Deep Learning

Ups and downs of Deep Learning

- 1958: Perceptron (linear model)
- 1969: Perceptron has limitation
- 1980s: Multi-layer perceptron
  - Do not have significant difference from DNN today
- 1986: Backpropagation
  - Usually more than 3 hidden layers is not helpful
- 1989: 1 hidden layer is “good enough”, why deep?
- 2006: RBM initialization (breakthrough)
- 2009: GPU
- 2011: Start to be popular in speech recognition
- 2012: win ILSVRC image competition

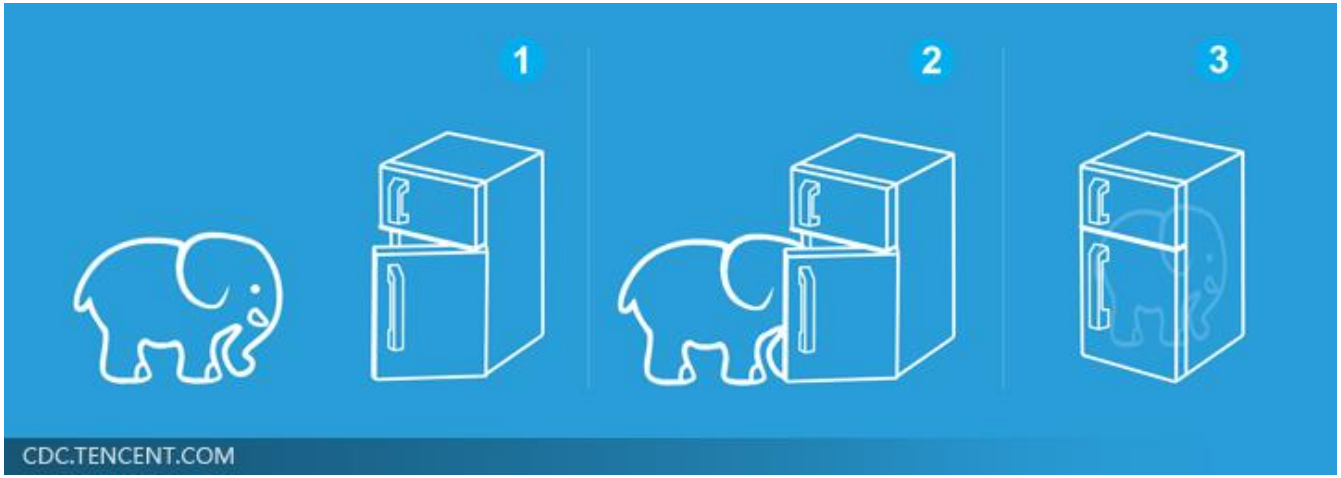
Three Steps for Deep Learning

Step 1: Neural Network

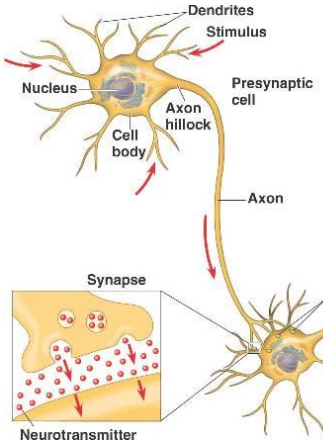
Step 2: goodness of function

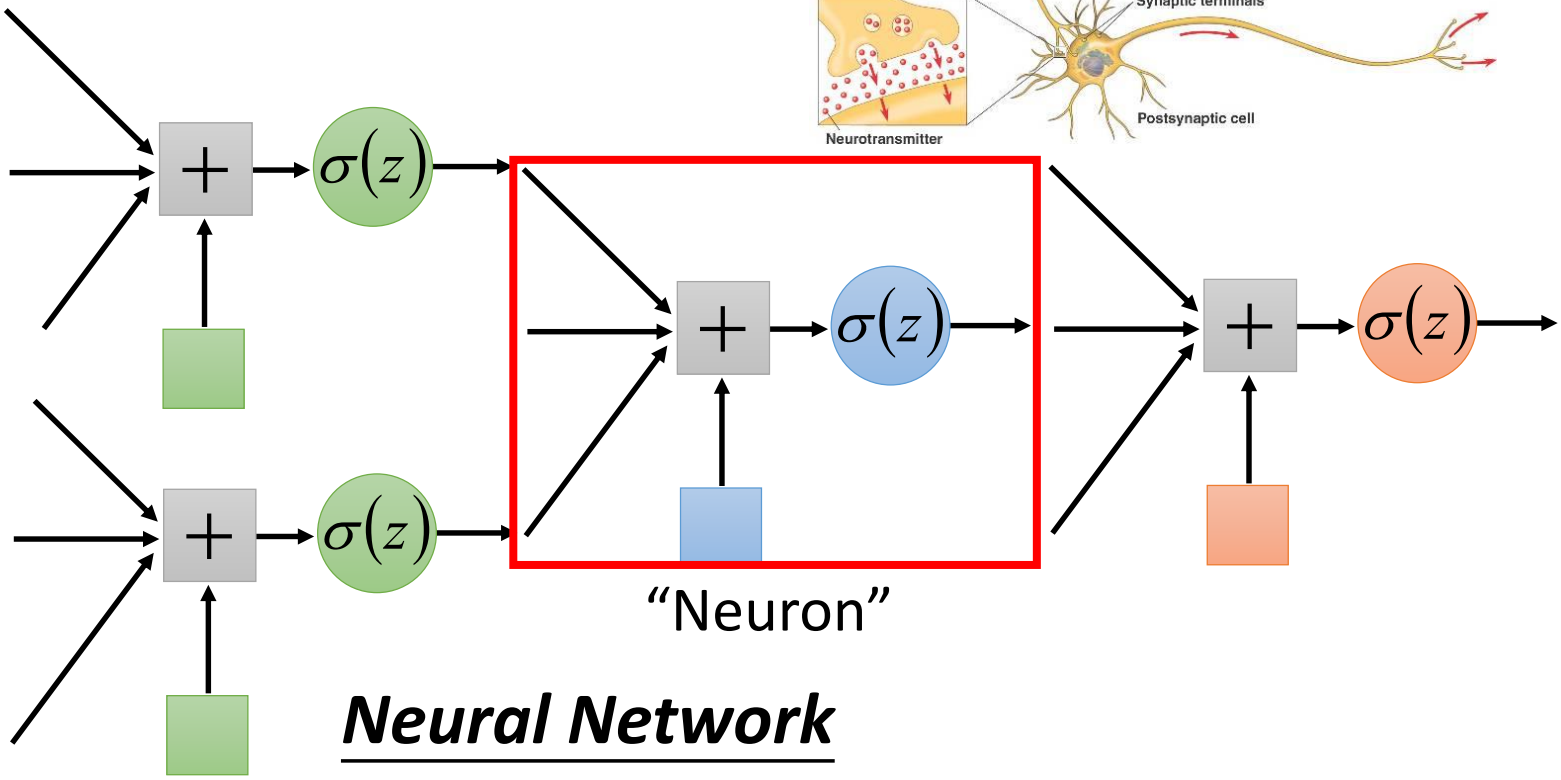
Step 3: pick the best function

Deep Learning is so simple ……



Neural Network





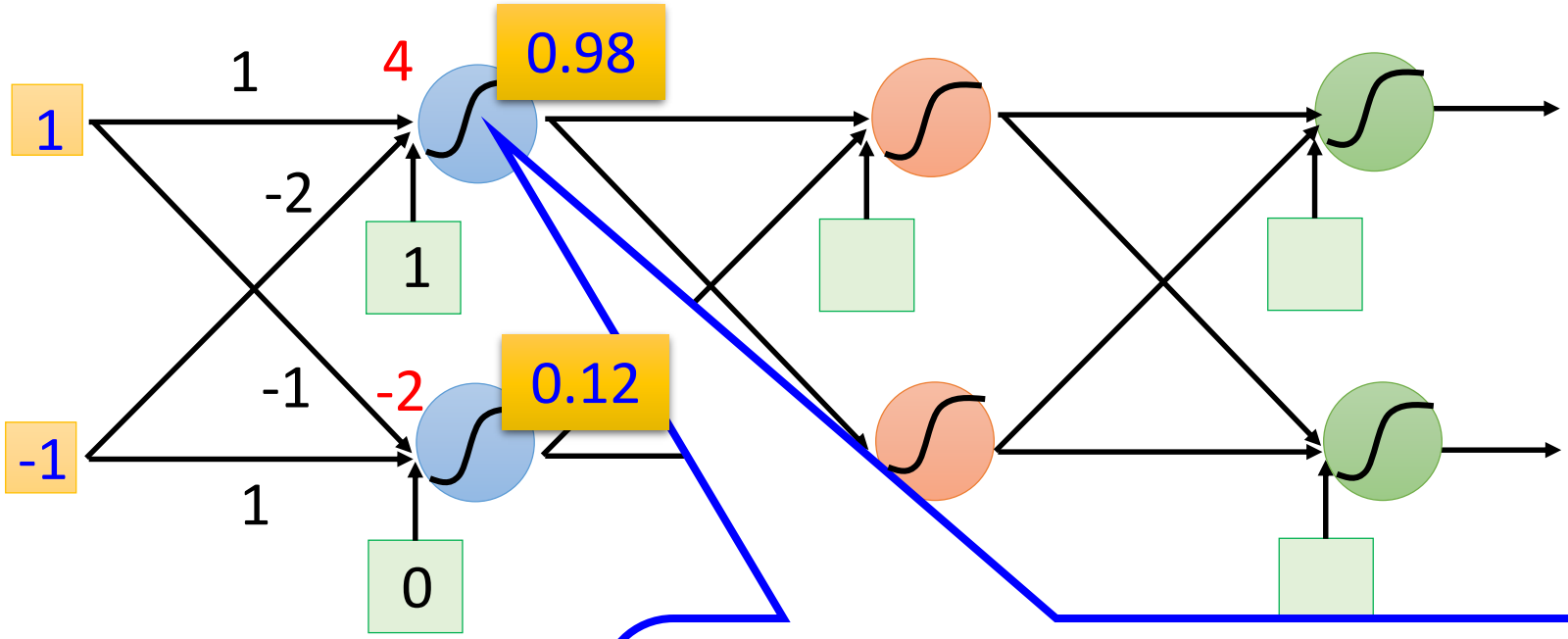
"Neuron"

