CS626: Speech, Natural Language Processing and the Web

Named Entity Identification and Recognition- Classification and Sequence Labelling

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Two kinds of insights needed

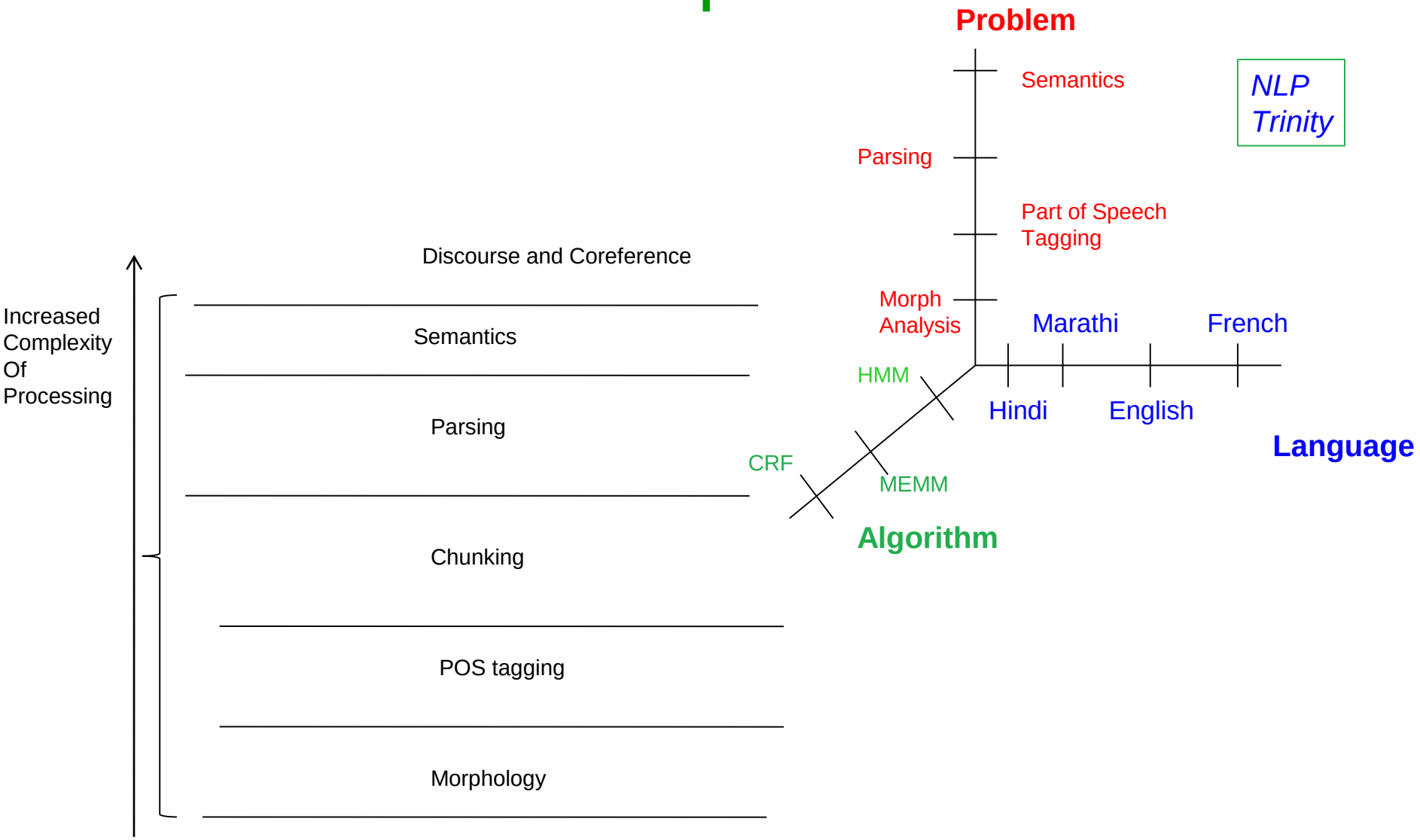
- How language operates
- Linguistics
- Properties of the PROBLEM

- How machine learning operates
- Sense of Distributions
- Properties of Data

Task *vs.* Technique Matrix

Task (row) vs. Technique (col) Matrix	**Rules Based/Knowledge-Based**	**Classical ML**				**Deep Learning**		
		Perceptron	Logistic Regression	SVM	Graphical Models (HMM, MEMM, CRF)	Dense FF with BP and softmax	RNN-LSTM	CNN
Morphology								
POS								
Chunking								
Parsing								
NER, MWE								
Coref								
WSD								
Machine Translation								
Semantic Role Labeling								
Sentiment								
Question Answering								

NLP Perspective



Inherent resilience of the structure called LANGUAGE

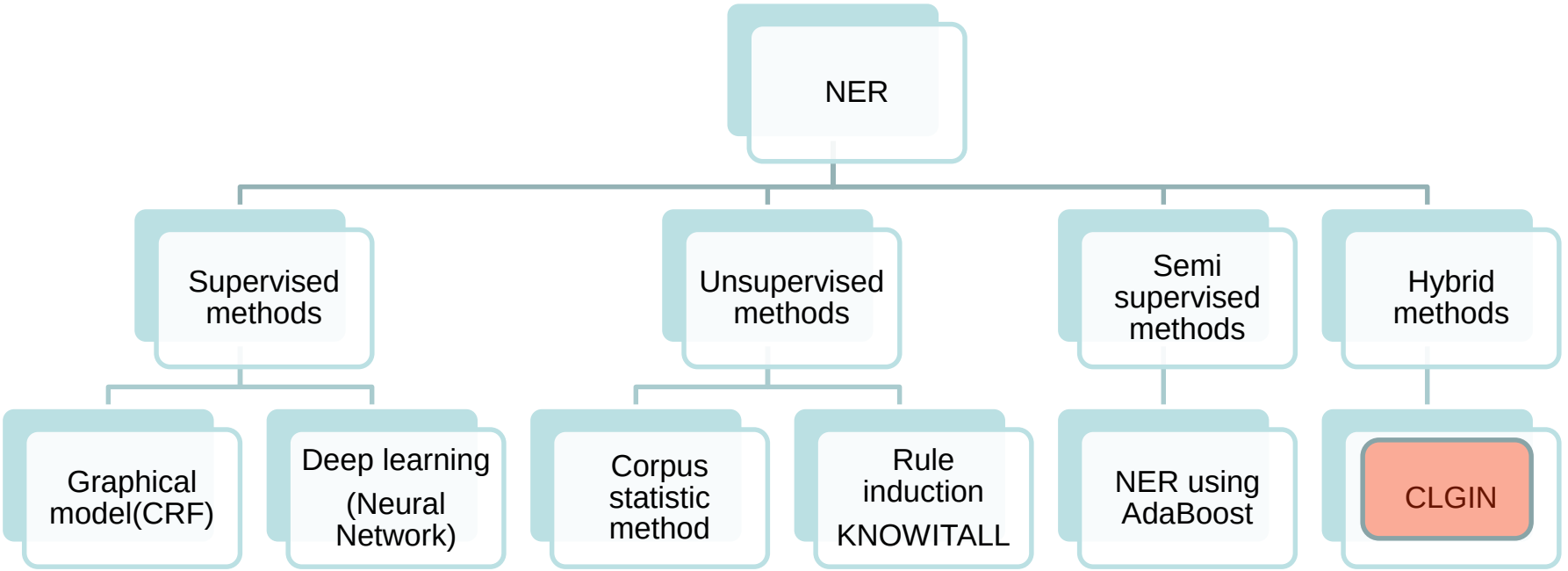
- Example: Apple increased its laptop production
- I know that Apple increased its laptop production
- I know apples are costly (fruit apple): plural ‘s’ disambiguates
- An apple a day keeps the doctor away: article disambiguates
- I bought an Apple for my accounting work: capital ‘A’ disambiguates
- Vulnerability: He has an apple: looseness in capitalization makes disambiguation impossible
- Some insight into how language operates

Multilingual Named Entity Recognition

- If a named entity is recognized in one language, it can be added to lexicon (gazetteer list) and used for processing tasks in other languages

- *Extract Once, Use Many times*

Approaches


NER
Supervised methods
Unsupervised methods
Semi supervised methods
Hybrid methods
Graphical model(CRF)
Deep learning (Neural Network)
Corpus statistic method
Rule induction KNOWITALL
NER using AdaBoost
CLGIN

Background: Information Extraction

Definition: Information Extraction

- To extract information that fits pre-defined schemas or templates
- IE Definition
  - Entity: an object of interest such as a person or organization
  - Attribute: A property of an entity such as name, type
  - Relation: A relationship that holds between two or more entities such as Position of Person in a Company

Information Extraction

- **Note** the difference between Named Entity Identification and Named Entity Recognition
- **Named Entity Identification** is a binary classification problem which classifies whether a given token is a named entity or not
- **Named Entity Recognition** involves detection and categorization of named entities

Goal of IE

As a task: **Filling slots from text- unstructured→structured**

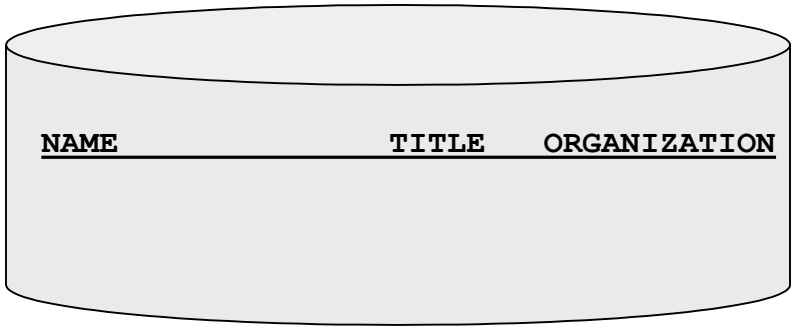
October 14, 2002, 4:00 a.m. PT

For years, Microsoft Corporation CEO Bill Gates railed against the economic philosophy of open-source software with Orwellian fervor, denouncing its communal licensing as a "cancer" that stifled technological innovation.

