Introduction of Structured Learning

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Structured Learning

- We need a more powerful function *f*
  - Input and output are both objects with structures
  - *Object*: sequence, list, tree, bounding box …

$$f : X \rightarrow Y$$

X is the space of one kind of object

Y is the space of another kind of object

In the previous lectures, the input and output are both vectors.

Example Application

- **Speech recognition**
    - *X*: Speech signal (sequence) → *Y*: text (sequence)
- **Translation**
    - *X*: Mandarin sentence (sequence) → *Y*: English sentence (sequence)
- **Syntactic Paring**
    - *X*: sentence → *Y*: parsing tree (tree structure)
- **Object Detection**
    - *X*: Image → *Y*: bounding box
- **Summarization**
    - *X*: long document → *Y*: summary (short paragraph)
- **Retrieval**
    - *X*: keyword → *Y*: search result (a list of webpage)

Unified Framework

Training

- Find a function F

$$\mathrm{F}: X \times Y \rightarrow \mathrm{R}$$

- F(x,y): evaluate how compatible the objects x and y is

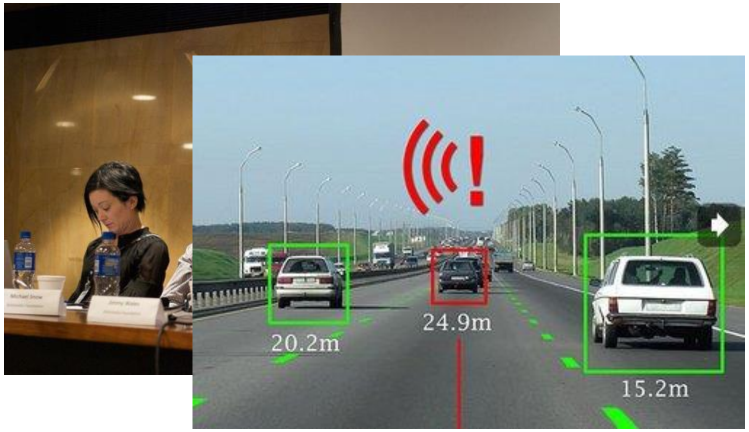
Inference (Testing)

- Given an object x

$$\tilde{y} = \arg\max_{y \in Y} F(x, y)$$

$$f : X \rightarrow Y \;\Rightarrow\; f(x) = \tilde{y} = \arg\max_{y \in Y} F(x, y)$$

Unified Framework – Object Detection



- Task description
  - Using a bounding box to highlight the position of a certain object in an image
  - E.g. A detector of Haruhi

X : Image → Y : Bounding Box

Haruhi

(the girl with yellow ribbon)

Unified Framework – Object Detection

Training

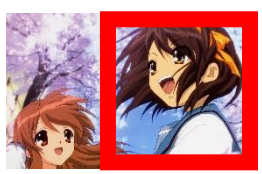
- Find a function F

$$F: X \times Y \rightarrow R$$

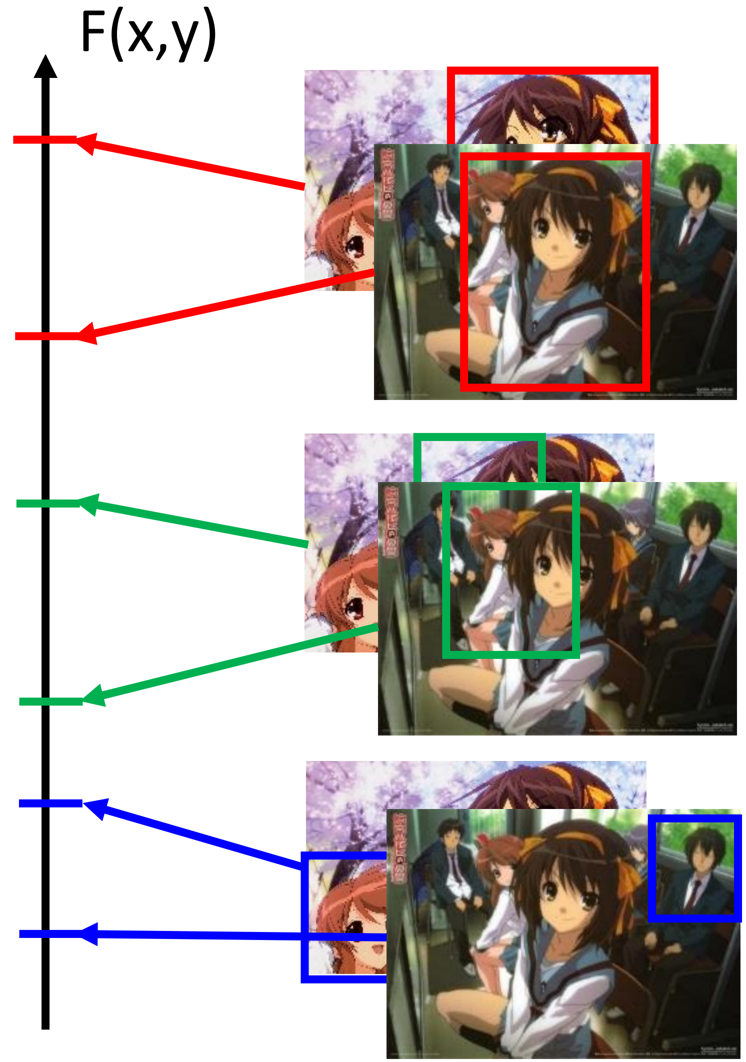
- F(x,y): evaluate how compatible the objects x and y is