Neural Network

Different connection leads to different network structures

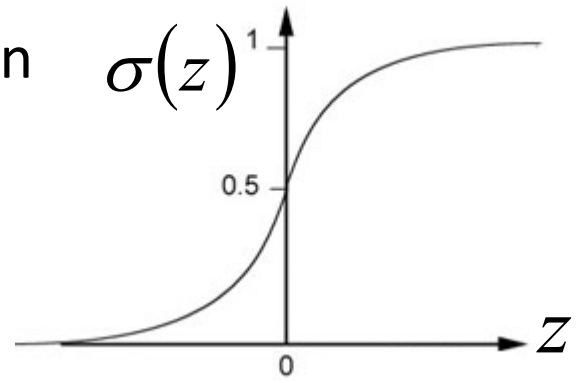
Network parameter θ: all the weights and biases in the "neurons"

Fully Connect Feedforward Network

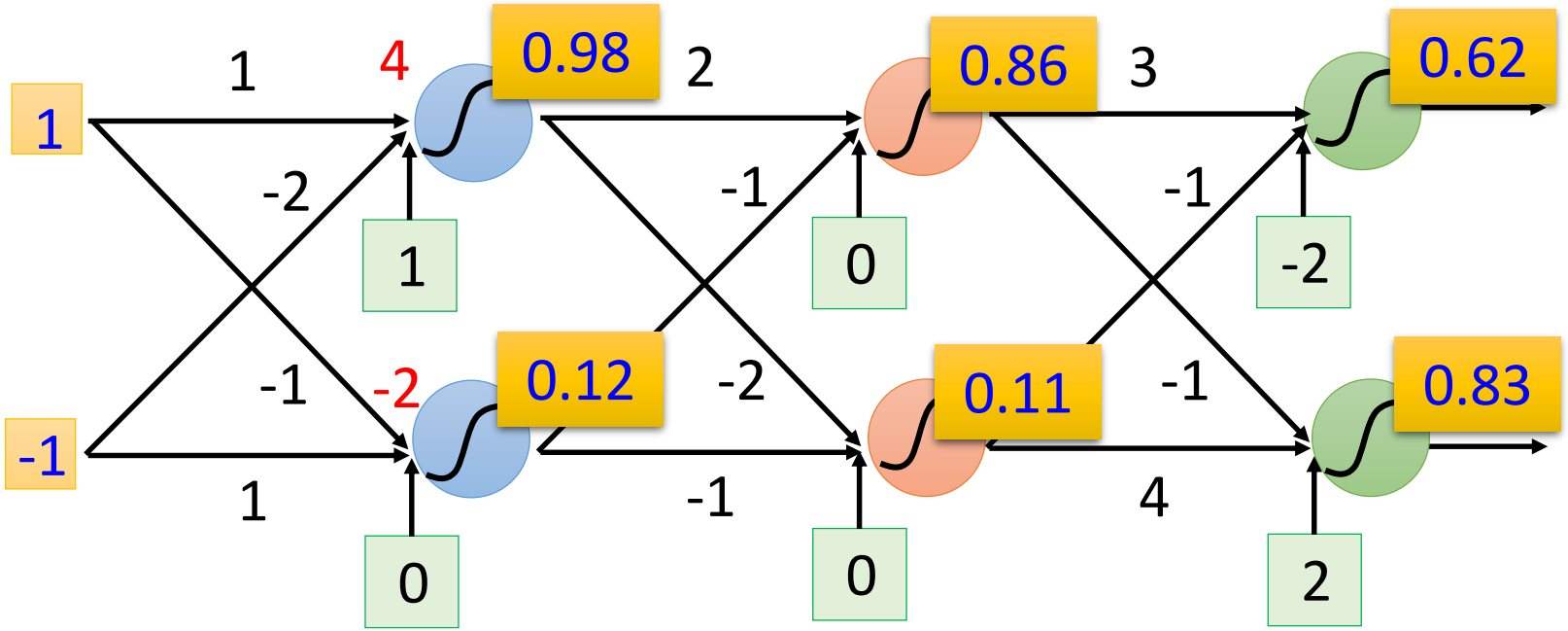


Sigmoid Function

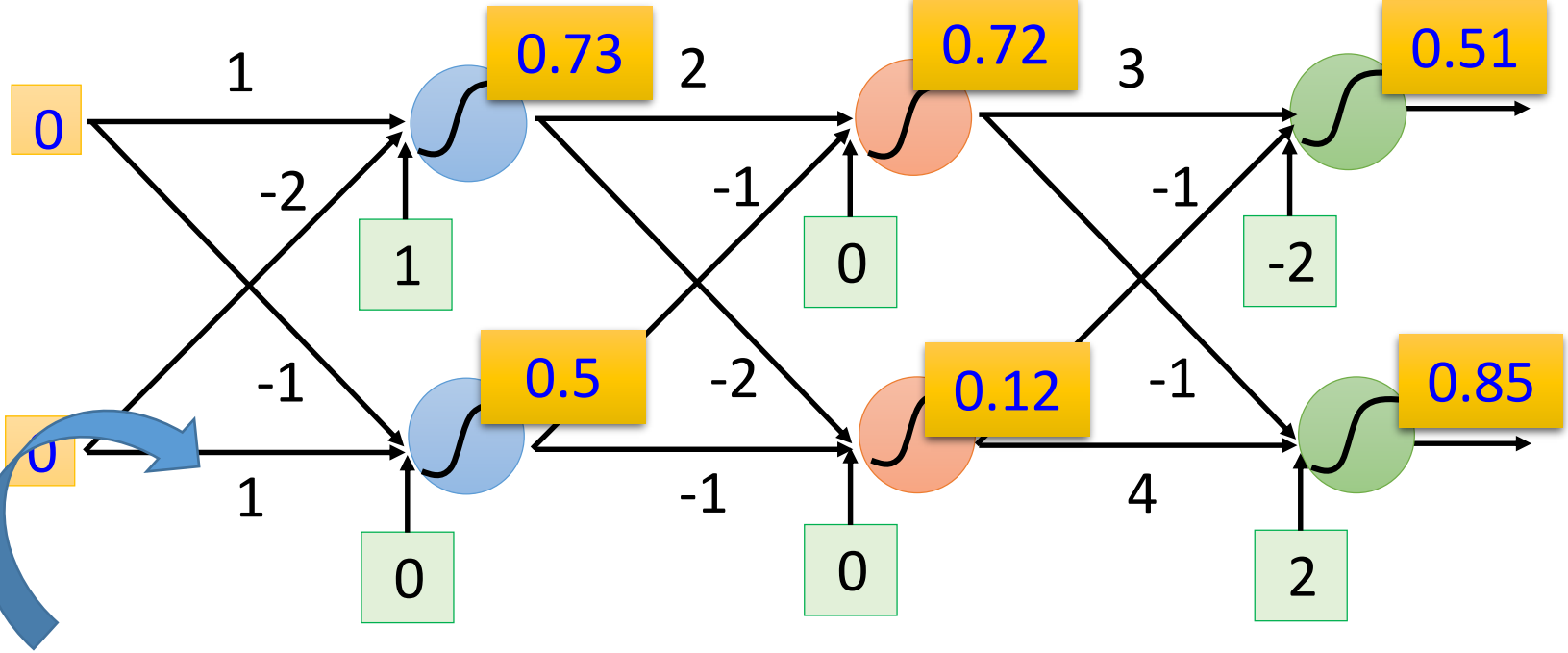
$$\sigma(z) = \frac{1}{1+e^{-z}}$$



Fully Connect Feedforward Network



Fully Connect Feedforward Network



This is a function.