Today, Microsoft claims to "love" the open-source concept, by which software code is made public to encourage improvement and development by outside programmers. Gates himself says Microsoft will gladly disclose its crown jewels--the coveted code behind the Windows operating system--to select customers.

"We can be open source. We love the concept of shared source," said Bill Veghte, a Microsoft VP. "That's a super-important shift for us in terms of code access.“

Richard Stallman, founder of the Free Software Foundation, countered saying…



Courtesy of William W. Cohen

Unstructured→structured

As a task:

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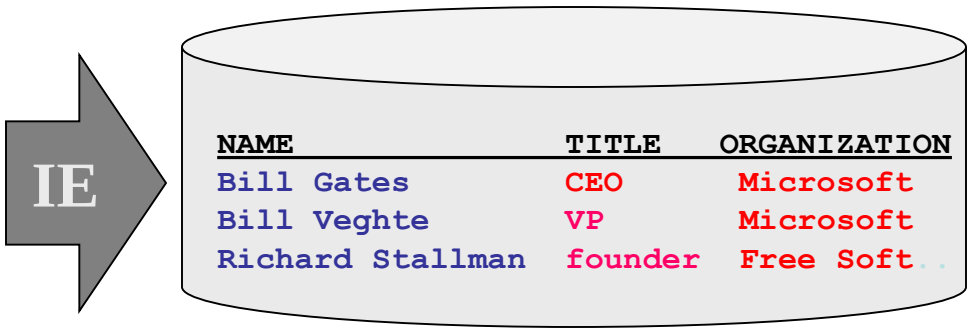

Courtesy of William W. Cohen

Named Entity Identification (NEI) and Named Entity Recognition (NER)

Definition

NERC – Named Entity Recognition and Classification (NERC) involves identification of proper names in texts, and classification into a set of pre-defined categories of interest as:

- Person names (names of people)
- Organization names (companies, government organizations, committees, etc.)
- Location names (cities, countries etc)
- Miscellaneous names (Date, time, number, percentage, monetary expressions, number expressions and measurement expressions)

NEI and NER

- **Note** the difference between Named Entity Identification and Named Entity Recognition
- **Named Entity Identification** is a binary classification problem which classifies whether a given token is a named entity or not
- **Named Entity Recognition** involves detection and categorization of named entities

Challenge of NEI and NER

- Variation of NEs – e.g. Prof. Manning, Chris Manning, Dr Chris Manning
- Ambiguity of NE types:
  - Washington (location vs. person)
  - May (person vs. month)
  - Ford (person vs organization)
  - 1945 (date vs. time)
- Ambiguity with common words, e.g. “Kabita“

  - Name of person vs. poem

More complex problems in NER

- Issues of style, structure, domain, genre etc.
- Punctuation, spelling, spacing, formatting, ... all have an impact:

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Many to Many Relationship

- The many-many relationship between entities and their names makes the task of NER more complex

	NAMES			
ENTITIES	E353	Manning	Prof_Manning	Chris_Manning
	E201	Oxygen	O_2	
	E356	Kolkata	Calcullta	West Bengal Capital
	E404	IIT	Indian_Institute_of_ Technology	Indian_Institute_of_ Tech.

- Rows are labelled with **entity ids** and columns contain **names**

E.g.: E353 to represent the specific person entity ‘Chris Manning'

What would be skyline NER performance

- Human performance is considered to be the ultimate goal to be reached by the m/c.
- Human performance is measured by IAA (Inter Annotator Agreement)
- The connection between human performance and IAA is a subtle one
- Still IAA can indirectly provide a skyline
- E.g., WSD IAA is around 85% which translates to skyline performance of percentage in the vicinity of 80s
- Multiplication: humans are no match for machines
- Similarly Question Answering looms as a falling frontier for humans (e.g. Jeopardy contest → WATSON)

Applications

- Intelligent document access
  - Browse document collections by the entities that occur in them
  - Application domains:
    - News
    - Scientific articles, e.g, MEDLINE abstracts
- Information retrieval and extraction
  - Augmenting a query given to a retrieval system with NE information, more refined information extraction is possible
  - For example, if a person wants to search for document containing ‘kabiTA’ as a proper noun, adding the NE information will eliminate irrelevant documents with only ‘kabiTA’ as a common noun

Applications

- Machine translation
  - NER plays an important role in translating documents from one language to other
  - Often the NEs are transliterated rather than translated
  - For example, ‘yAdabpur bishvabidyAlaYa’ → ‘Jadavpur University’
- Automatic Summarization
  - NEs given more priorities in deciding the summary of a text
  - Paragraphs containing more NEs are most likely to be included into the summary

Applications

- Question-Answering Systems
  - NEs are important to retrieve the answers of particular questions (Who is the PM of India/Which country is Modi PM of?)
- Speech Related Tasks
  - NER is important for identifying the number format, telephone number and date format
  - In speech rhythm- necessary to provide a short break after the name of person
  - Solving Out Of Vocabulary words is important in speech recognition

Corpora, Annotation

- MUC-6 and MUC-7 corpora - English
- CONLL shared task corpora
  - http://cnts.uia.ac.be/conll2003/ner/ : NEs in English and German
  - http://cnts.uia.ac.be/conll2002/ner/ : NEs in Spanish and Dutch
- ACE – English - http://www.ldc.upenn.edu/Projects/ACE/
- TIDES surprise language exercise (NEs in Hindi)
- NERSSEAL shared task- NEs in Bengali, Hindi, Telugu, Oriya and Urdu (http://ltrc.iiit.ac.in/ner-ssea-08/index.cgi?topic=5)

Corpora, Annotation

- Biomedical and Biochemical corpora
  - BioNLP-04 shared task
  - BioCreative shared tasks
  - AiMed

Tag set

Text is tagged (1/2)

Identifying and classifying elements in text into predefined categories such as the names of persons, organizations, locations, expressions of times, quantities, monetary values, percentages, etc.

Text is tagged (2/2)

Example:

Jim bought 300 shares of ABC Corp. in 2006.

<ENAMEX TYPE="PERSON"> Jim </ENAMEX> bought <NUMEX

TYPE = "QUANTITY"> 300 </NUMEX> shares of <ENAMEX TYPE =

"ORGANIZATION"> ABC Corp. </ENAMEX> in <TIMEX TYPE = "

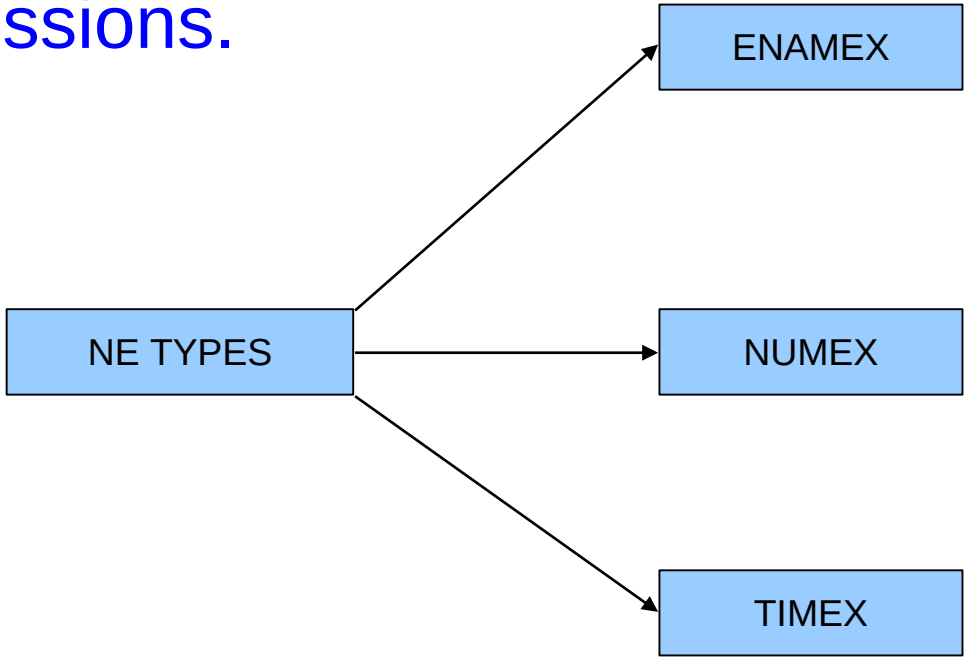
DATE "> 2006 </TIMEX>.