x: Image ➡ 

y: Bounding Box ➡

F(x,y) ➡ F()

the correctness of taking range of y in x as “Haruhi”



Unified Framework – Object Detection

Training

- Find a function F

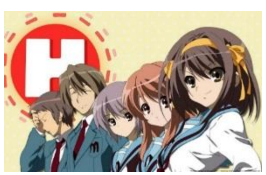
$$F : X \times Y \rightarrow R$$

- F(x,y): evaluate how compatible the objects x and y is

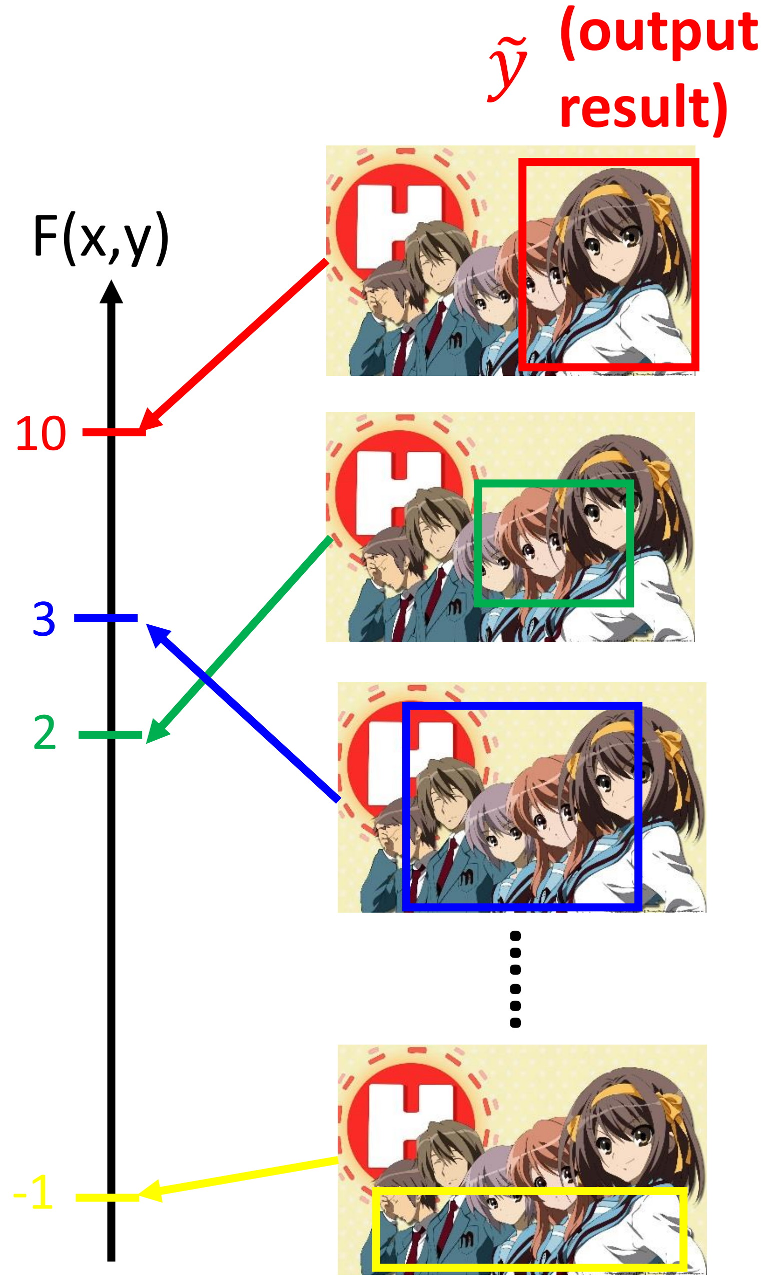
Inference (Testing)