Input vector, output vector

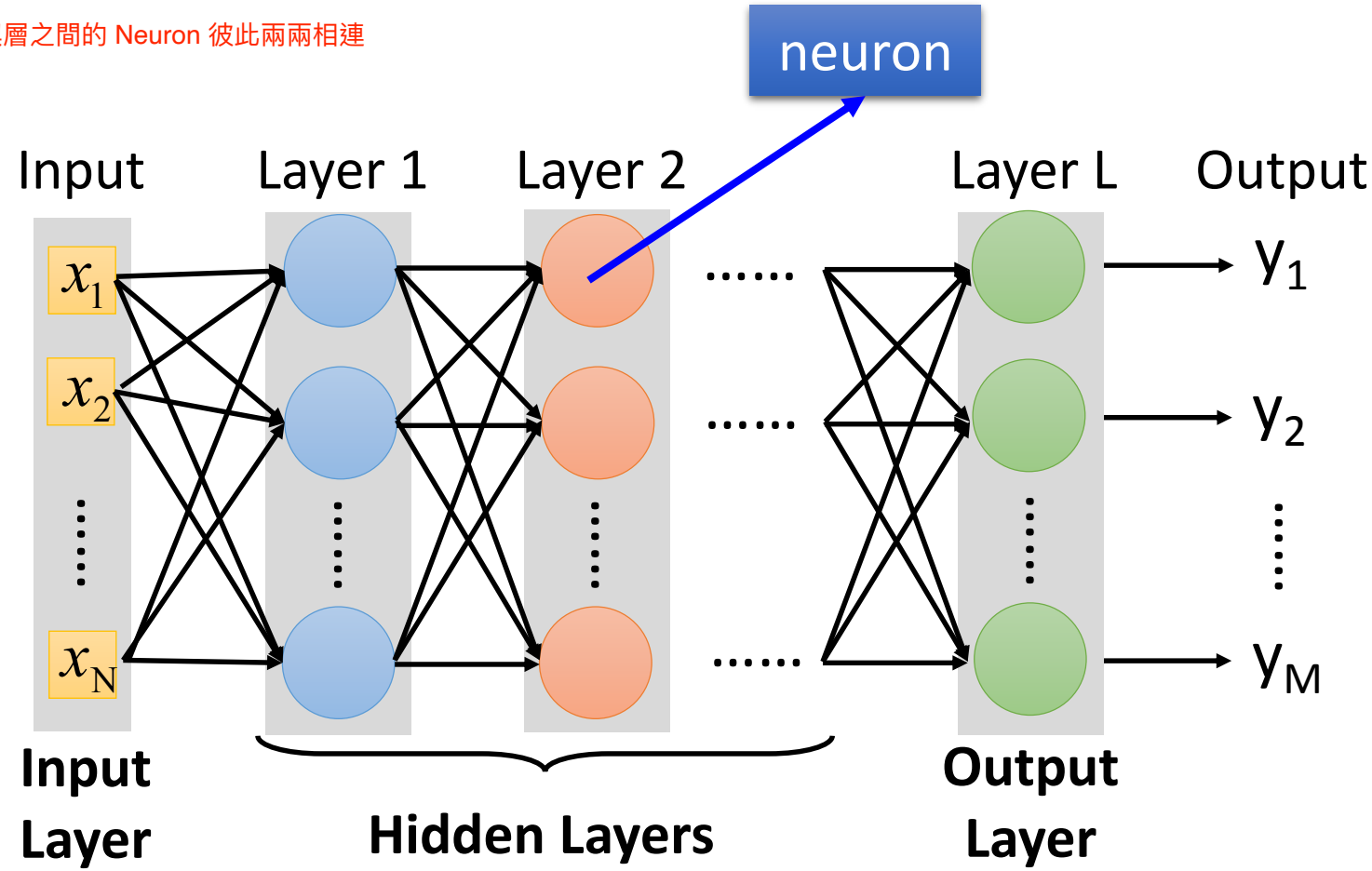
$$f\left(\begin{bmatrix}1\\-1\end{bmatrix}\right)=\begin{bmatrix}0.62\\0.83\end{bmatrix} \quad f\left(\begin{bmatrix}0\\0\end{bmatrix}\right)=\begin{bmatrix}0.51\\0.85\end{bmatrix}$$

Given network structure, define ***a function set***

Fully Connect Feedforward Network

層與層之間的 Neuron 彼此兩兩相連

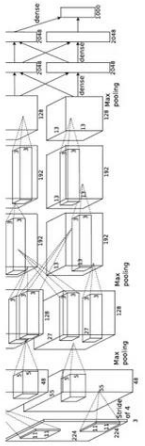
Value 由後往前傳



Deep = Many hidden layers

http://cs231n.stanford.edu/slides/winter1516_lecture8.pdf

8 layers



16.4%

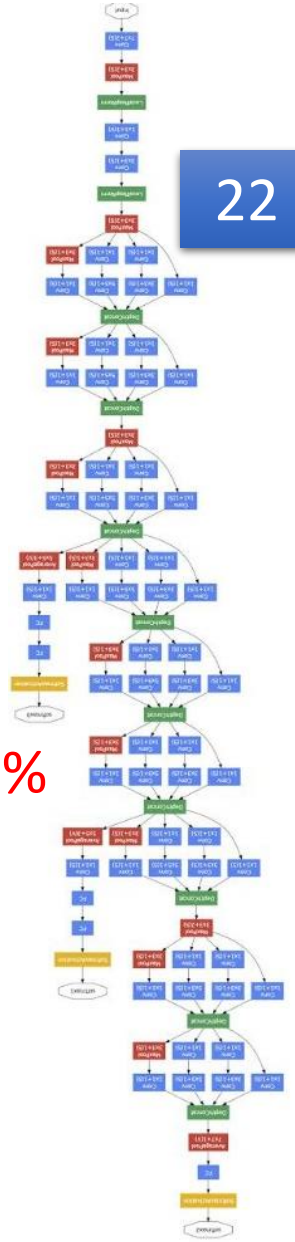
AlexNet (2012)

19 layers

7.3%

VGG (2014)

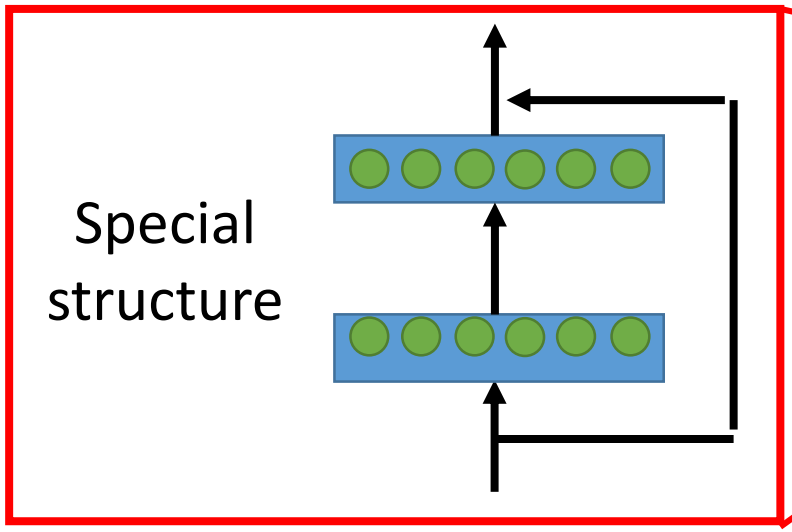
22 layers



6.7%

GoogleNet (2014)

Deep = Many hidden layers



152 layers

101 layers

3.57%

16.4%

AlexNet
(2012)

7.3%

VGG
(2014)

6.7%

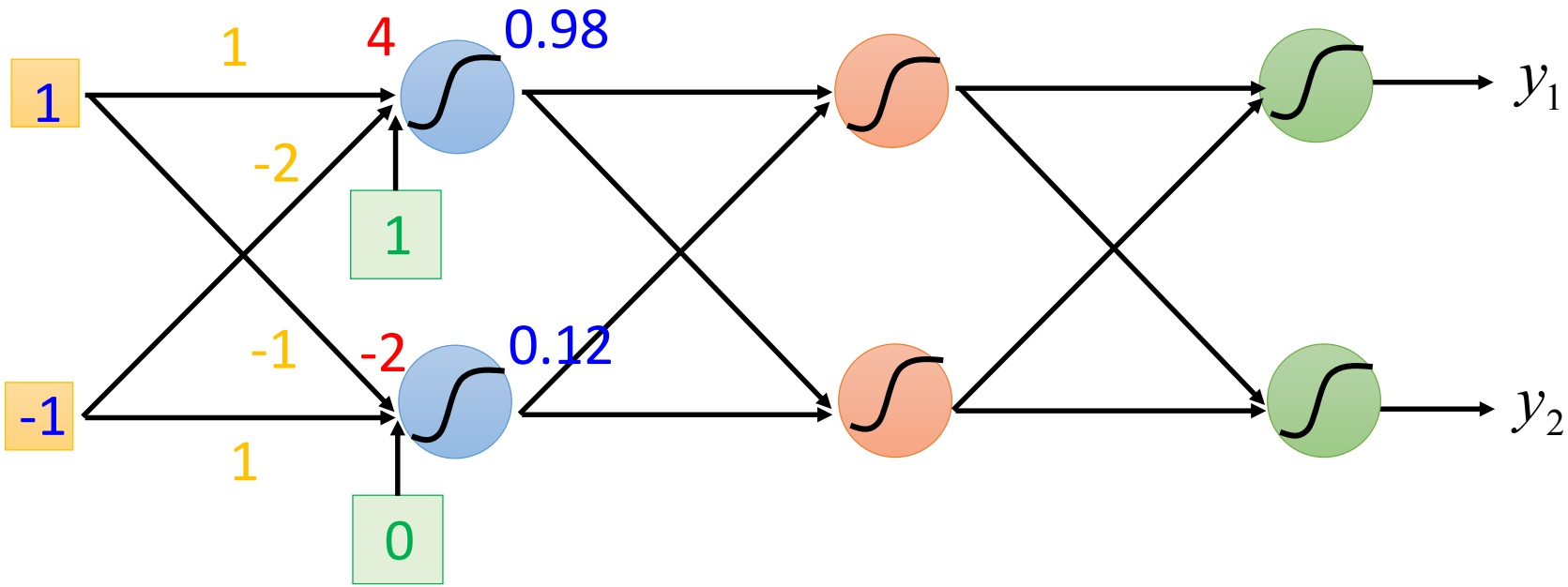
GoogleNet
(2014)

