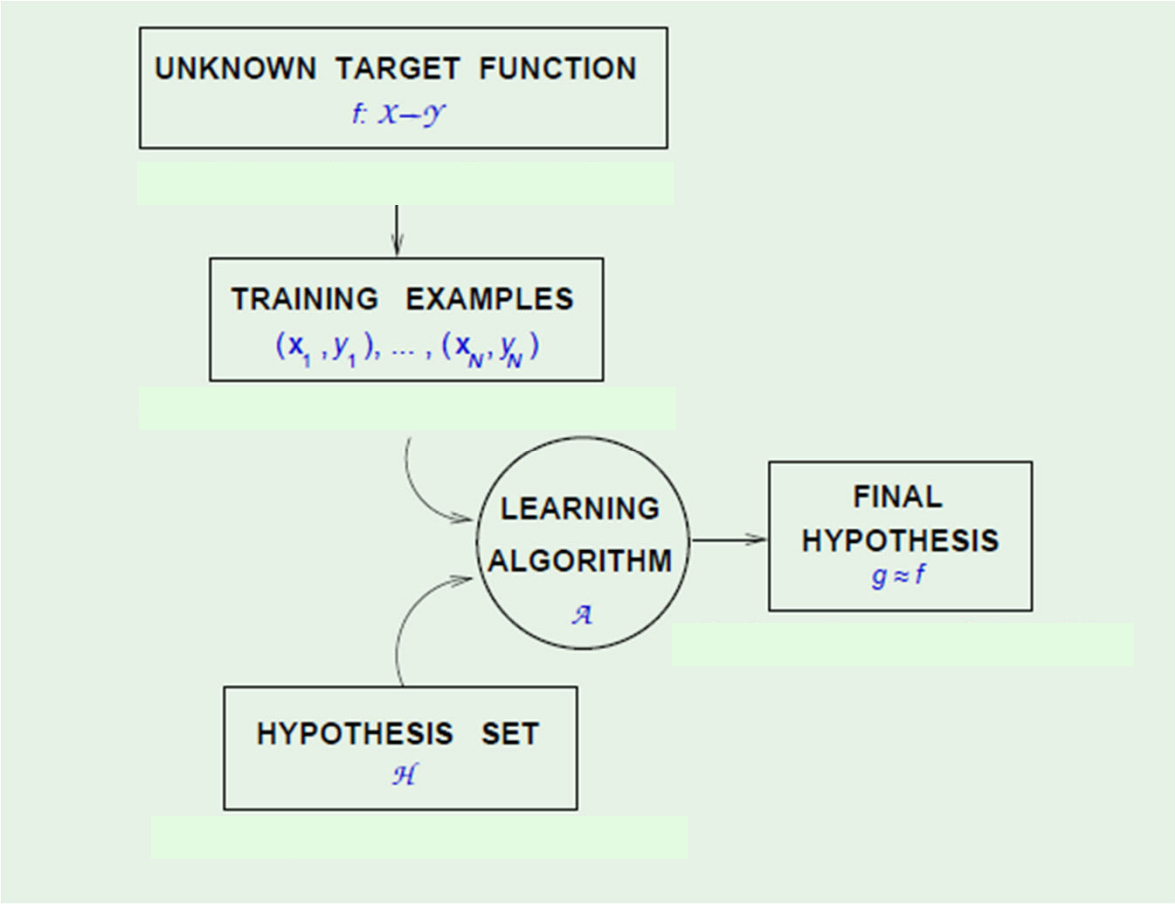


Metrics

		True condition	
	Total population	Condition positive	Condition negative
Predicted condition	Predicted condition positive	**True positive**	**False positive**, Type I error
	Predicted condition negative	**False negative**, Type II error	**True negative**

Lesson


UNKNOWN TARGET FUNCTION
$f: X \to Y$
TRAINING EXAMPLES
$(x_1, y_1), \ldots, (x_N, y_N)$
LEARNING ALGORITHM
$\mathcal{A}$
FINAL HYPOTHESIS
$g \approx f$
HYPOTHESIS SET
$\mathcal{H}$