- Given an object x

$$\tilde{y} = \arg\max_{y \in Y} F(x, y)$$

input x = 

Enumerate all possible bounding box y



Unified Framework
- Summarization

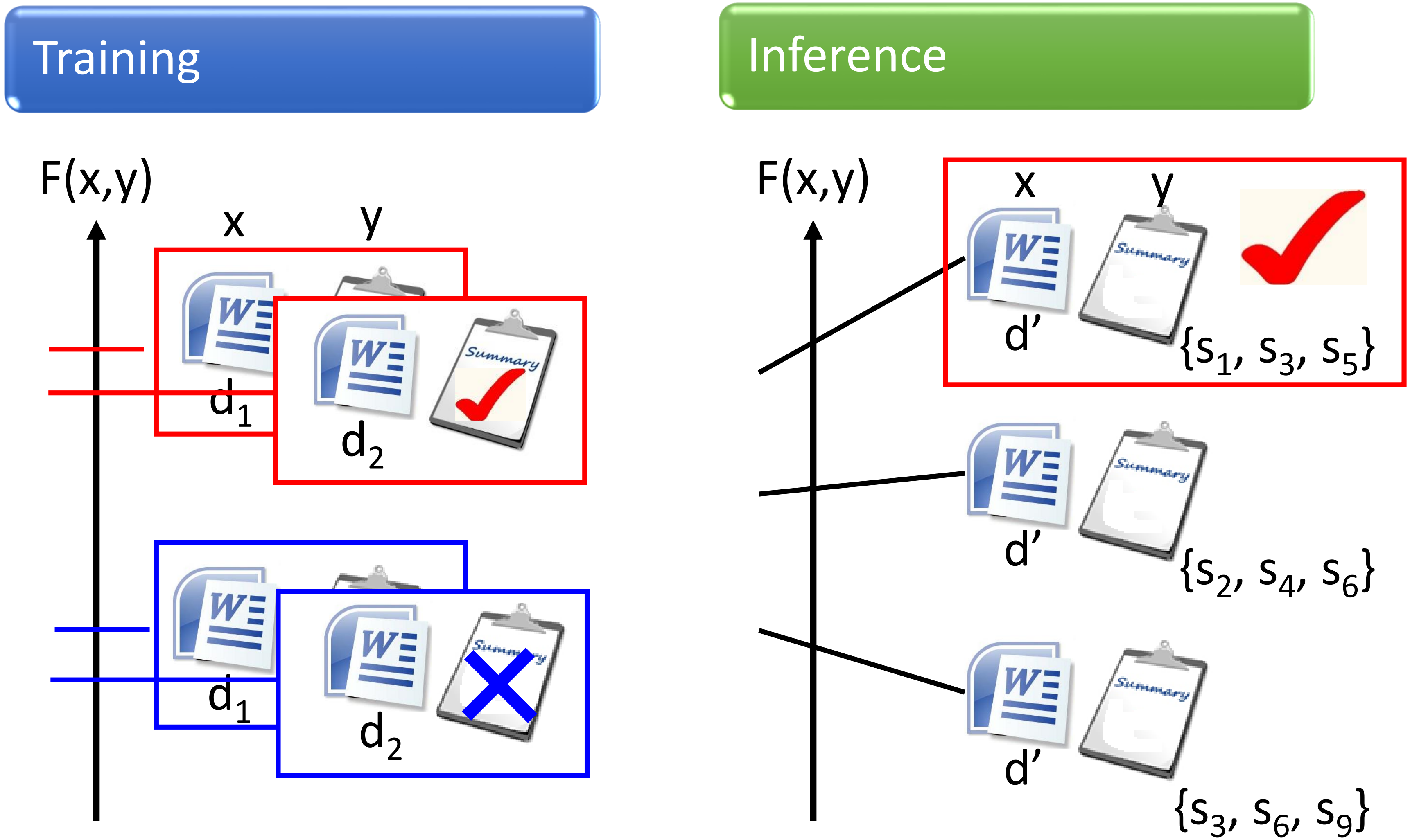
- Task description
  - Given a long document
  - Select a set of sentences from the document, and cascade the sentences to form a short paragraph