Residual Net
(2015)

Taipei
101

Neural Network 的運作實際上就是一連串的「矩陣運算」

Matrix Operation

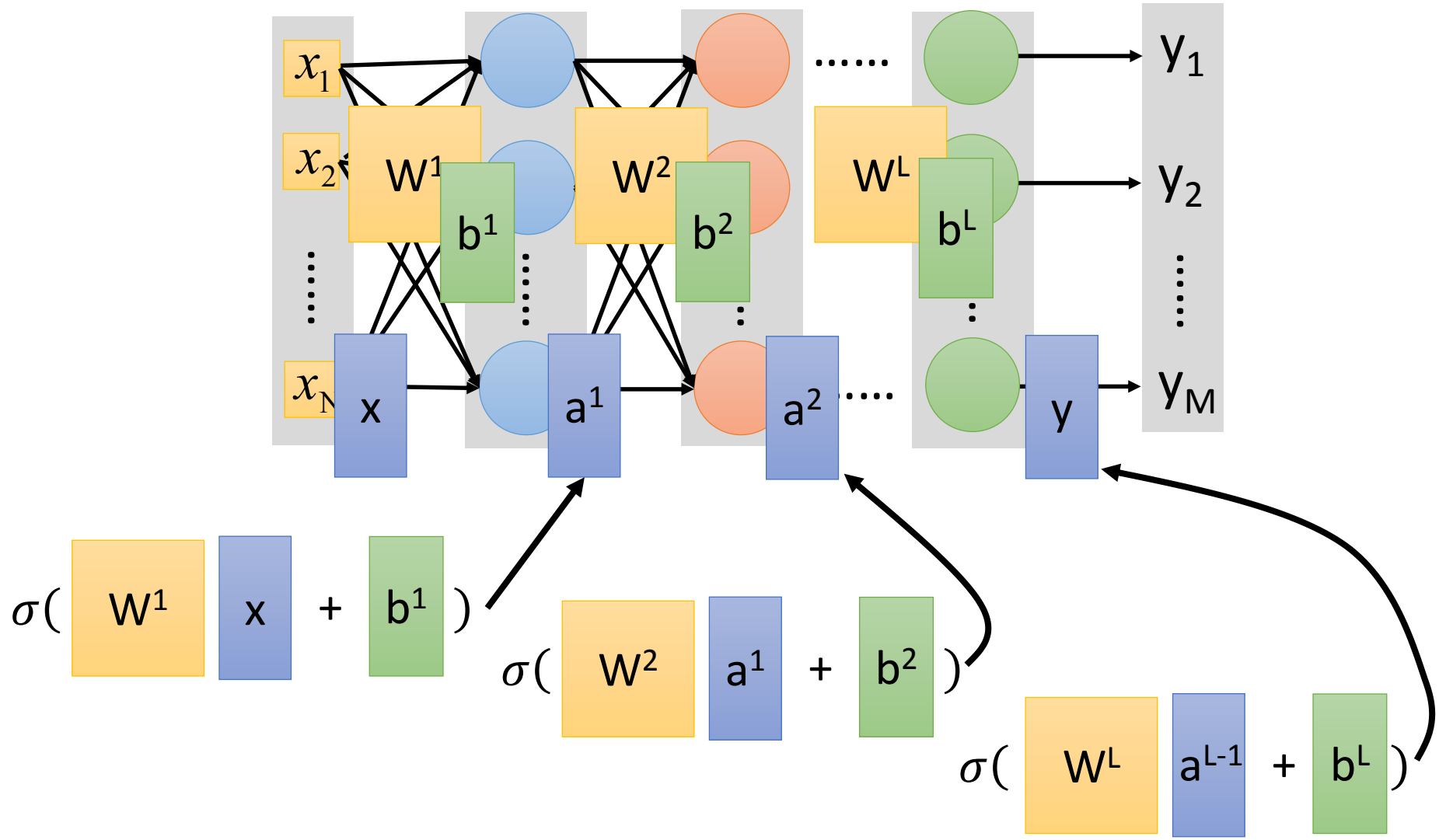


一層運算：(一個 Matrix ＊ 一個 Vector) + 一個 Vector => 通過 Activation Function

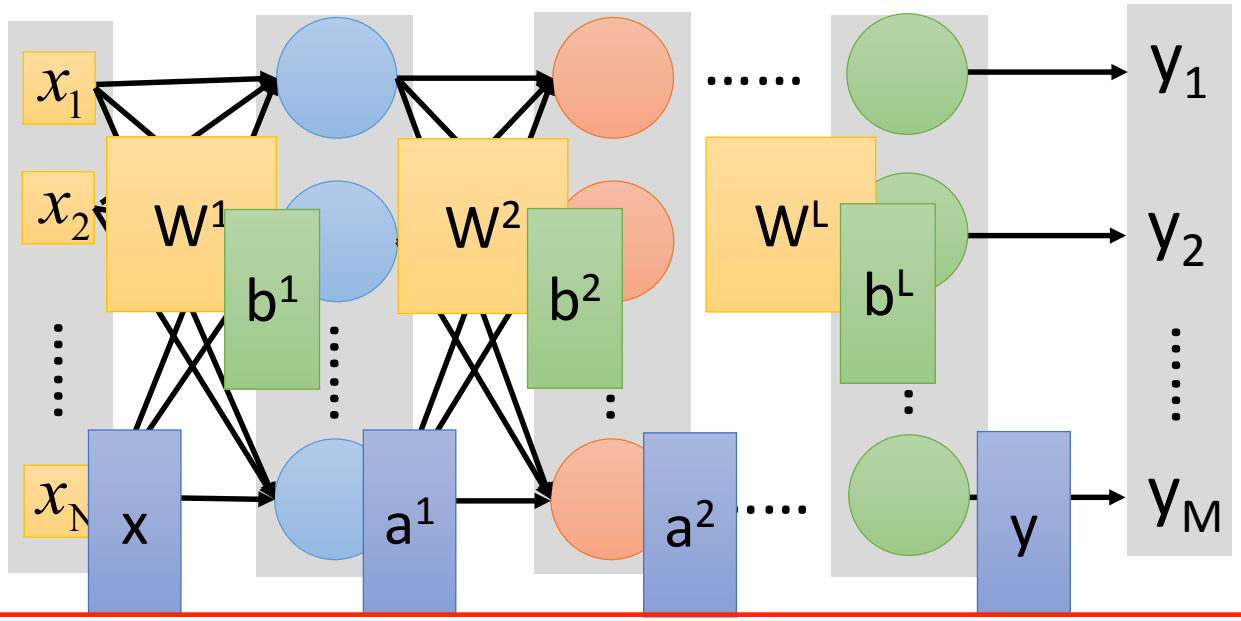
$$\sigma\left(\begin{bmatrix}1 & -2\\ -1 & 1\end{bmatrix}\begin{bmatrix}1\\ -1\end{bmatrix}+\begin{bmatrix}1\\ 0\end{bmatrix}\right)=\begin{bmatrix}0.98\\ 0.12\end{bmatrix}$$

$$\begin{bmatrix}4\\ -2\end{bmatrix}$$

Neural Network



Neural Network



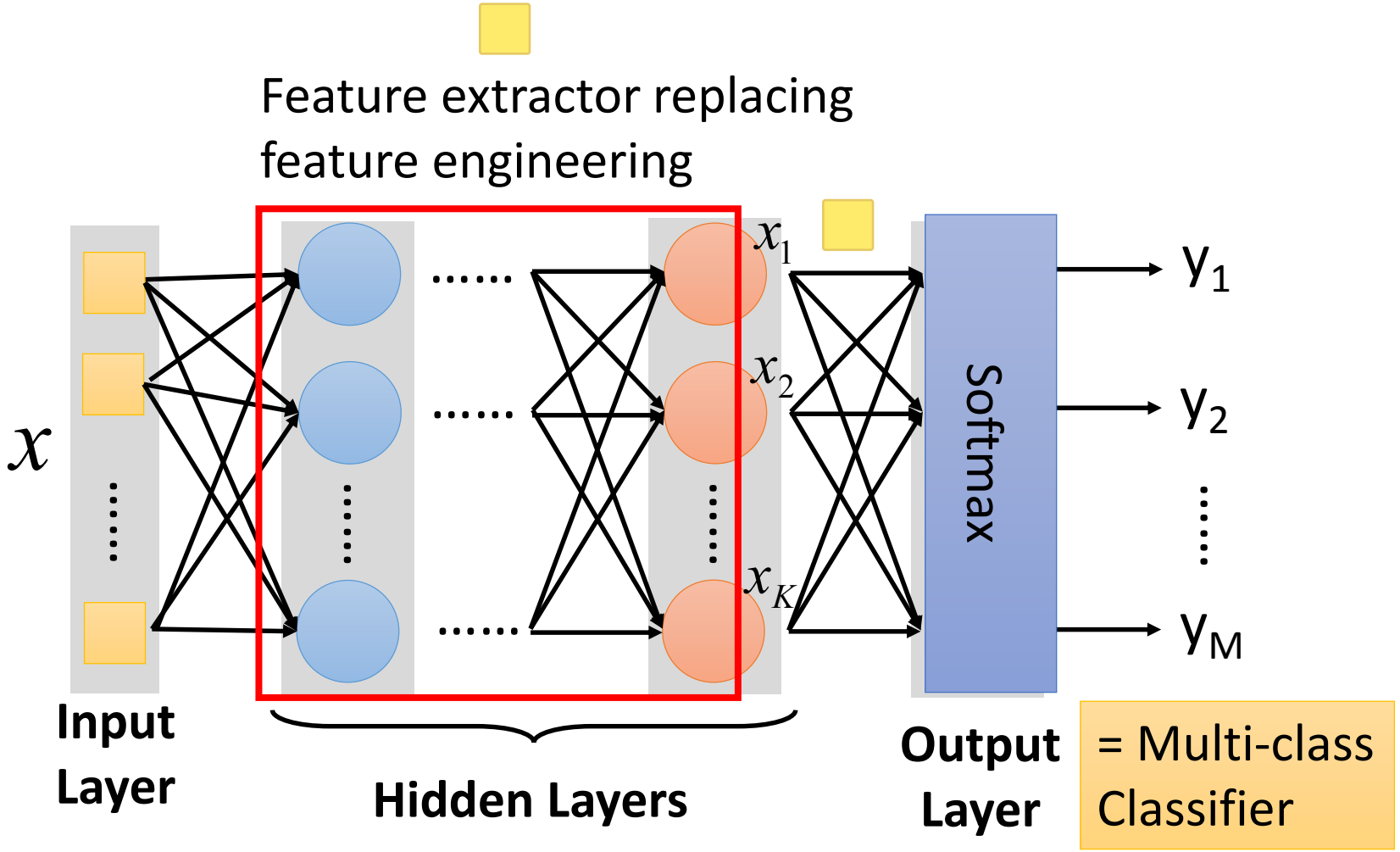
將 Neural Network 的運算視為一連串的「矩陣運算」的好處：可以利用 GPU 加速矩陣運算