MUC TAGSET

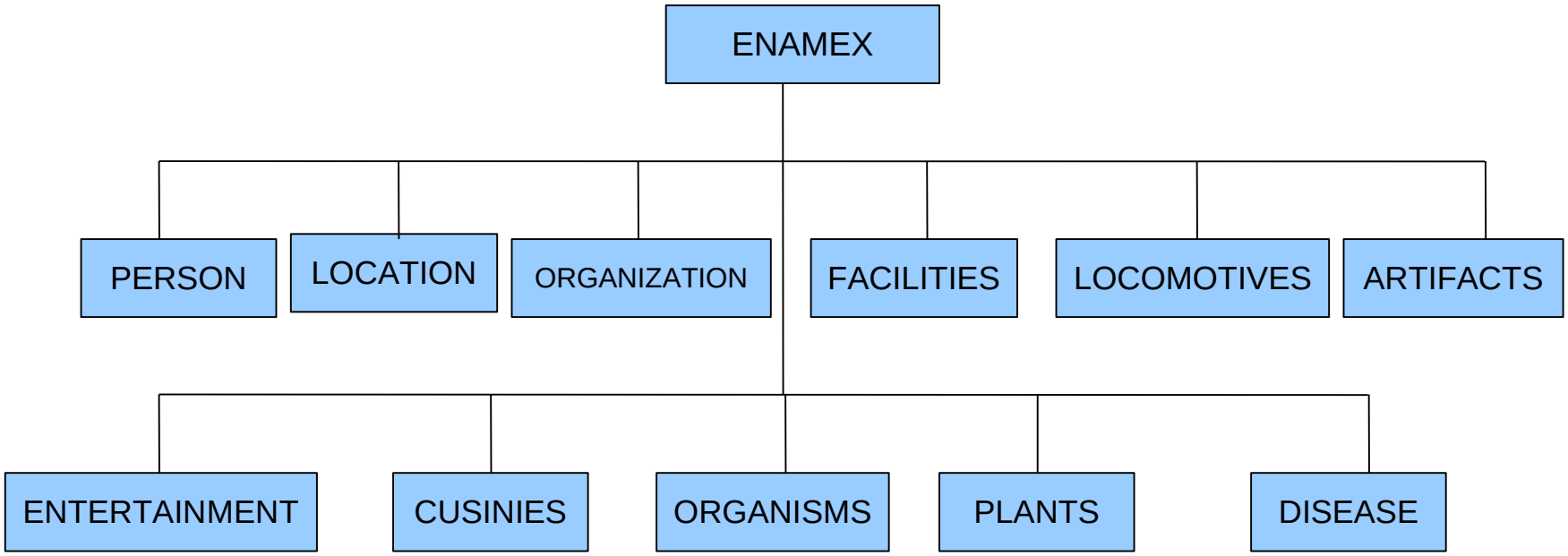
The Named entity hierarchy contains 106 tags

It is divided into three major classes Entity Name, Time and Numerical

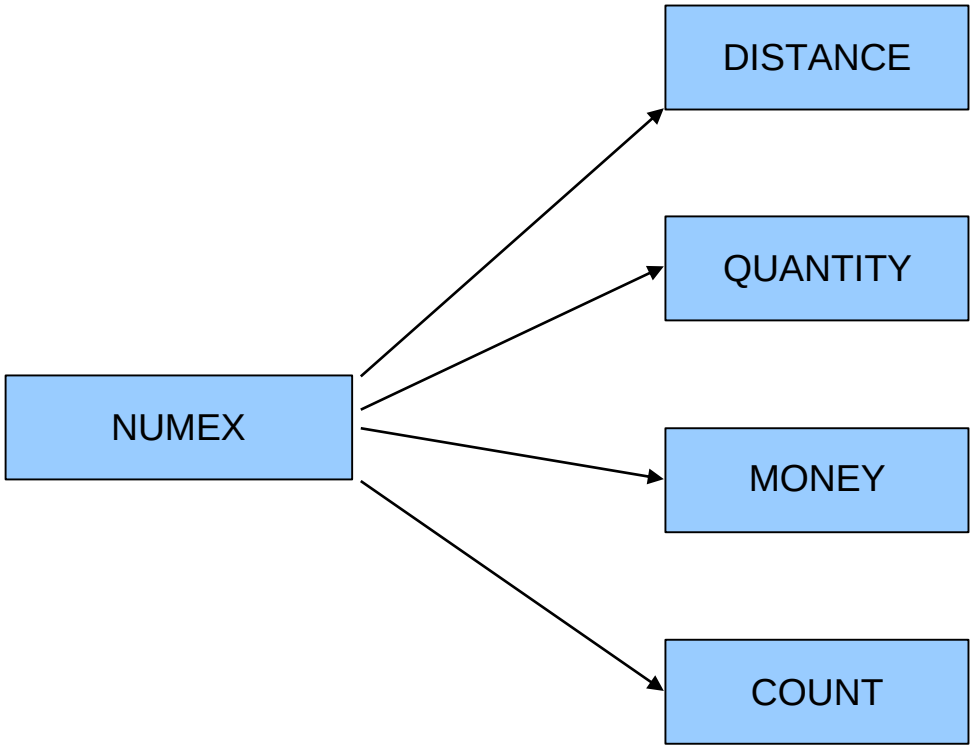
expressions.



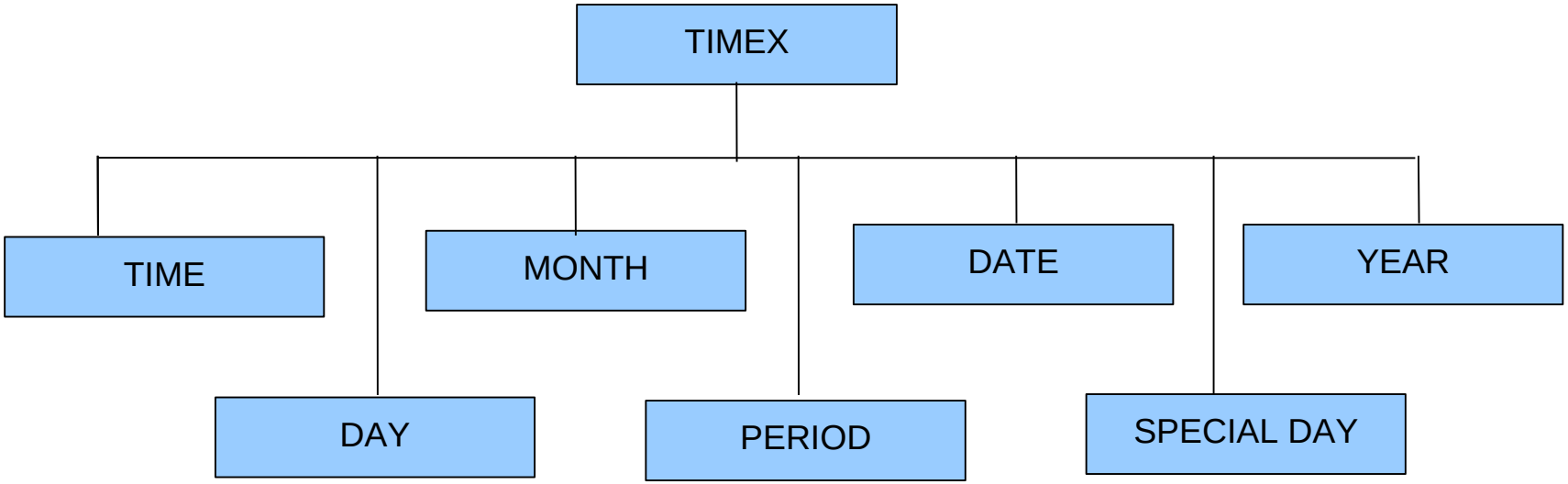
ENAMEX TYPES



NUMEX TYPES



TIMEX Types



PERSON

- Person
  - Individual
    - Family name
    - Title
  - Group

- Persons are entities limited to humans. A person may be a single individual or a group.

- Individual refer to names of each individual person, also includes names of fictional characters found in stories/novels etc.