X → Y

long document
$=\{s_1, s_2, s_3, \ldots\ldots s_i \ldots\}$
s_i: the i^{th} sentence

summary
$=\{s_1, s_3, s_5\}$

Unified Framework
- Summarization



Unified Framework
- Retrieval

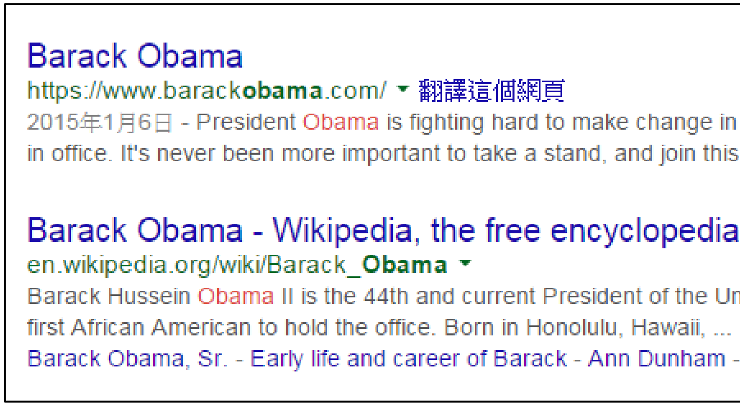
- Task description
  - User input a keyword Q
  - System returns a ***list*** of web pages

X $\quad\quad$ Y

“Obama”
(keyword)