$$y = f(x)$$

Using parallel computing techniques to speed up matrix operation

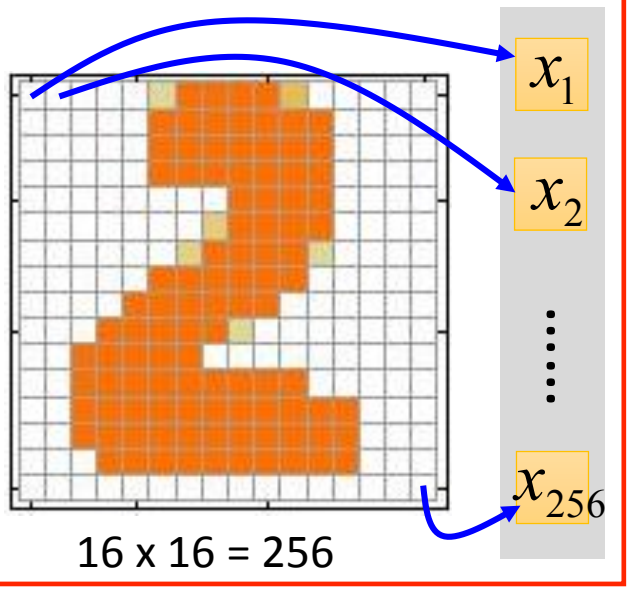
$$= \sigma(W^L \cdots \sigma(W^2 \sigma(W^1 x + b^1) + b^2) \cdots + b^L)$$