- Individual name occurs with family name
- an individual is often referred with a title such as Mr., Mrs., Ms., Dr., etc along with their name

- GROUP refers to set of individual

PERSON: Example

Mr. Chandrababu Naidu is the President of Telugu Desam Party

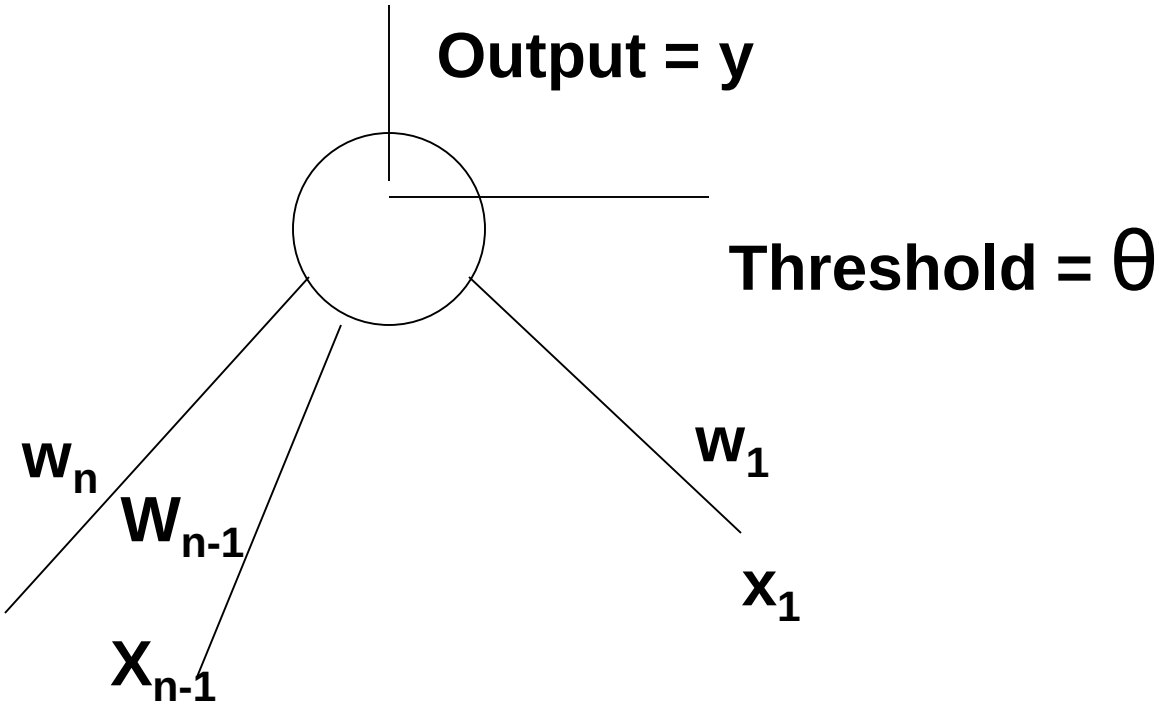
Chandrababu : Person => Individual
Naidu : Person => Family Name
Mr. : Person => Title

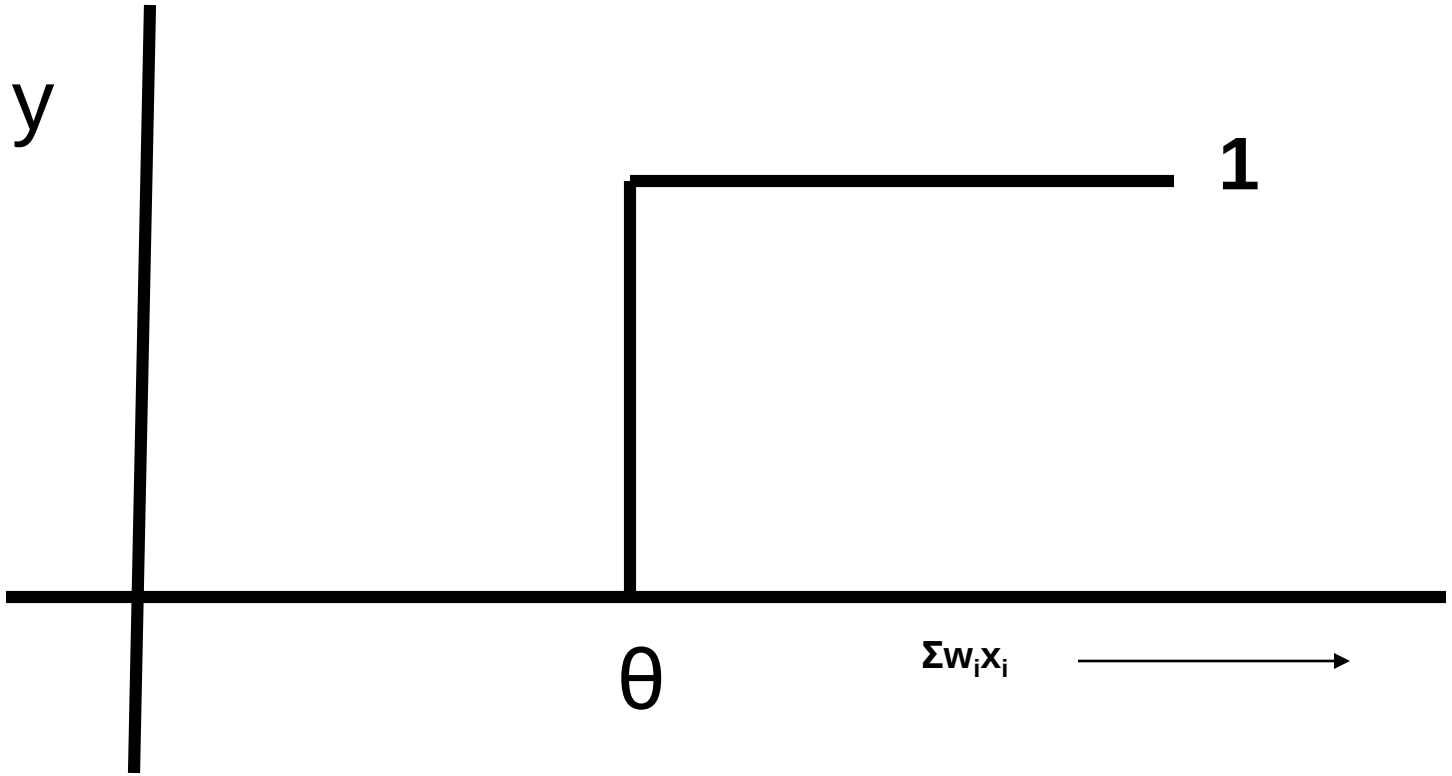
2)Apolo Hospital doctors : Person => GROUP

First example of Linear Separator: Perceptron

The Perceptron Model

A perceptron is a computing element with input lines having associated weights and the cell having a threshold value. The perceptron model is motivated by the biological neuron.





Step function / Threshold function

y = 1 for Σwixi >=θ

=0 otherwise

Features of Perceptron

- **Input output behavior is discontinuous and the derivative does not exist at $\Sigma w_i x_i = \theta$**

- **$\Sigma w_i x_i - \theta$ is the net input denoted as net**

- **Referred to as a linear threshold element - linearity because of x appearing with power 1**

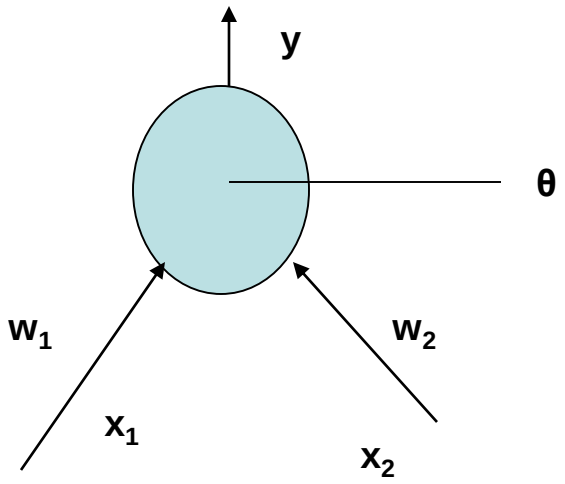
- **y= f(net): Relation between y and net is non-linear**

Computation of Boolean functions

AND of 2 inputs

X1	x2	y
0	0	0
0	1	0
1	0	0
1	1	1

The parameter values (weights & thresholds) need to be found.



Computing parameter values

w1 * 0 + w2 * 0 <= θ ➔ θ >= 0; since y=0

w1 * 0 + w2 * 1 <= θ ➔ w2 <= θ; since y=0

w1 * 1 + w2 * 0 <= θ ➔ w1 <= θ; since y=0

w1 * 1 + w2 *1 > θ ➔ w1 + w2 > θ; since y=1

w1 = w2 = = 0.5

satisfy these inequalities and find parameters to be used for computing AND function.

Other Boolean functions

- **OR can be computed using values of w1 = w2 = 1 and = 0.5**

- **XOR function gives rise to the following inequalities:**

w1 * 0 + w2 * 0 <= θ ➔ θ >= 0

w1 * 0 + w2 * 1 > θ ➔ w2 > θ

w1 * 1 + w2 * 0 > θ ➔ w1 > θ

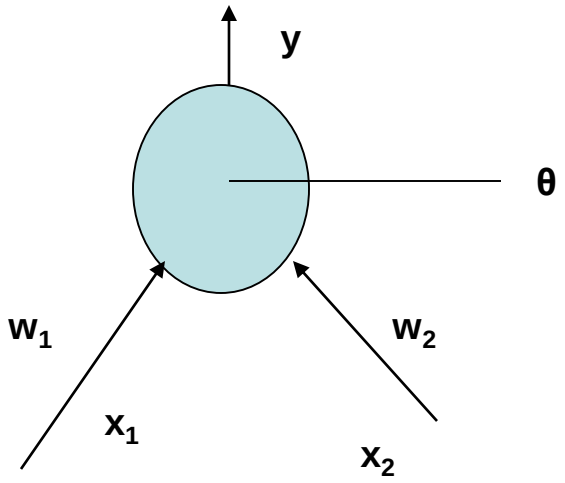
w1 * 1 + w2 *1 <= θ ➔ w1 + w2 <= θ

No set of parameter values satisfy these inequalities.

AND of 2 inputs

X1	x2	y
0	0	0
0	1	0
1	0	0
1	1	1

The parameter values (weights & thresholds) need to be found.