→

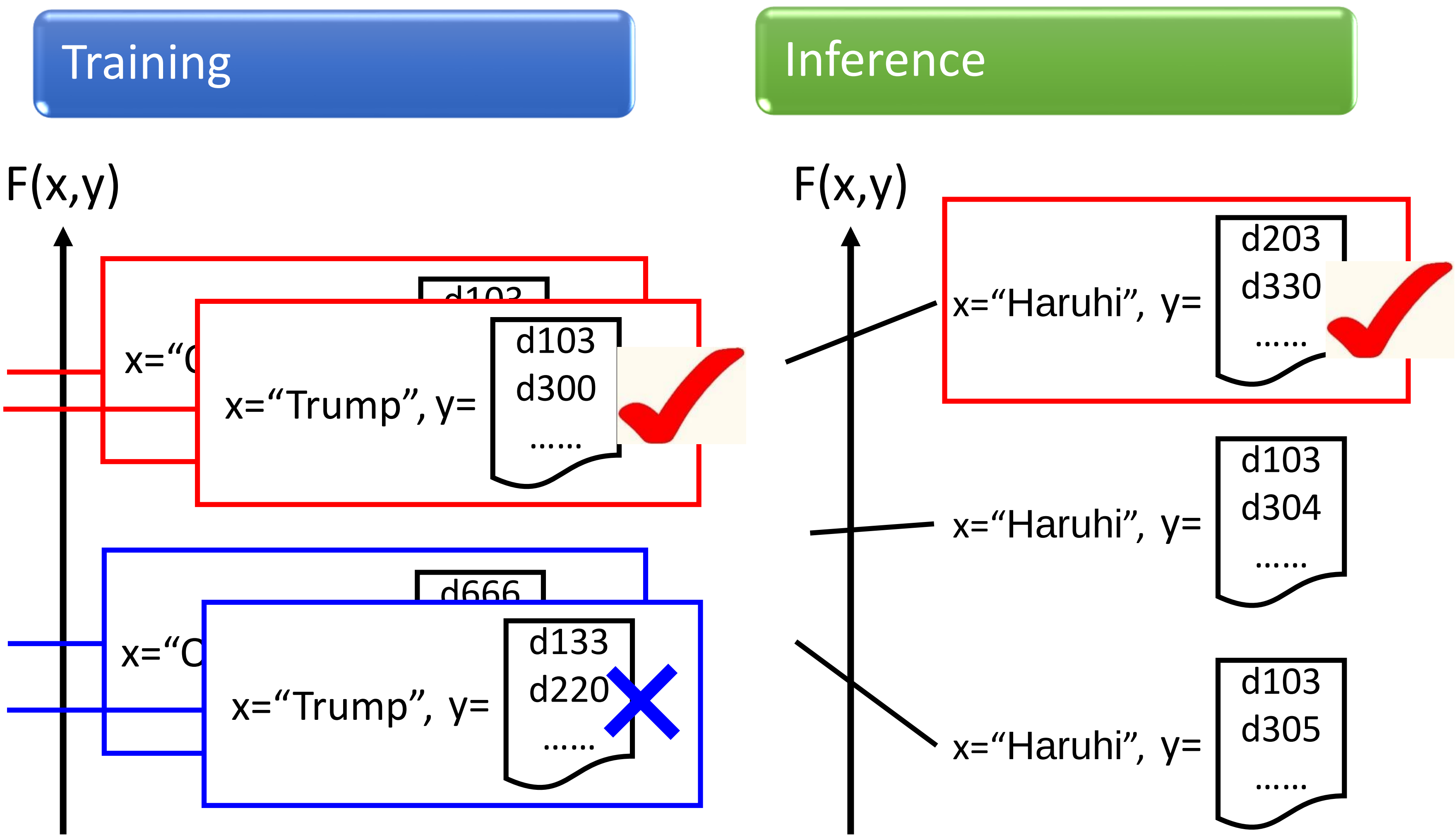
d10011
d98776
⋮


Barack Obama
https://www.barackobama.com/ ▾ 翻譯這個網頁
2015年1月6日 - President Obama is fighting hard to make change in
in office. It's never been more important to take a stand, and join this

Barack Obama - Wikipedia, the free encyclopedia
en.wikipedia.org/wiki/Barack_Obama ▾
Barack Hussein Obama II is the 44th and current President of the Un
first African American to hold the office. Born in Honolulu, Hawaii, ...
Barack Obama, Sr. - Early life and career of Barack - Ann Dunham -

A list of web pages (Search Result)

Unified Framework - Retrieval



Statistics

Unified Framework

Training

- Find a function F

$$F : X \times Y \to R$$

- F(x,y): evaluate how compatible the objects x and y is

Inference

- Given an object x

$$\tilde{y} = \arg\max_{y \in Y} F(x, y)$$

$$F(x, y) = P(x, y)?$$

Training

- Estimate the probability P(x,y)

$$P : X \times Y \to [0,1]$$

Inference

- Given an object x

$$\tilde{y} = \arg\max_{y \in Y} P(y \mid x)$$

$$= \arg\max_{y \in Y} \frac{P(x, y)}{P(x)}$$

$$= \arg\max_{y \in Y} P(x, y)$$

Statistics

Unified Framework

$$F(x, y) = P(x, y)?$$

Drawback for probability

- Probability cannot explain everything
- 0-1 constraint is not necessary

Strength for probability

- Meaningful

Energy-based Model: http://www.cs.nyu.edu/~yann/research/ebm/

Training

- Estimate the probability P(x,y)

$$P : X \times Y \to [0,1]$$

Inference

- Given an object x

$$\tilde{y} = \arg\max_{y \in Y} P(y \mid x)$$

$$= \arg\max_{y \in Y} \frac{P(x, y)}{P(x)}$$

$$= \arg\max_{y \in Y} P(x, y)$$

Unified Framework

That's it!?

Training

- Find a function F

$$\mathrm{F}: X \times Y \rightarrow \mathrm{R}$$

- F(x,y): evaluate how compatible the objects x and y is

Inference (Testing)

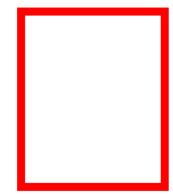
- Given an object x

$$\tilde{y} = \arg\max_{y \in Y} F(x, y)$$

There are three problems in this framework.