Output Layer



Example Application

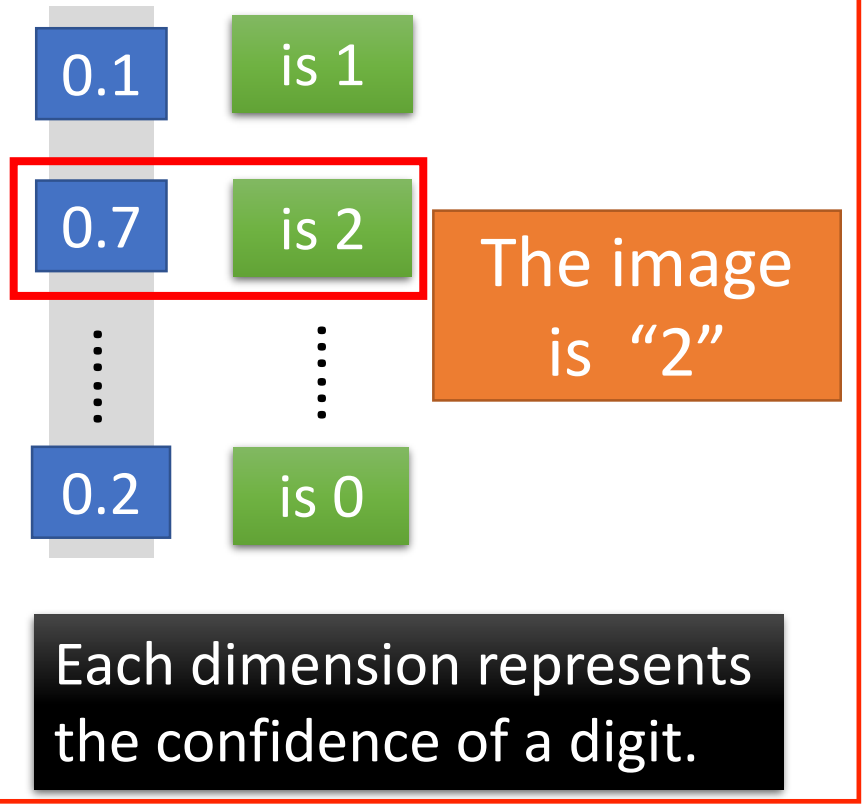
Input



Ink → 1

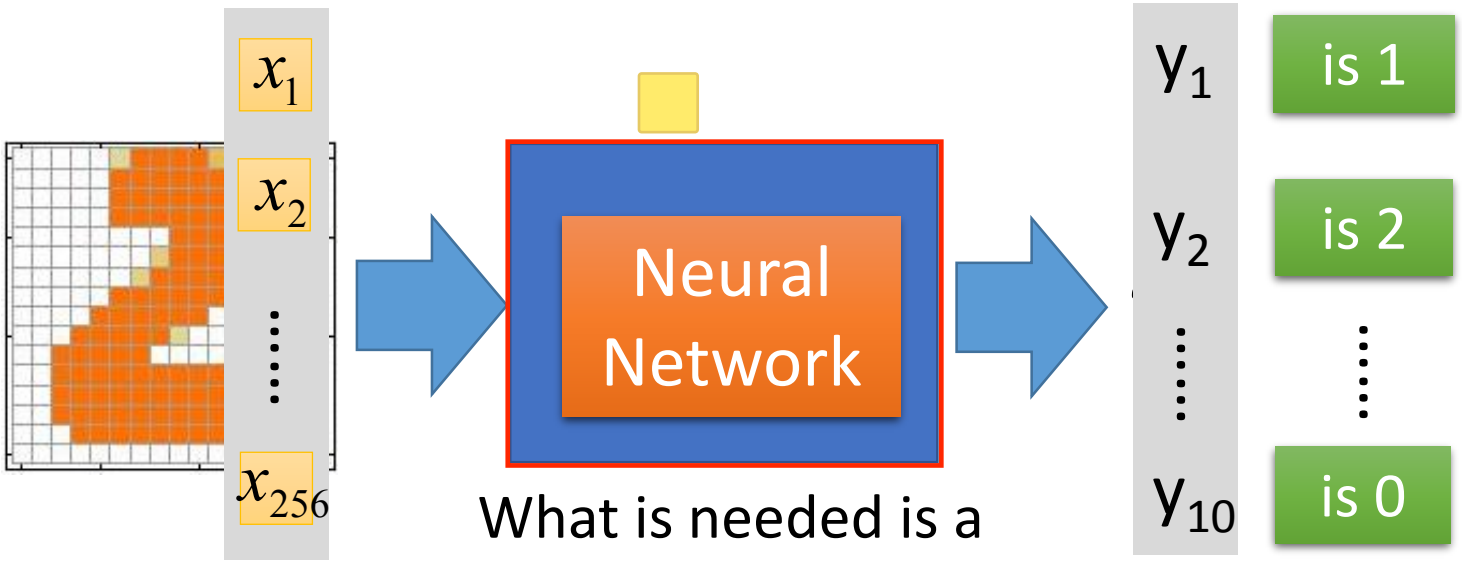
No ink → 0

Output



Example Application

- Handwriting Digit Recognition

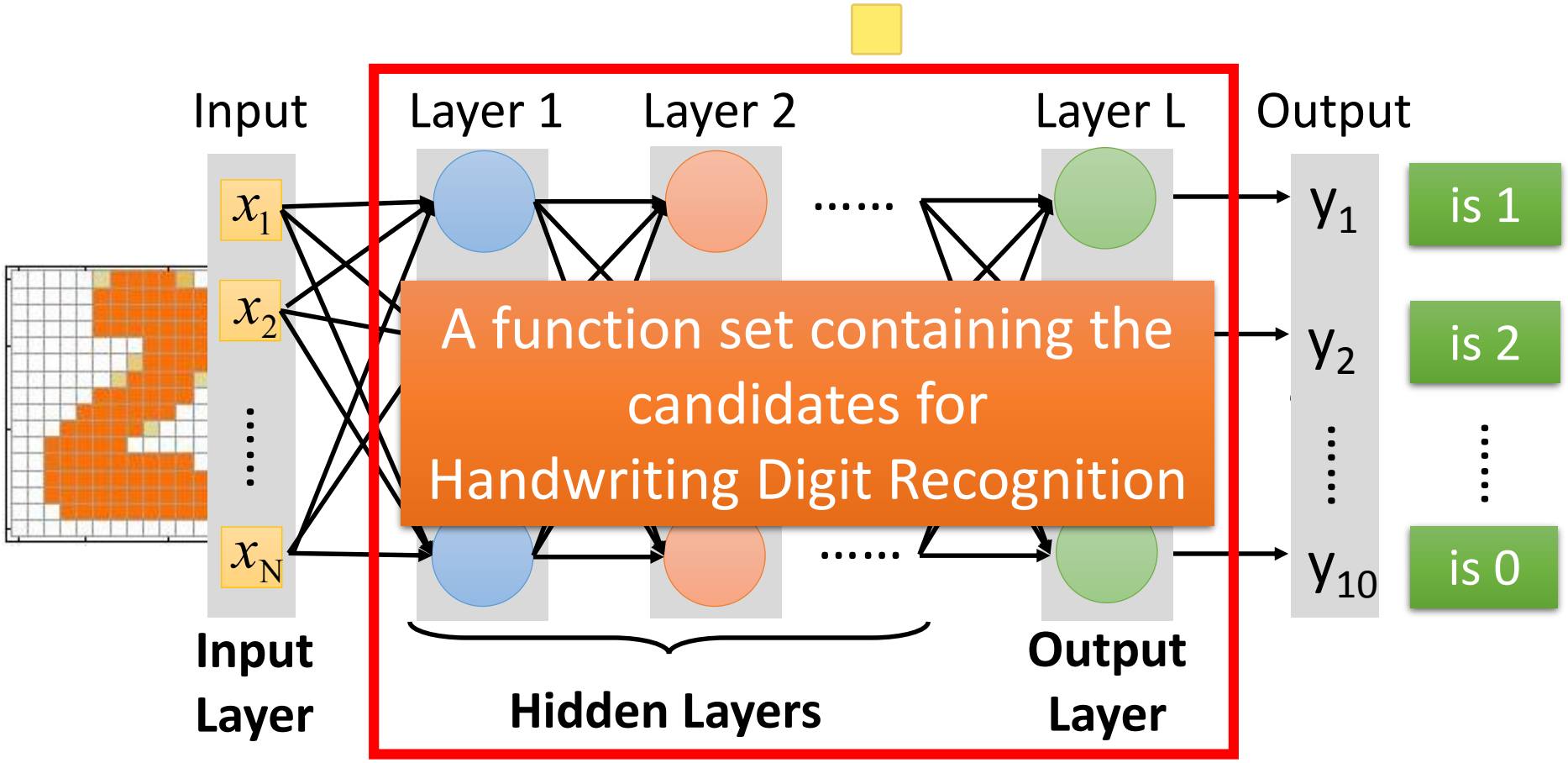


What is needed is a function ……

Input:
256-dim vector

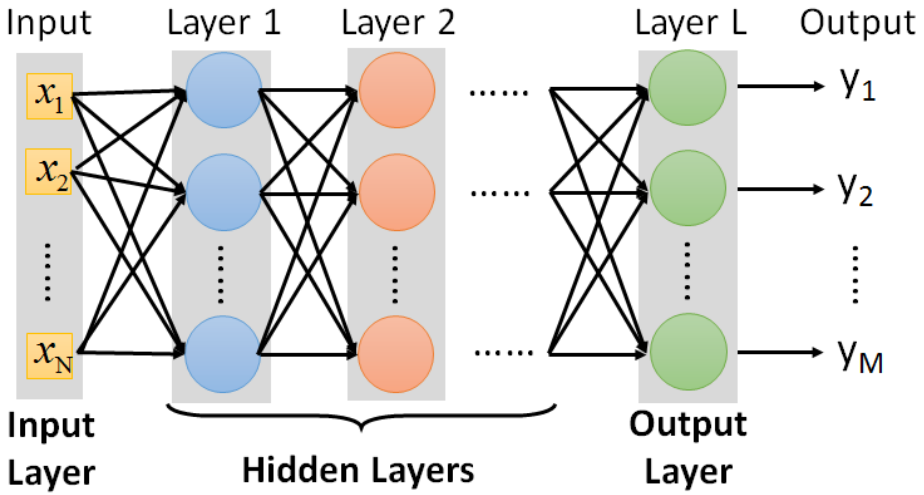
output:
10-dim vector

Example Application



You need to decide the network structure to let a good function in your function set.

FAQ



- Q: How many layers? How many neurons for each layer?

  Trial and Error + Intuition

- Q: Can the structure be automatically determined?
  - E.g. Evolutionary Artificial Neural Networks
- Q: Can we design the network structure?

  Convolutional Neural Network (CNN)