Lesson

- Step 1 (Input)

$$e \mapsto \mathbf{f}(e) = (h_1(e), \ldots, h_N(e)) = (x_1, \ldots, x_N)$$

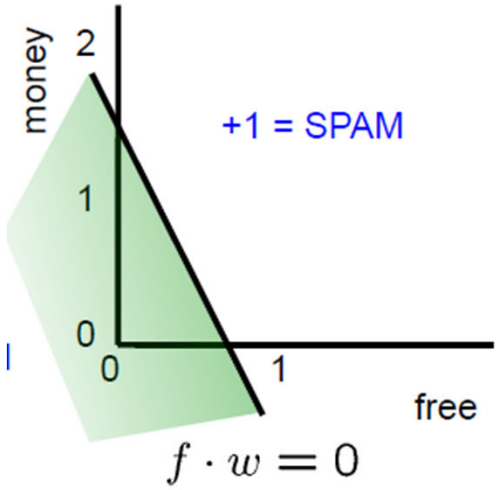
- Step 2 (Combine)

$$\langle \mathbf{w}, \mathbf{f}(e) \rangle = \sum_{i=1}^{N} w_i x_i$$

- Step 3 (Output)

$$\text{sign}(z) = \begin{cases} 1 & \text{if } z \geq 0 \\ -1 & \text{if } z < 0 \end{cases}$$

Lesson



x

"free money"

$f(x)$

BIAS	1
free	1
money	1
...	

w

BIAS	-3
free	4
money	2
...	

$$(1)(-3) + (1)(4) + (1)(2) + \ldots = 3$$

Lesson

- Hypothesis

$$\text{sign}\left(\langle \mathbf{w}, \mathbf{f}(e)\rangle - \text{threshold}\right) = \begin{cases} 1 & \text{then spam} \\ -1 & \text{then not spam} \end{cases}$$

- Step 2 (Combine)

$$f_{N+1}(e) \equiv 1$$

$$w_{N+1} = -\text{threshold}$$

- Step 3 (Output)

$$\text{sign}\left(\langle \mathbf{w}, \mathbf{f}(e)\rangle\right) = \begin{cases} 1 & \text{then spam} \\ -1 & \text{then not spam} \end{cases}$$

Lesson

input: A training set $(\mathbf{x}_1, y_1), \ldots, (\mathbf{x}_m, y_m)$

initialize: $\mathbf{w}^{(1)} = (0, \ldots, 0)$

  for $t = 1, 2, \ldots$

    if $(\exists\, i \;\text{ s.t. }\; y_i \langle \mathbf{w}^{(t)}, \mathbf{x}_i \rangle \leq 0)$ then