Problem 1

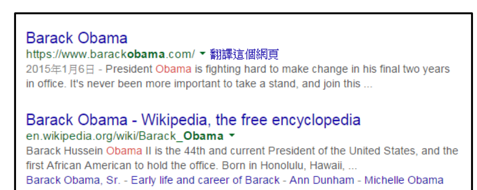
- ***Evaluation***: What does F(x,y) look like?
  - How F(x,y) compute the “compatibility” of objects x and y

Object Detection: F(x=  , y= )

Summarization: F(x=  , y= 

)

(a long document) (a short paragraph)

Retrieval: F(x= “Obama” , y= 
Barack Obama
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Barack Obama, Sr. - Early life and career of Barack - Ann Dunham - Michelle Obama

)

(keyword) (Search Result)

Problem 2

- **Inference**: How to solve the "arg max" problem

$$y = \arg\max_{y \in Y} F(x, y)$$

The space Y can be extremely large!

Object Detection: Y=All possible bounding box (maybe tractable)

Summarization: Y=All combination of sentence set in a document …

Retrieval: Y=All possible webpage ranking ….

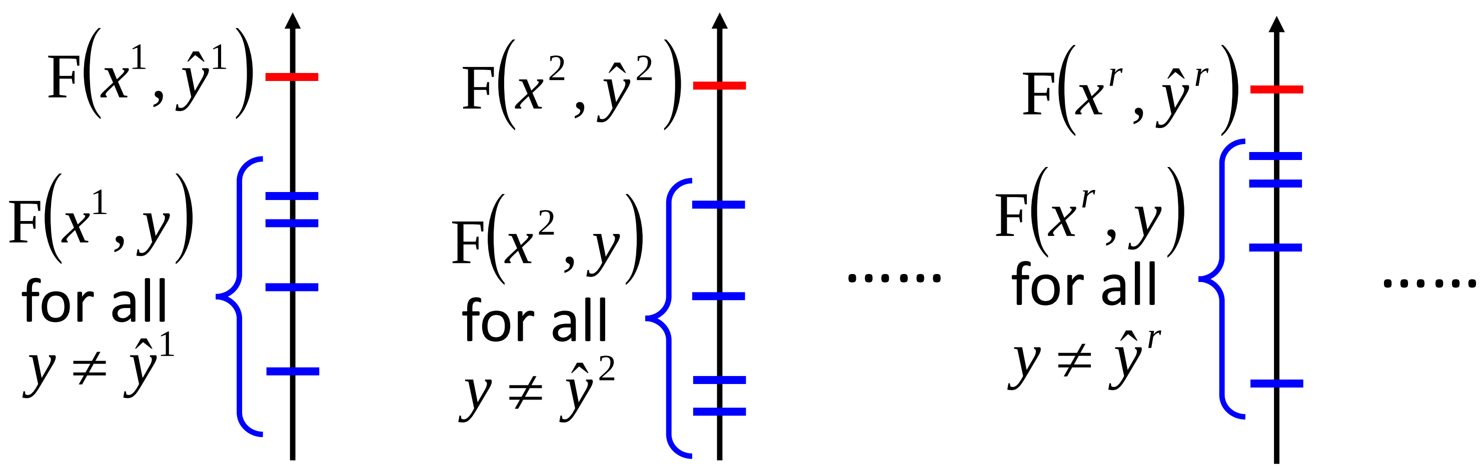
Problem 3

- ***Training***: Given training data, how to find F(x,y)

Principle

Training data: $\left\{\left(x^1,\hat{y}^1\right),\left(x^2,\hat{y}^2\right),\ldots,\left(x^r,\hat{y}^r\right),\ldots\right\}$

We should find F(x,y) such that ……



Three Problems

Problem 1: Evaluation

- What does F(x,y) look like?

Problem 2: Inference

- How to solve the “arg max” problem

$$y = \arg\max_{y \in Y} F(x, y)$$

Problem 3: Training

- Given training data, how to find F(x,y)

Three Problems

Problem 1: Evaluation

- What does F(x,y) look like?

Problem 2: Inference

- How to solve the “arg max

$$y = \arg m$$

Problem 3: Training

- Given training data, how t

Have you heard the three problems elsewhere?