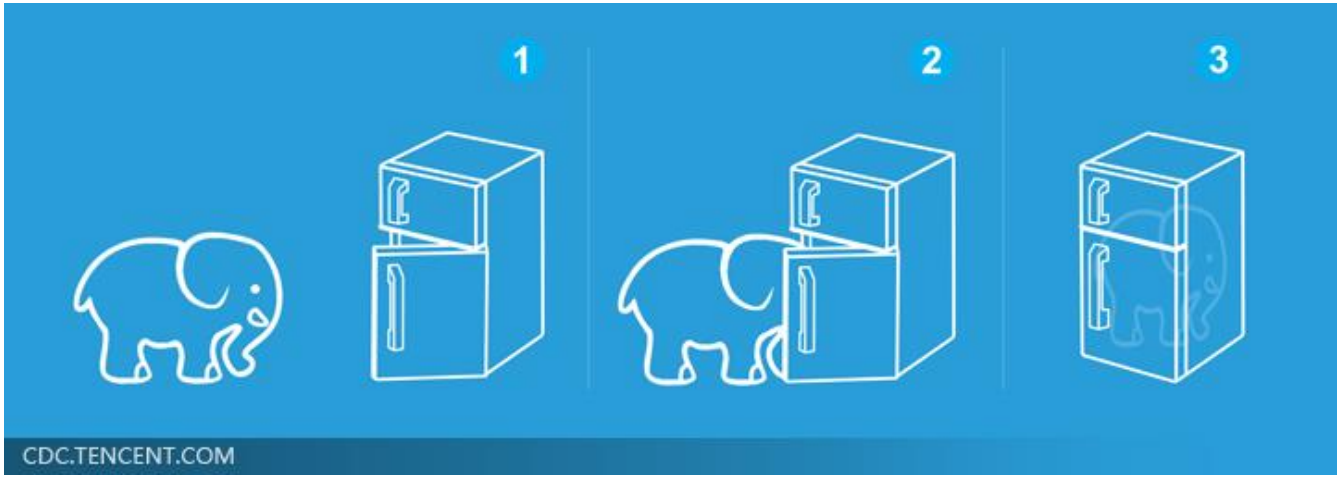
Three Steps for Deep Learning

Step 1: Neural Network

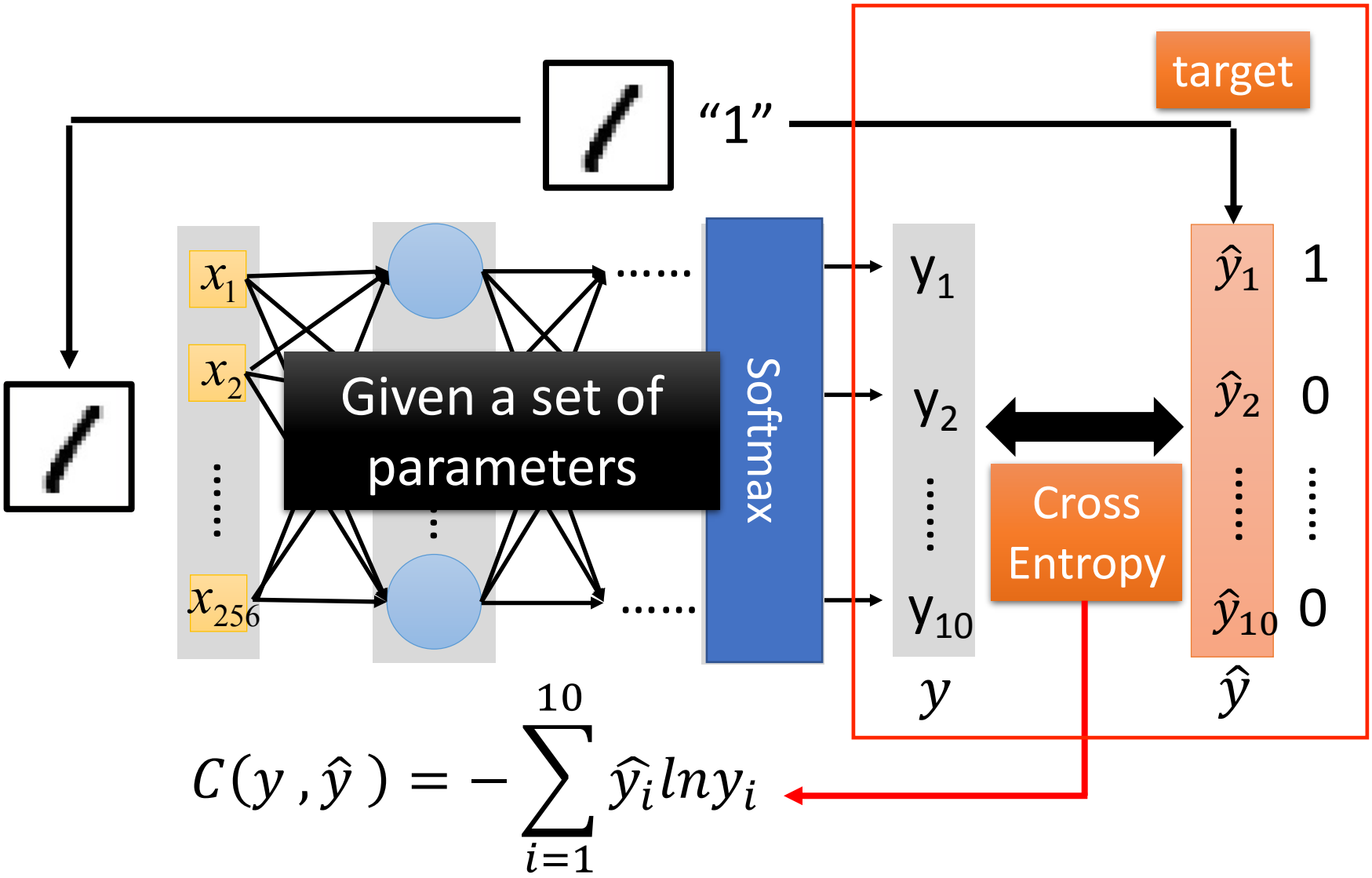
Step 2: goodness of function

Step 3: pick the best function

Deep Learning is so simple ……



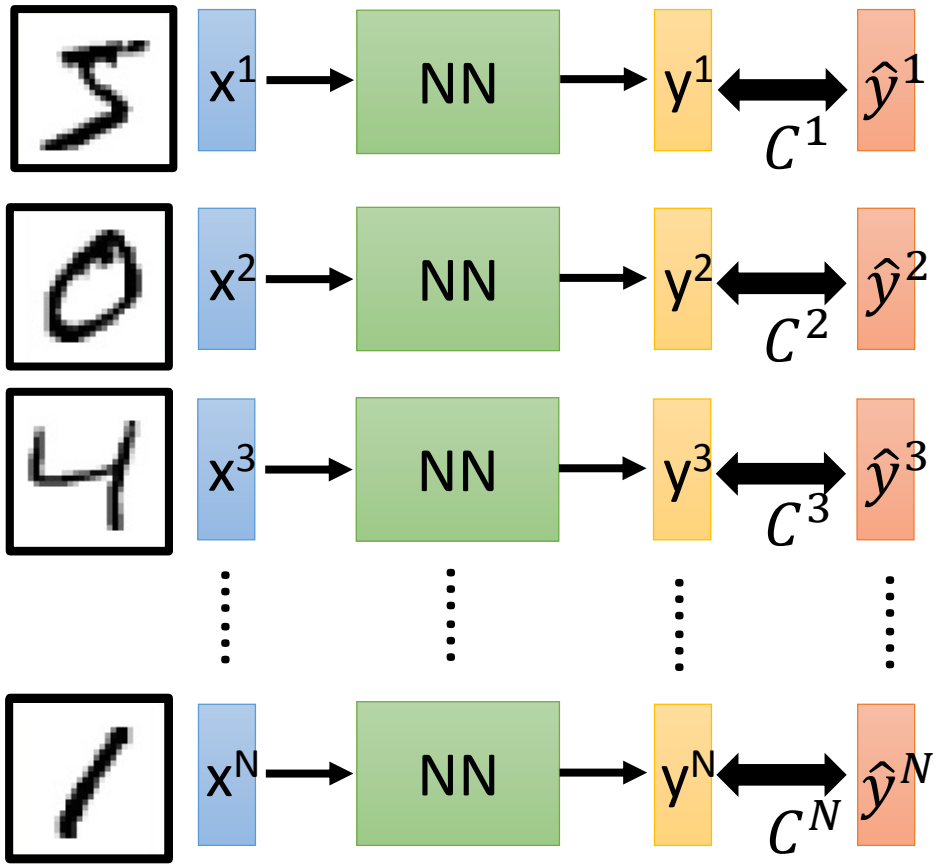
Loss for an Example



$$C(y, \hat{y}) = -\sum_{i=1}^{10} \hat{y}_i ln y_i$$

Total Loss

For all training data …



Total Loss:

$$L = \sum_{n=1}^{N} C^n$$

Find ***a function in function set*** that minimizes total loss L

Find ***the network parameters*** θ^* that minimize total loss L

Three Steps for Deep Learning

Step 1:
Neural Network

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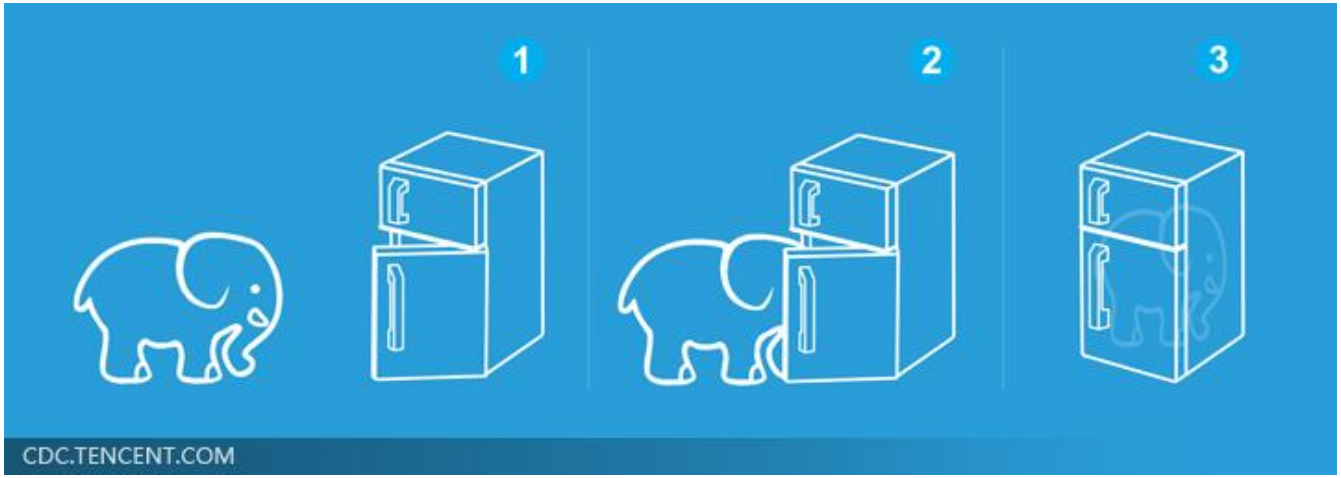
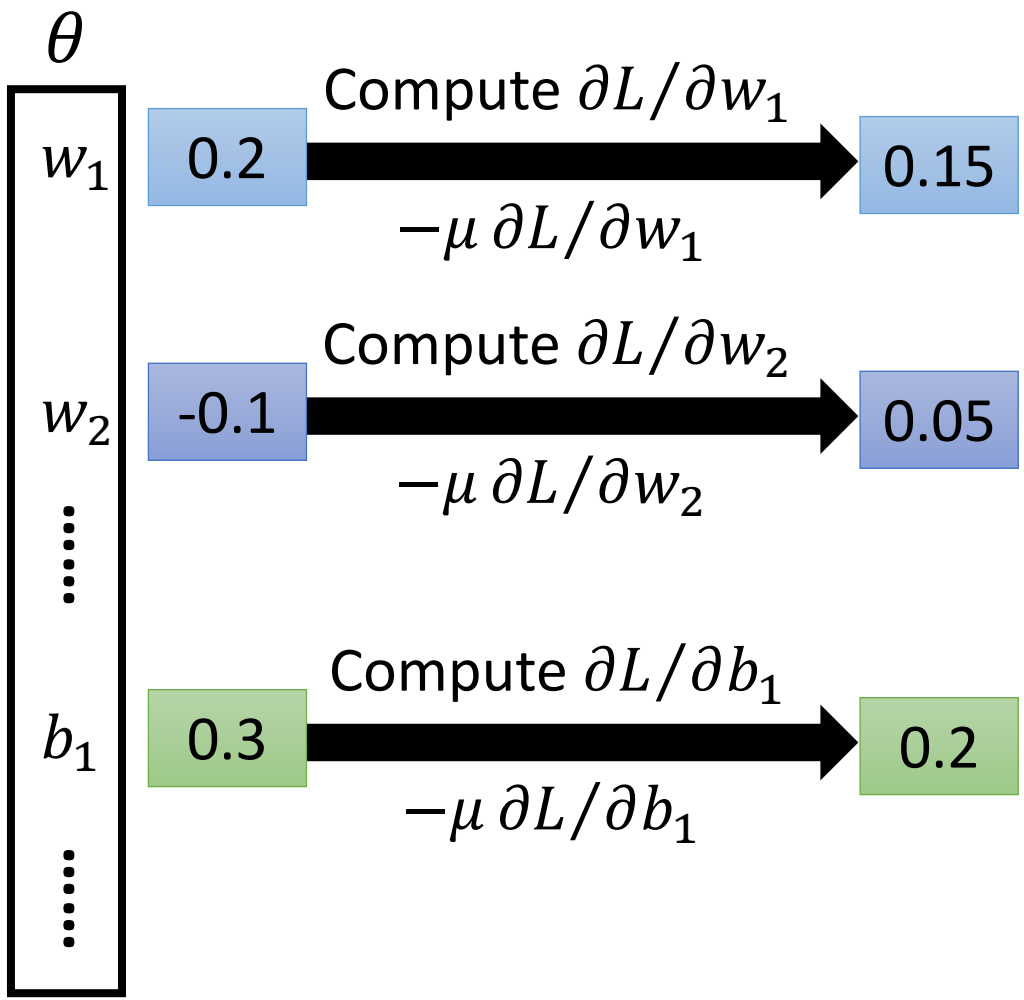