      $\mathbf{w}^{(t+1)} = \mathbf{w}^{(t)} + y_i \mathbf{x}_i$

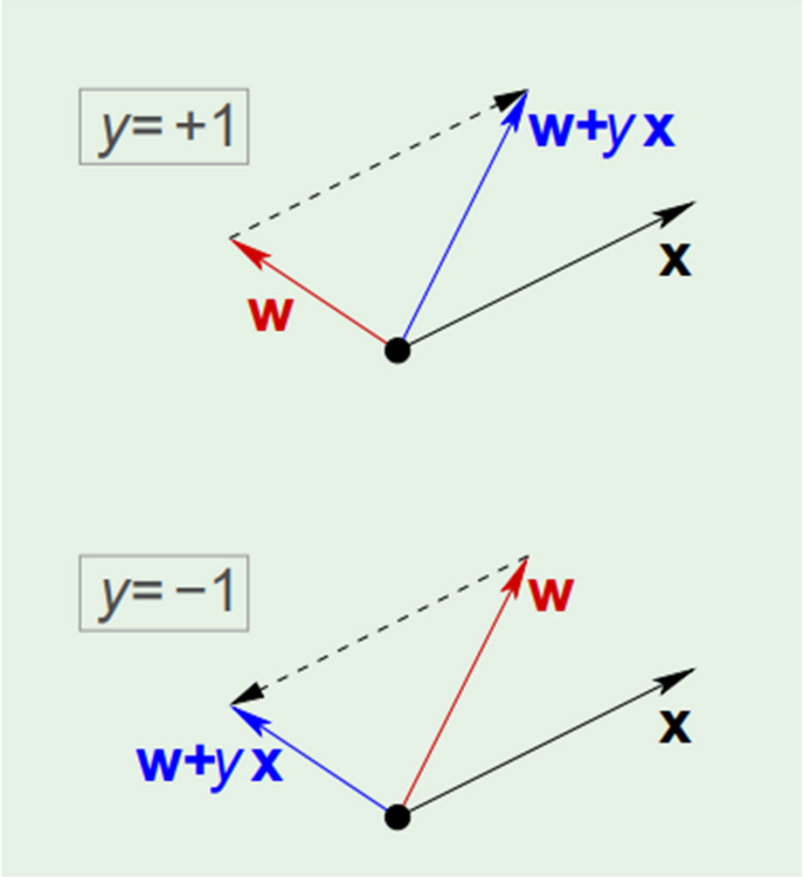
    else

      output $\mathbf{w}^{(t)}$

Lesson

$$y \langle w_t, x \rangle$$

$$y \langle w_{t+1}, x \rangle = y \langle w_t, x \rangle + ||x||^2$$



Lesson

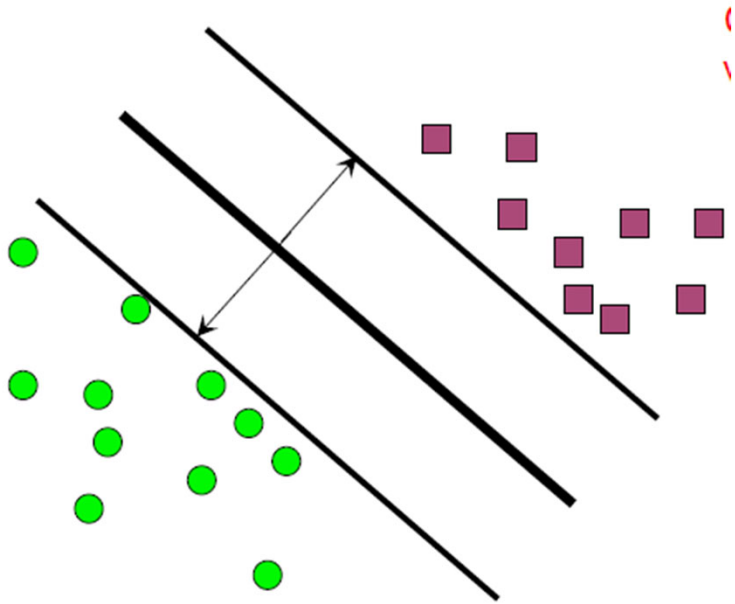
- Set

$$\gamma = \min_{1 \leq i \leq N} \frac{y_i \langle w, x_i \rangle}{||w||}$$

$$R = \max_{1 \leq i \leq N} ||x_i||$$

- The maximum number of mistakes made by the perceptron algorithm is $\frac{R^2}{\gamma^2}$