Constraints on w1, w2 and θ

w1 * 0 + w2 * 0 <= θ ➔ θ >= 0; since y=0

w1 * 0 + w2 * 1 <= θ ➔ w2 <= θ; since y=0

w1 * 1 + w2 * 0 <= θ ➔ w1 <= θ; since y=0

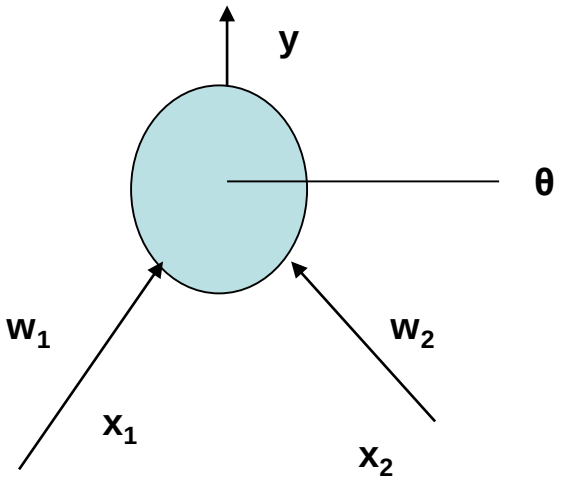
w1 * 1 + w2 *1 > θ ➔ w1 + w2 > θ; since y=1

w1 = w2 = = 0.5, θ=0.9

These inequalities are satisfied by ONE particular region

Non Linearly Separable: XOR

X1	x2	y
0	0	0
0	1	1
1	0	1
1	1	0



The parameter values (weights & thresholds) need to be found.

Constraints on w1, w2 and θ

w1 * 0 + w2 * 0 <= θ ➔ θ >= 0; since y=0

w1 * 0 + w2 * 1 < θ ➔ w2 < θ; since y=1

w1 * 1 + w2 * 0 < θ ➔ w1 < θ; since y=1

w1 * 1 + w2 *1 <= θ ➔ w1 + w2 <= θ; since y=0

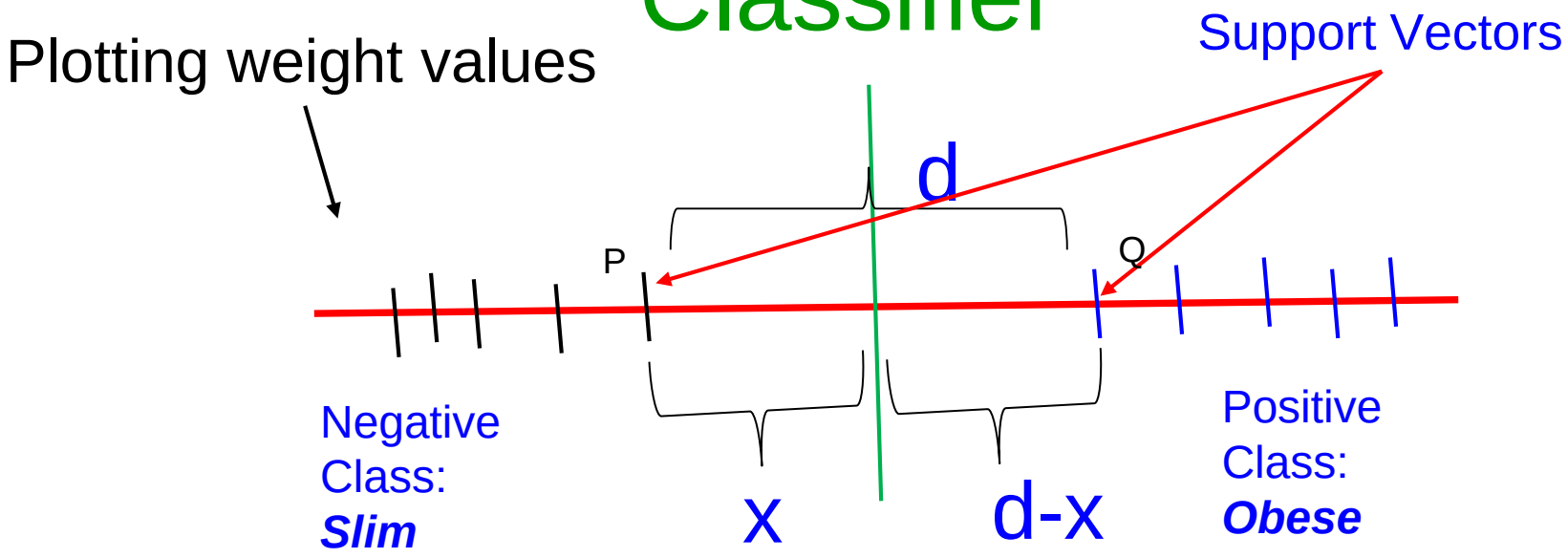
These inequalities are unsatisfiable.

XOR is NOT linearly separable

Support Vector Machine (SVM)

Slide courtesy: Dr. Sachin Pawar, CFILT and TCS

SVM is a Maximum Margin Classifier



P and Q are “support” points

$$margin,\ m = x^2 + (d-x)^2$$

$$\frac{dm}{dx} = 2x - 2(d-x)$$

$$equate\ to\ 0$$

$$x = \frac{d}{2}$$

What if the threshold is not in the middle

- Threshold in the middle maximizes margin
- This DECREASES the probability of misclassification
- Intuitively, if the threshold abuts too closely one of the supports- say negative class support P- then in future any negative point away from P will be wrongly labelled as positive

- Maximum margin minimizes the probability of misclassification

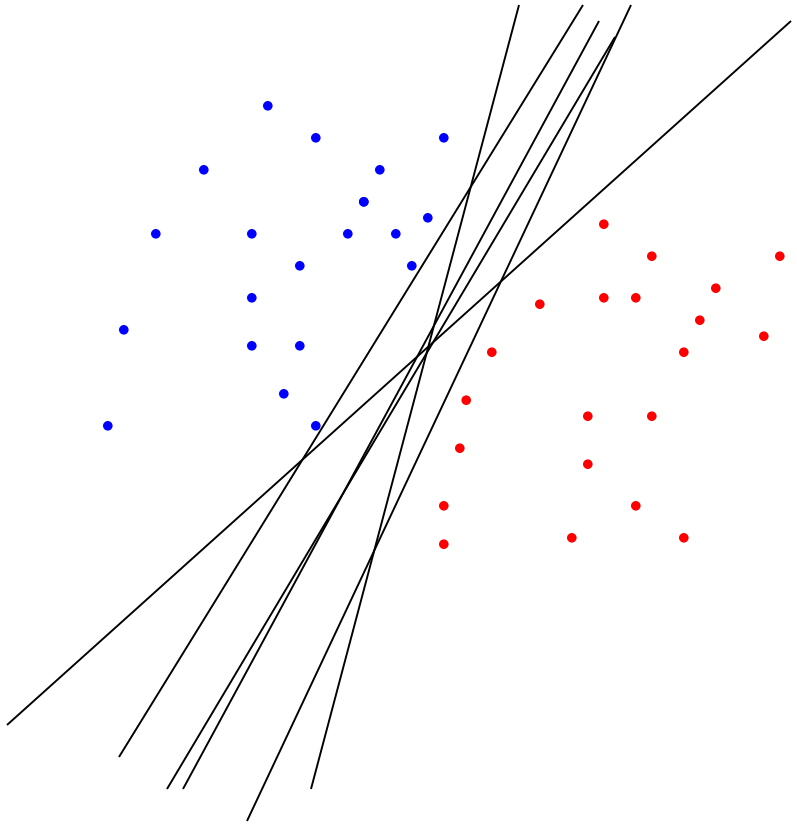
- Refer to Bias Variance trade off

Introduction

- Support Vector Machine (SVM): Learns a linear separator for separating instances belonging to two different classes
  - In case of 1 dimensional instances, the separator is a point
  - In case of 2 dimensional instances, the separator is a line
  - In case of 3 dimensional instances, the separator is a plane
  - In case of instances in more than 3 dimensional space, the separator is a hyperplane

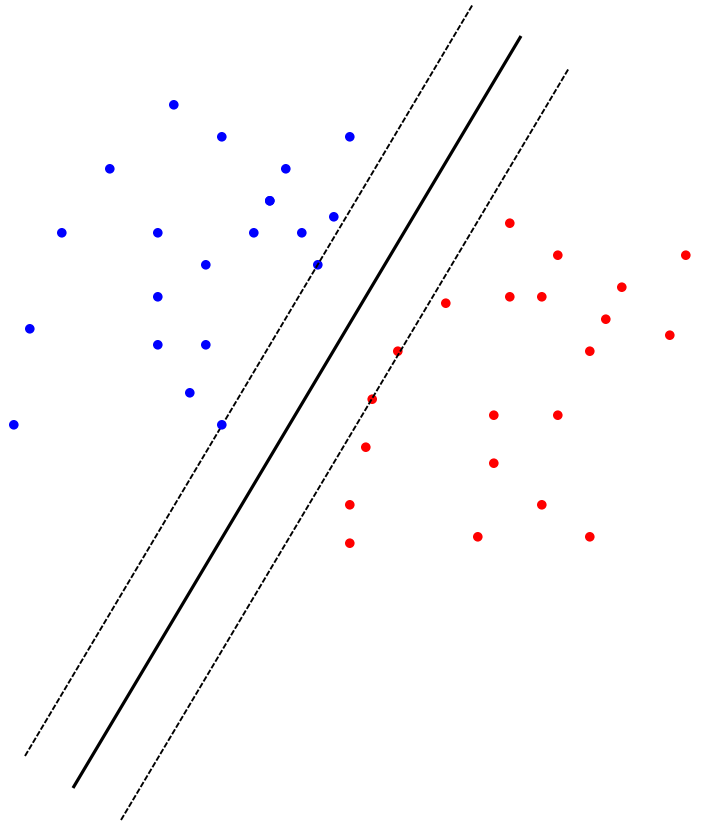
- Given a set of linearly separable instances, there exist infinite number of linear separators which can separate the instances into 2 classes
  - SVM chooses that linear separator which has the maximum “margin”
  - Intuition: A linear separator with the maximum margin will generalize better for new unseen instances in test data
  - So called, BIAS VARIANCE TRADE OFF