Hidden Markov Model

- **Three Basic Problems for HMMs**

Given an observation sequence $\overline{O}=(o_1,o_2,\ldots,o_T)$, and an HMM λ =(A,B,π)

- Problem *1* :
  How to *efficiently* compute P($\overline{\mathbf{O}}$| λ) ?
  ⇨ *Evaluation problem*
- Problem *2* :
  How to choose an optimal state sequence **q**=($q_1,q_2,\ldots\ldots, q_T$) ?
  ⇨ *Decoding Problem*
- Problem *3* :
  Given some observations $\overline{O}$ for the HMM λ , how to adjust the model parameter λ =(A,B,π) to maximize P($\overline{\mathbf{O}}$| λ)?
  ⇨ *Learning /Training Problem*

From 數位語音處理

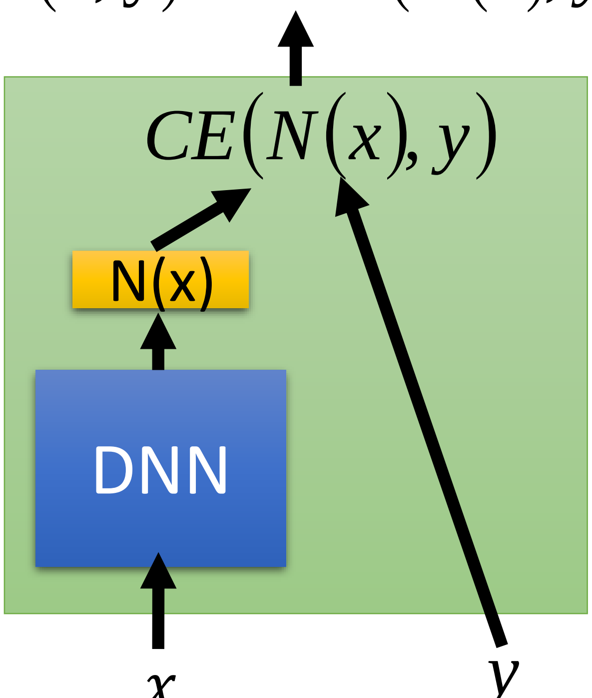
Link to DNN?

The same as what we have learned.

Training

$$F : X \times Y \rightarrow R$$

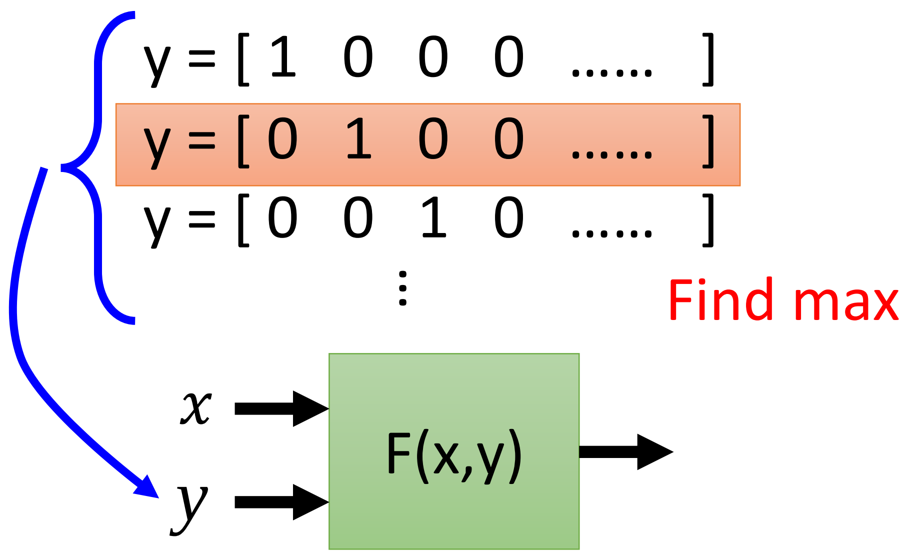
$$F(x, y) = -CE(N(x), y)$$



Inference

$$\tilde{y} = \arg\max_{y \in Y} F(x, y)$$

In handwriting digit classification, there are only 10 possible y.



You have to know ……

- ***Viterbi Algorithm***
  - 數位語音處理:
    - http://speech.ee.ntu.edu.tw/DSP2015Autumn/Videos/20150930_4.0.fsp.wmv/index.html (請用 IE 開啟)
    - http://speech.ee.ntu.edu.tw/DSP2015Autumn/Videos/20151007_4.0.fsp.wmv/index.html (請用 IE 開啟)
  - 演算法
  - 數位通信相關課程