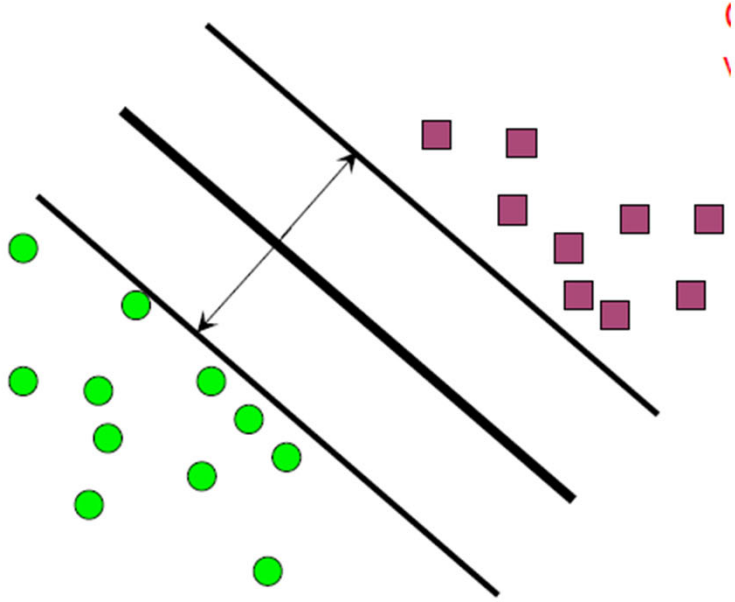
Lesson



Lesson

The distance between x and the plane defined by (w, b) is

$$\frac{|\langle w, x\rangle + b|}{||w||}$$



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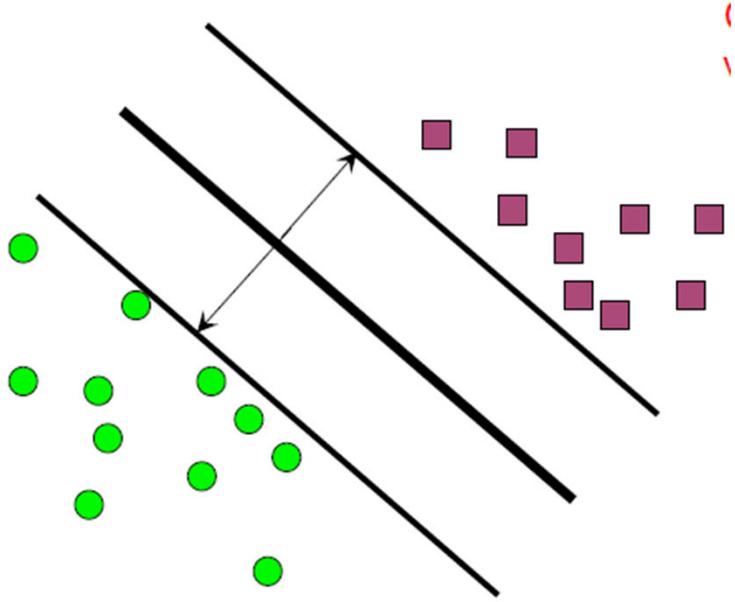

Lesson

Determine

$$\min\{\|\mathbf{x}-\mathbf{v}\| : \langle \mathbf{w}, \mathbf{v}\rangle + b = 0\}.$$

Set

$$\mathbf{v} = \mathbf{x} - (\langle \mathbf{w}, \mathbf{x}\rangle + b)\mathbf{w}$$

Note

$$\langle \mathbf{w}, \mathbf{v}\rangle + b = \langle \mathbf{w}, \mathbf{x}\rangle - (\langle \mathbf{w}, \mathbf{x}\rangle + b)\|\mathbf{w}\|^2 + b = 0,$$

$$\|\mathbf{x}-\mathbf{v}\| = |\langle \mathbf{w}, \mathbf{x}\rangle + b|\,\|\mathbf{w}\| = |\langle \mathbf{w}, \mathbf{x}\rangle + b|.$$

Lesson

For an u such that

$$\langle \mathbf{w}, \mathbf{u} \rangle + b = 0.$$

have

$$\begin{aligned}
\|\mathbf{x} - \mathbf{u}\|^2 &= \|\mathbf{x} - \mathbf{v} + \mathbf{v} - \mathbf{u}\|^2 \\
&= \|\mathbf{x} - \mathbf{v}\|^2 + \|\mathbf{v} - \mathbf{u}\|^2 + 2\langle \mathbf{x} - \mathbf{v}, \mathbf{v} - \mathbf{u} \rangle \\
&\geq \|\mathbf{x} - \mathbf{v}\|^2 + 2\langle \mathbf{x} - \mathbf{v}, \mathbf{v} - \mathbf{u} \rangle \\
&= \|\mathbf{x} - \mathbf{v}\|^2 + 2(\langle \mathbf{w}, \mathbf{x} \rangle + b)\langle \mathbf{w}, \mathbf{v} - \mathbf{u} \rangle \\
&= \|\mathbf{x} - \mathbf{v}\|^2,
\end{aligned}$$

Lesson

- Advantages
  - Bound on Number of Iterations Independent of Dimension
  - On-Line Learning
- Disadvantages
  - Limited to Linearly Separable
  - Overfitting (Improved by Averaging or Early Stopping)

Demo

The Data

1. The historical data consist of 39,859 customers. The historical data contain 19,901 customers that churned (*i.e.* left the company) and 19,958 that did not churn (see the "churndep" variable).
3. Here are the data set's 11 possible predictor variables for churning behavior:

Position	Variable Name	Variable Description
1	revenue	Mean monthly revenue in dollars
2	outcalls	Mean number of outbound voice calls
3	incalls	Mean number of inbound voice calls
4	months	Months in Service
5	eqpdays	Number of days the customer has had his/her current equipment
6	webcap	Handset is web capable
7	marryyes	Married (1=Yes; 0=No)
8	travel	Has traveled to non-US country (1=Yes; 0=No)
9	pcown	Owns a personal computer (1=Yes; 0=No)
10	credited	Possesses a credit card (1=Yes; 0=No)
11	retcalls	Number of calls previously made to retention team

The dependent variable, Churndep, = 1 if the customer churned, = 0 otherwise.