SVM: Linear Separator



- An example of two dimensional instances
- Two classes:
  - Positive and Negative
- Linearly separable data
- Infinite number of linear separators are possible

SVM: Linear Separator



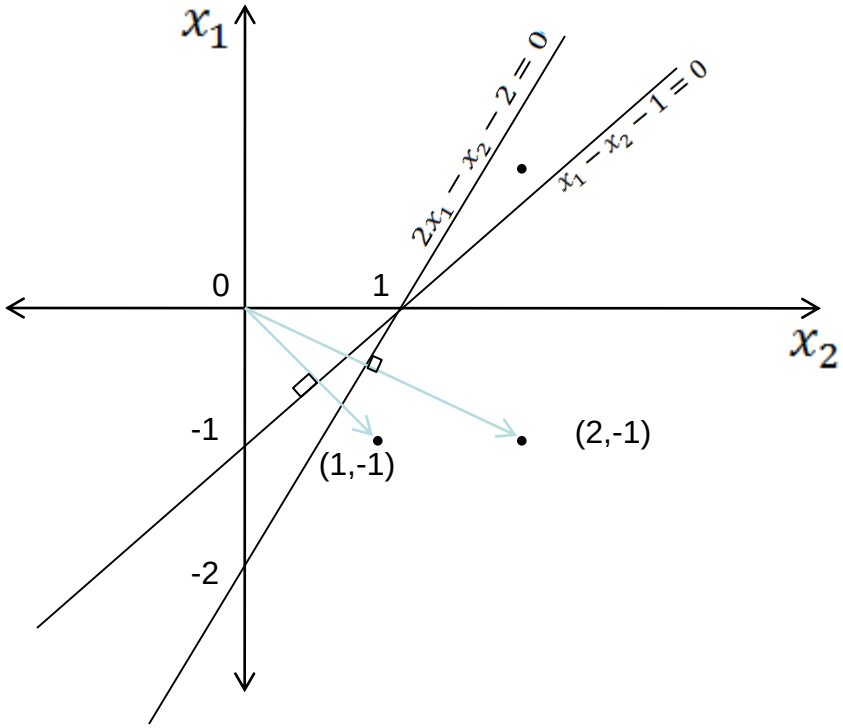
- **Goal**: To find the linear separator which provides the maximum margin of separation between two classes
- Support vectors: Instances which lie on the margin boundaries

Representation of a linear separator

- A linear separator in n-dimensional space is represented using an equation of the form:
- Can be expressed in a vector form as:

$$w_1 x_1 + w_2 x_2 + \cdots + w_n x_n + w_0 = 0$$

$$\mathbf{w}^T \cdot \mathbf{x} + w_0 = 0$$

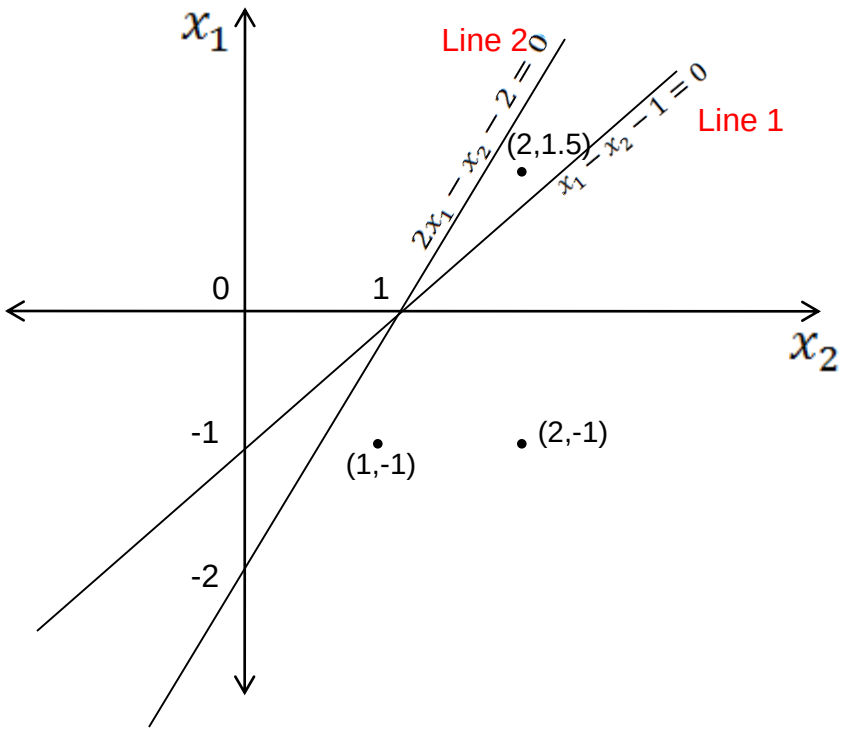


- The vector w is perpendicular to the lines of the form $w^T.x+w_0=0$

- The learning task in SVM is to determine the optimal values of the parameters representing the linear separator with the maximum margin, i.e., w and w_0

Representation of a linear separator

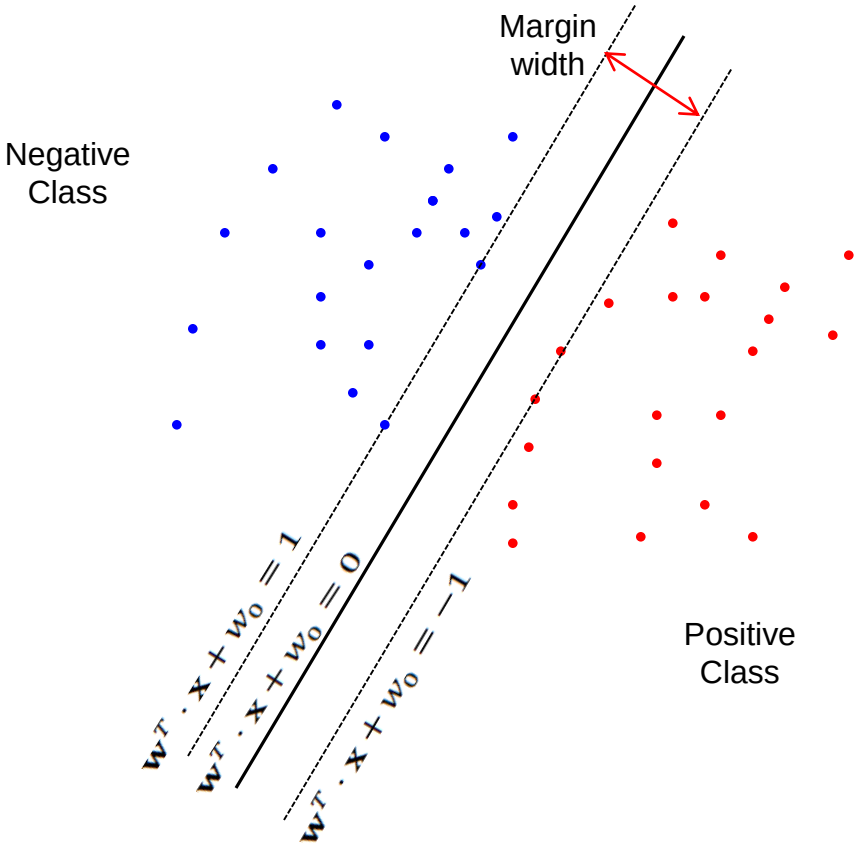
- A linear separator in n-dimensional space is represented using an equation of the form: $w_1 x_1 + w_2 x_2 + \cdots + w_n x_n + w_0 = 0$
- Can be expressed in a vector form as: $\mathbf{w}^T \cdot \mathbf{x} + w_0 = 0$



For a particular linear separator, any point x^i lying on the "positive" side will have positive value of $w^T.x^i+w_0$

- Also, any point x^i lying on the "negative" side will have negative value of $w^T.x^i+x_0$
- E.g., the point (2,1.5) is on positive side of Line 2 (gives value 0.5) and on negative side of Line 1 (-0.5)