Neural Network 中的 Gradient Descent 與 Linear Regression 完全相同！

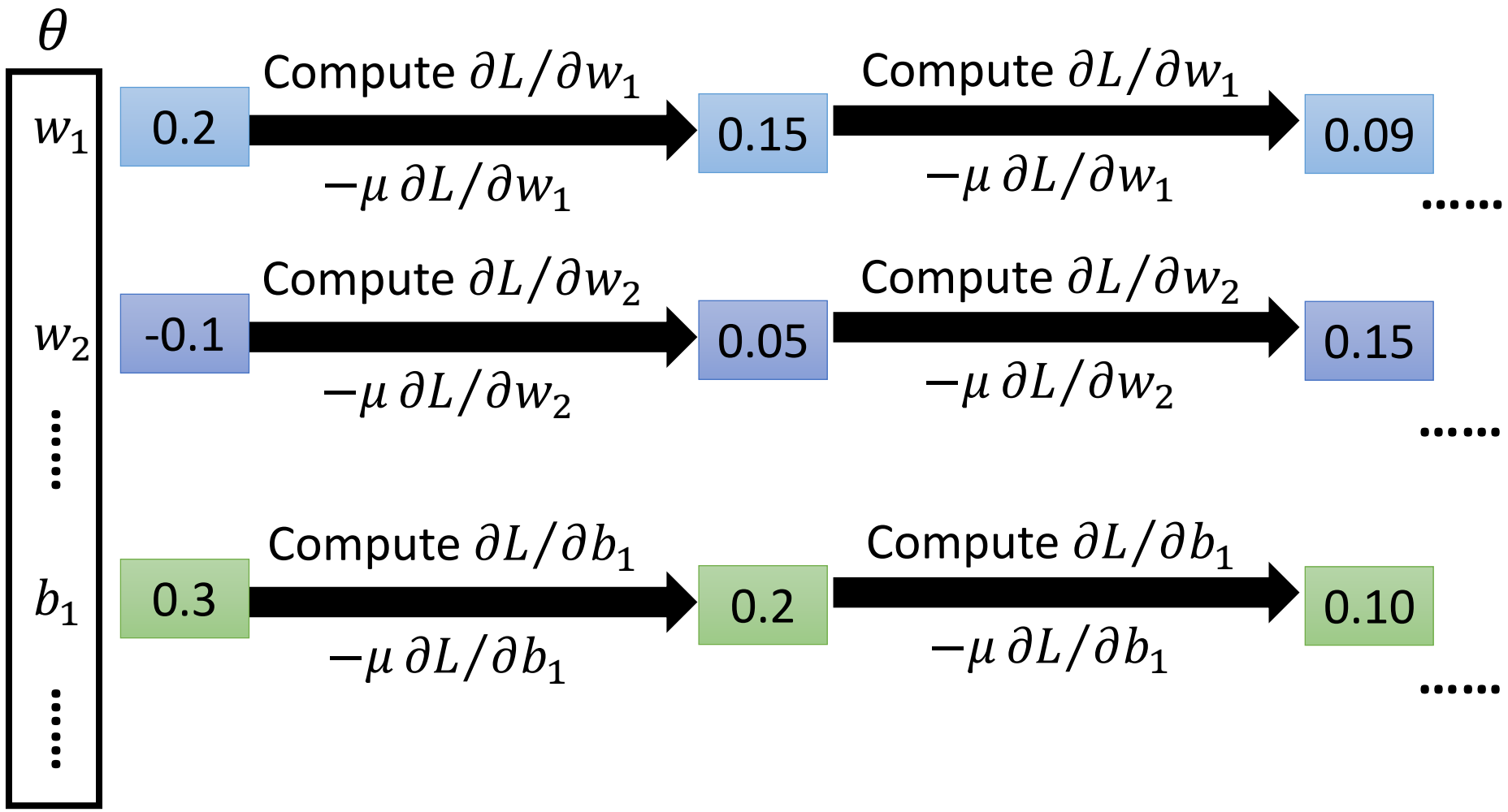
Gradient Descent



$$\nabla L = \begin{bmatrix} \frac{\partial L}{\partial w_1} \\ \frac{\partial L}{\partial w_2} \\ \vdots \\ \frac{\partial L}{\partial b_1} \\ \vdots \end{bmatrix}$$

gradient

Gradient Descent



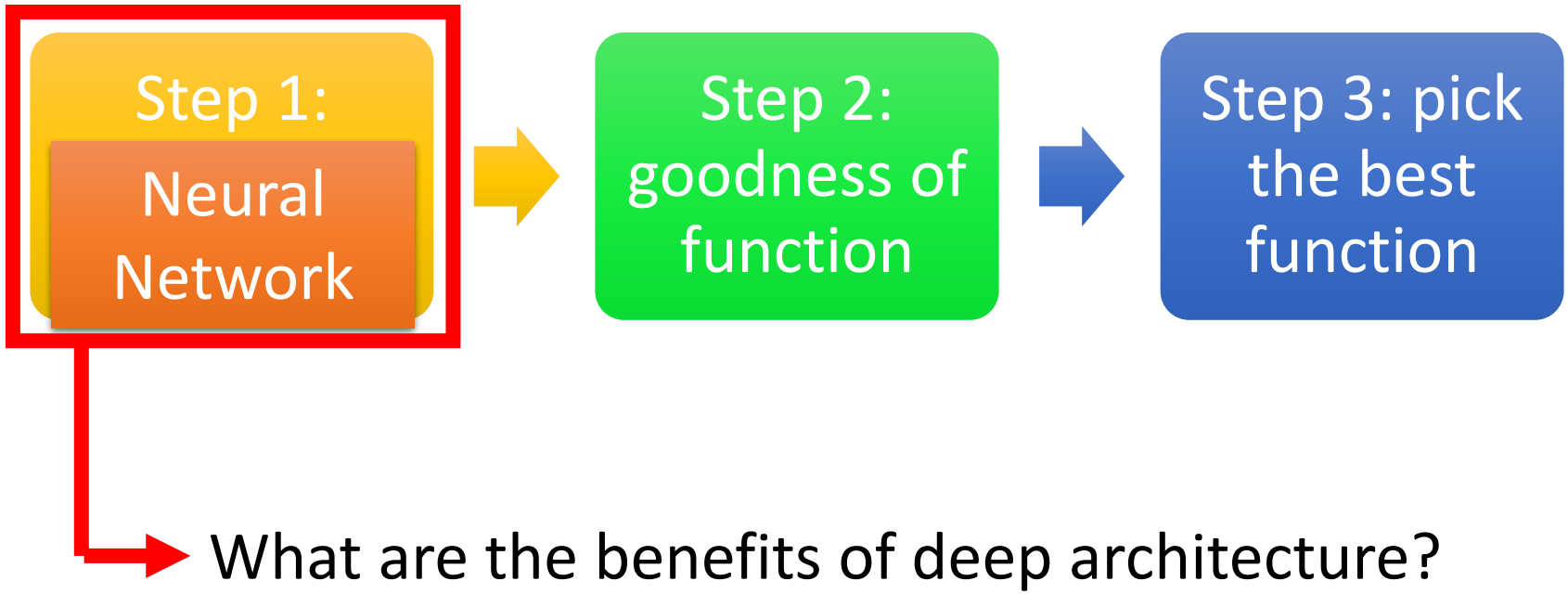
Backpropagation

- Backpropagation: an efficient way to compute $\partial L/\partial w$ in neural network

libdnn
台大周伯威
同學開發

Ref:
http://speech.ee.ntu.edu.tw/~tlkagk/courses/MLDS_2015_2/Lecture/DNN%20backprop.ecm.mp4/index.html

Concluding Remarks



Deeper is Better?

Layer X Size	Word Error Rate (%)
1 X 2k	24.2
2 X 2k	20.4
3 X 2k	18.4
4 X 2k	17.8
5 X 2k	17.2
7 X 2k	17.1

Not surprised, more parameters, better performance

Seide, Frank, Gang Li, and Dong Yu. "Conversational Speech Transcription Using Context-Dependent Deep Neural Networks." *Interspeech*. 2011.

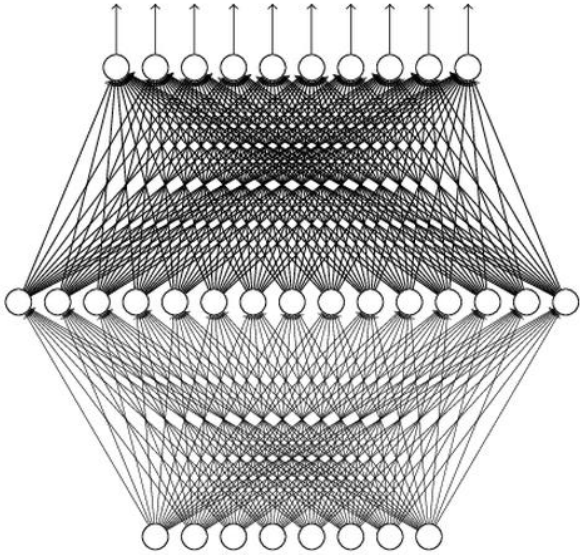
Universality Theorem

Any continuous function f

$$f : R^N \rightarrow R^M$$

Can be realized by a network with one hidden layer

(given **enough** hidden neurons)



Reference for the reason:
http://neuralnetworksanddeeplearning.com/chap4.html

Why “Deep” neural network not “Fat” neural network?

(next lecture)