SVM: Training

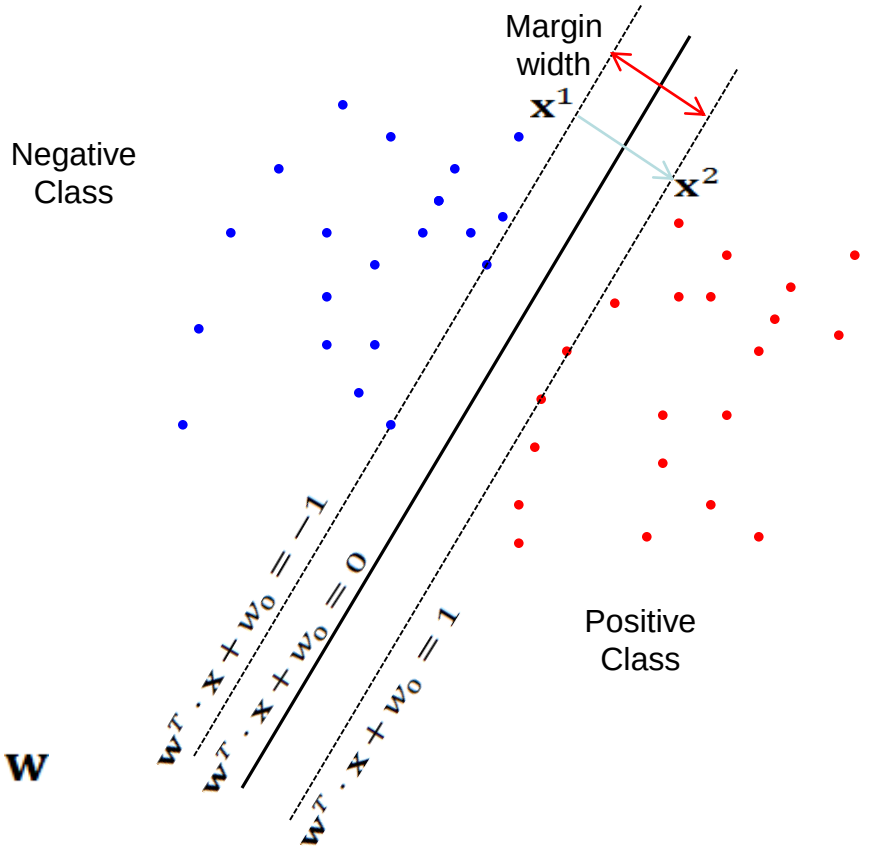


- **Training instances**:

$$\{\langle \mathbf{x}^1, y^1 \rangle, \langle \mathbf{x}^2, y^2 \rangle, \cdots \langle \mathbf{x}^N, y^N \rangle\}$$

- x^i is a point in n-dimensional space
- $y^i \in \{+1, -1\}$ is its corresponding true class label
- **Goal**: To find optimal linear separator which maximizes the margin

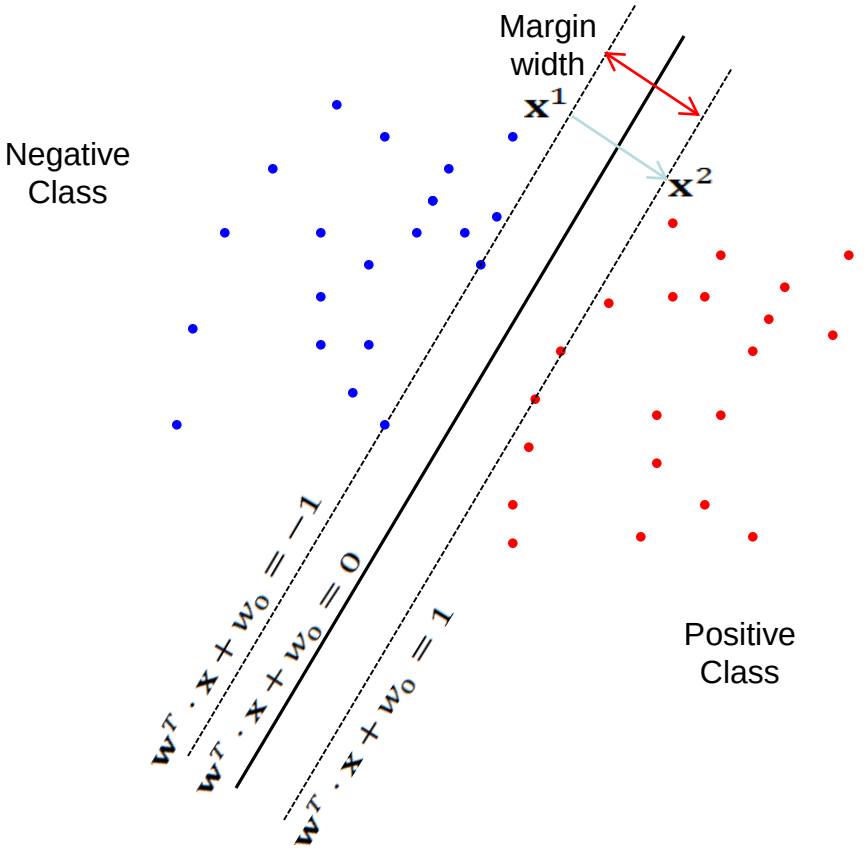
Computing Margin Width



- Consider two points x^1 and x^2 such that they lie on the opposite margins and the vector x^2-x^1 is perpendicular to the linear separator.
- The vector *w* is also perpendicular to the linear separator.
- Therefore, (x2-x1)=λ.w
- By definition,

$$\mathbf{w}^T \cdot \mathbf{x}^2 + w_0 = 1$$
$$\mathbf{w}^T \cdot \mathbf{x}^1 + w_0 = -1$$
$$\mathbf{w}^T \cdot (\mathbf{x}^2 - \mathbf{x}^1) = 2$$

Computing Margin Width



- Substituting

$$(\mathbf{x}^2 - \mathbf{x}^1) = \lambda \cdot \mathbf{w}$$

$$\mathbf{w}^T \cdot (\mathbf{x}^2 - \mathbf{x}^1) = 2$$

- Margin width:

$$\lambda \mathbf{w}^T \cdot \mathbf{w} = 2 \Rightarrow \lambda = \frac{2}{\mathbf{w}^T \cdot \mathbf{w}}$$

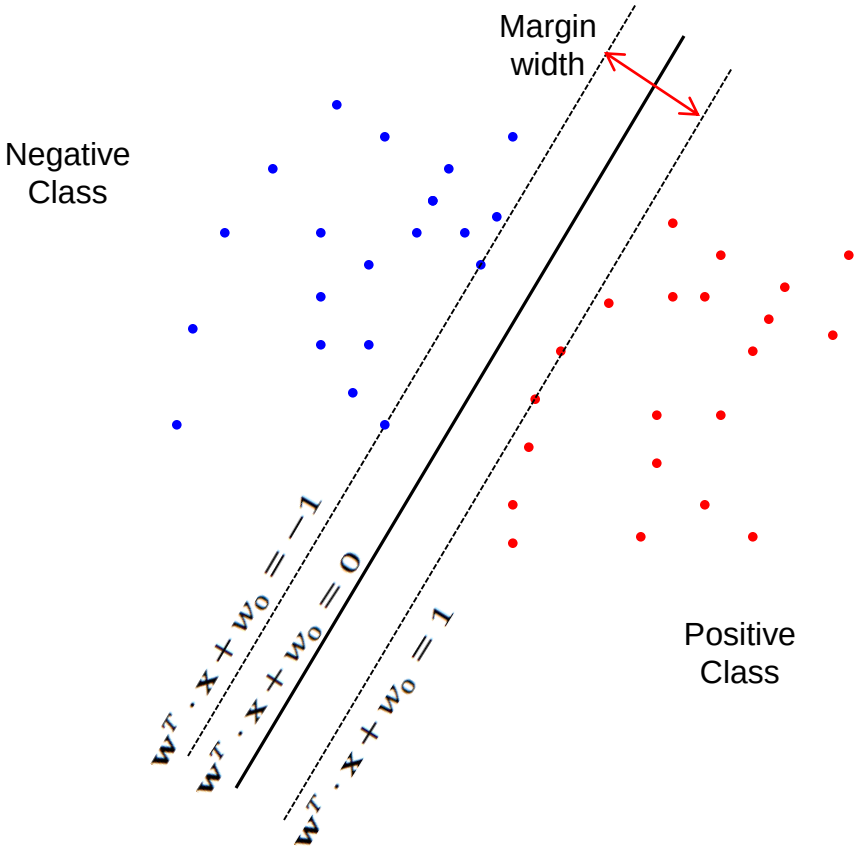
$$\|\mathbf{x}^2 - \mathbf{x}^1\| = \sqrt{(\mathbf{x}^2 - \mathbf{x}^1)^T \cdot (\mathbf{x}^2 - \mathbf{x}^1)}$$

$$\|\mathbf{x}^2 - \mathbf{x}^1\|^2 = \lambda^2 (\mathbf{w}^T \cdot \mathbf{w})$$

$$\|\mathbf{x}^2 - \mathbf{x}^1\|^2 = \frac{4}{(\mathbf{w}^T \cdot \mathbf{w})^2} (\mathbf{w}^T \cdot \mathbf{w})$$

$$\|\mathbf{x}^2 - \mathbf{x}^1\|^2 = \frac{4}{\mathbf{w}^T \cdot \mathbf{w}} \propto \frac{1}{\mathbf{w}^T \cdot \mathbf{w}}$$

SVM: Optimization Problem



- Objective:
  - Maximize the margin

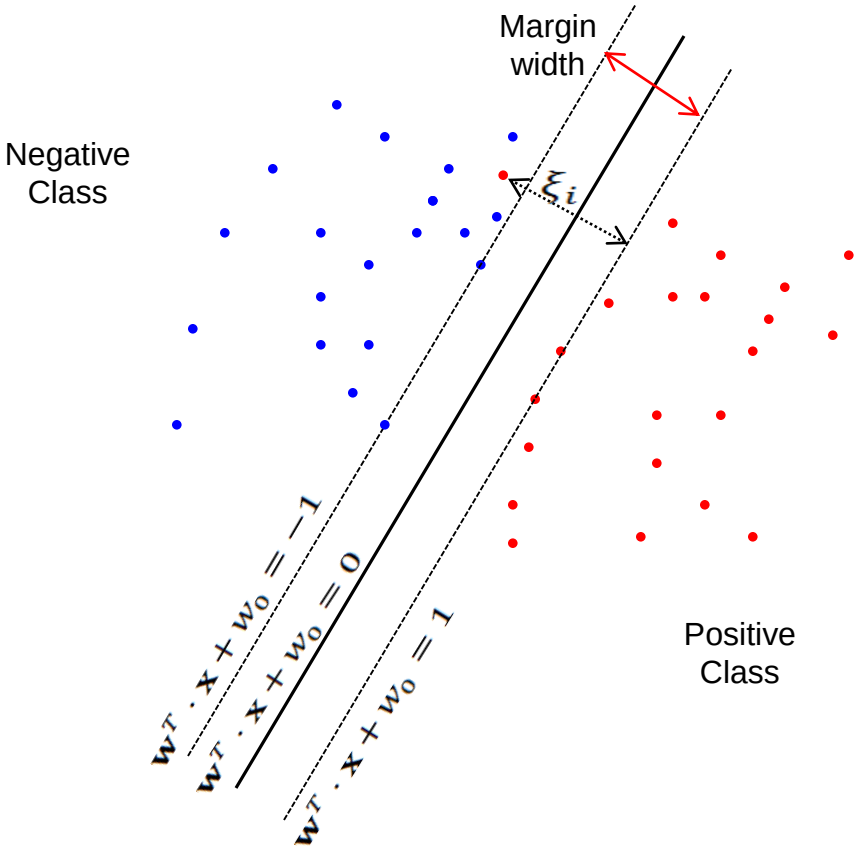
$$\min_{\mathbf{w}, w_0} \left(\frac{1}{2} \mathbf{w}^T \cdot \mathbf{w} \right)$$

- Subject to the following constraints:
  - Every training instance should lie on the appropriate (positive / negative) side of the linear separator

$$y^i \left(\mathbf{w}^T \cdot \mathbf{x}^i + w_0 \right) \geq 1, \forall_{1 \leq i \leq N}$$

$$-y^i \left(\mathbf{w}^T \cdot \mathbf{x}^i + w_0 \right) + 1 \leq 0, \forall_{1 \leq i \leq N}$$

SVM: Soft-margin Formulation



- Objective:
  - Maximize the margin and minimize the training error

$$\min_{\mathbf{w}, w_0, \xi} \left(\frac{1}{2} \mathbf{w}^T \cdot \mathbf{w} \right) + C \cdot \sum_{i=1}^{N} \xi_i$$

- Subject to the following constraints:
  - Introducing slack variables so that the constraint is satisfied for training instances lying on incorrect side

$$-y^i \left(\mathbf{w}^T \cdot \mathbf{x}^i + w_0 \right) + 1 - \xi_i \leq 0, \forall_{1 \leq i \leq N}$$
$$-\xi_i \leq 0, \forall_{1 \leq i \leq N}$$

Optimization using Lagrange Multipliers

- One Lagrange multiplier is associated with each distinct constraint

$$L(\alpha_1, \cdots, \alpha_N, \mu_1, \cdots, \mu_N)$$

$$= \min_{\mathbf{w}, w_0, \xi} \left(\frac{1}{2} \mathbf{w}^T \cdot \mathbf{w} \right) + C \cdot \sum_{i=1}^{N} \xi_i$$

$$+ \sum_{i=1}^{N} \alpha_i \cdot \left(-y^i \left(\mathbf{w}^T \cdot \mathbf{x}^i + w_0 \right) + 1 - \xi_i \right)$$

$$+ \sum_{i=1}^{N} \mu_i \cdot (-\xi_i)$$

$$s.t. \quad \alpha_i \geq 0, \mu_i \geq 0, \forall_{1 \leq i \leq N}$$

Optimization using Lagrange Multipliers

- Differentiating w.r.t. $\mathbf{w}$

$$\frac{\partial L}{\partial \mathbf{w}} = \mathbf{w} - \sum_{i=1}^{N} \alpha_i y^i \mathbf{x}^i = 0 \quad \Rightarrow \boxed{\mathbf{w}^* = \sum_{i=1}^{N} \alpha_i y^i \mathbf{x}^i}$$

- Differentiating w.r.t. w_0

$$\frac{\partial L}{\partial w_0} = \sum_{i=1}^{N} -\alpha_i y^i = 0 \quad \Rightarrow \boxed{\sum_{i=1}^{N} \alpha_i y^i = 0}$$

- Differentiating w.r.t. ξ_i

$$\frac{\partial L}{\partial \xi_i} = C - \alpha_i - \mu_i = 0 \quad \Rightarrow \boxed{\mu_i + \alpha_i = C}$$

- Substituting optimal values:

$$L(\alpha_1, \cdots, \alpha_N, \mu_1, \cdots, \mu_N)$$

$$= \left(\frac{1}{2}\mathbf{w}^{*T} \cdot \mathbf{w}^*\right) + C \cdot \sum_{i=1}^{N} \xi_i^*$$

$$+ \sum_{i=1}^{N} \alpha_i \cdot \left(-y^i\left(\mathbf{w}^{*T} \cdot \mathbf{x}^i + w_0^*\right) + 1 - \xi_i^*\right) + \sum_{i=1}^{N} \mu_i \cdot (-\xi_i^*)$$

$$= \frac{1}{2}\left(\sum_{i=1}^{N} \alpha_i y^i \mathbf{x}^i\right)^T \cdot \left(\sum_{j=1}^{N} \alpha_j y^j \mathbf{x}^j\right) + C \cdot \sum_{i=1}^{N} \xi_i^*$$

$$+ \sum_{i=1}^{N} -\alpha_i y^i \left(\sum_{j=1}^{N} \alpha_j y^j \mathbf{x}^j\right)^T \mathbf{x}^i - w_0^* \sum_{i=1}^{N} \alpha_i y^i$$

$$+ \sum_{i=1}^{N} \alpha_i (1 - \xi_i) + \sum_{i=1}^{N} \mu_i \cdot (-\xi_i^*)$$

Terms involving ξ_i cancel each other out because $\mu_i + \alpha_i = C$

Sum in the red circle is zero

- Finally, we get:

$$L(\alpha_1, \cdots, \alpha_N) = \frac{-1}{2} \sum_{i=1}^{N} \sum_{j=1}^{N} \alpha_i \alpha_j y^i y^j \left(\mathbf{x}^{i^T} \mathbf{x}^j \right) + \sum_{i=1}^{N} \alpha_i$$

- Dual optimization problem:
  - Objective function:

$$\max_{\alpha_1, \cdots, \alpha_N} \frac{-1}{2} \sum_{i=1}^{N} \sum_{j=1}^{N} \alpha_i \alpha_j y^i y^j \left(\mathbf{x}^{i^T} \mathbf{x}^j \right) + \sum_{i=1}^{N} \alpha_i$$

  - Subject to the following constraints:

$$\alpha_i \geq 0, \mu_i \geq 0, \mu_i + \alpha_i = C, \forall_i \ \ and \ \sum_{i=1}^{N} \alpha_i y^i = 0$$

$$\Rightarrow \ \ \alpha_i \geq 0, \alpha_i \leq C, \forall_i \ \ and \ \sum_{i=1}^{N} \alpha_i y^i = 0$$

Any Quadratic Programming Solver can be used for solving this

Using SVM for Predictions

- How to predict the class label for a new instance $\mathbf{x}$ given a trained SVM
- Primal Form:
  - Compute $\mathbf{w}^T \cdot \mathbf{x} + w_0$; Positive value indicates the positive class and vice versa
  - E.g., $\mathbf{w} = [2, -1]\ and\ w_0 = -2$ be the learned parameters
  - For the new instance $\mathbf{x} = [2, 4]$ $\mathbf{w}^T \cdot \mathbf{x} + w_0 = -2$ and hence Negative class is predicted
- Dual Form:
  - Compute $$\mathbf{w}^T \cdot \mathbf{x} + w_0 = \left(\sum_{i=1}^{N} \alpha_i y^i \mathbf{x}^i \right)^T \mathbf{x} = \sum_{i=1}^{N} \alpha_i y^i \mathbf{x}^{i^T} \mathbf{x}$$
  - Positive value indicates the positive class and vice versa
  - Practically, most of the α_i values are zeros; non-zero only for support vectors