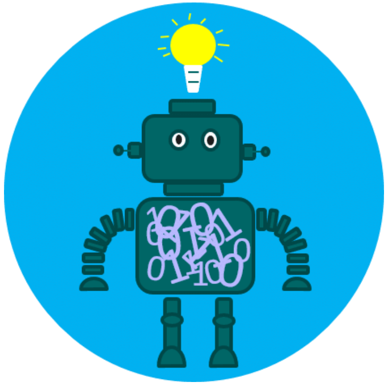
Applied Deep Learning

Introduction

February 14nd, 2022

http://adl.miulab.tw

National Taiwan University
國立臺灣大學



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What is Machine Learning?

什麼是機器學習？
白話文讓你了解！

What Computers Can Do?

- Programs can do the things you ask them to do

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Program for Solving Tasks

- Task: predicting positive or negative given a product review

"I love this product!" → `program.py` → +

if input contains "love", "like", etc.
output = positive

"It claims too much." → `program.py` → -

if input contains "too much", "bad", etc.
output = negative

"It's a little expensive." → `program.py` → ?

"台灣第一波上市!" → `program.py` → 推

"規格好雞肋..." → `program.py` → 噓

"樓下買了我才考慮" → `program.py` → ?

Some tasks are complex, and we don't know how to write a program to solve them.

Learning ≈ Looking for a Function

- Task: predicting positive or negative given a product review

"I love this product!" ↓ *f* +

if input contains "love", "like", etc.
output = positive

"It claims too much." ↓ *f* -

if input contains "too much", "bad", etc.
output = negative

"It's a little expensive." ↓ *f* ?

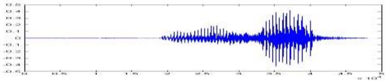
"台灣第一波上市!" ↓ *f* 推

"規格好雞肋..." ↓ *f* 噓

"樓下買了我才考慮" ↓ *f* ?

Given a large amount of data, the machine learns what the function *f* should be.

Learning ≈ Looking for a Function

- Speech Recognition $f($  $)=$ "你好"
- Handwritten Recognition $f($  $)=$ "2"
- Weather forecast $f($ Thursday $)=$ "  Saturday"
- Play video games $f($  $)=$ "move left"

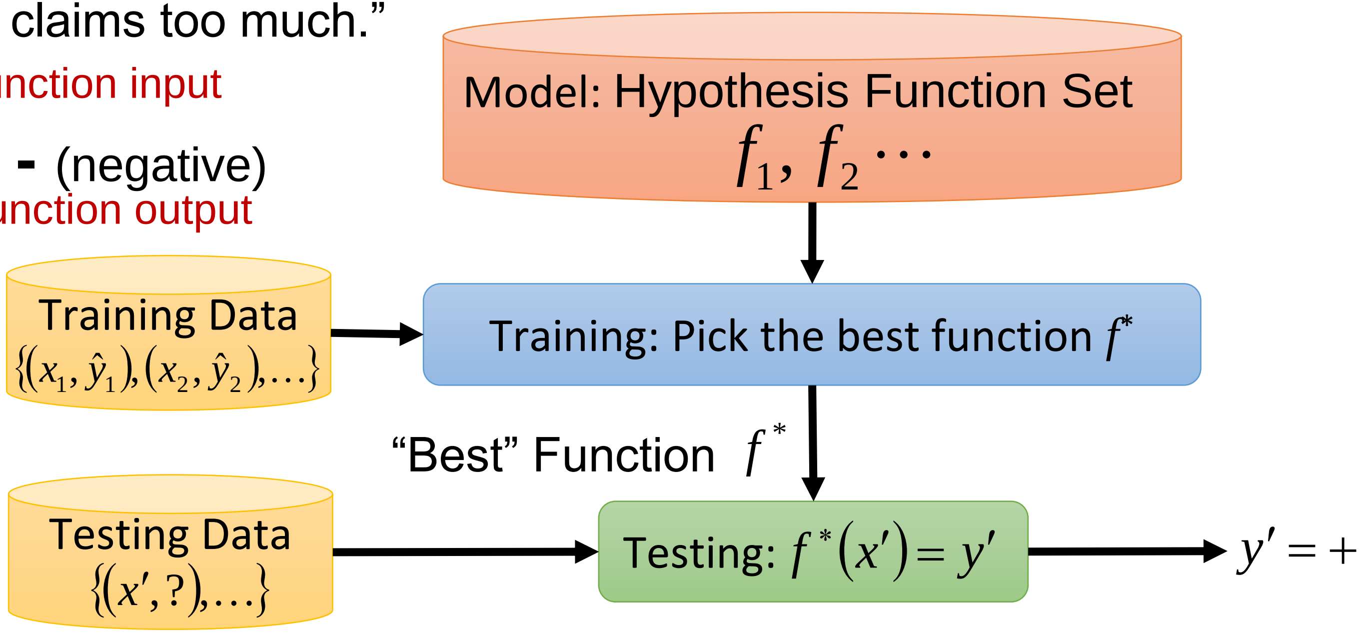
Machine Learning Framework

x : "It claims too much."

function input

$\hat{y}$: - (negative)

function output



Training is to pick the best function given the observed data
Testing is to predict the label using the learned function

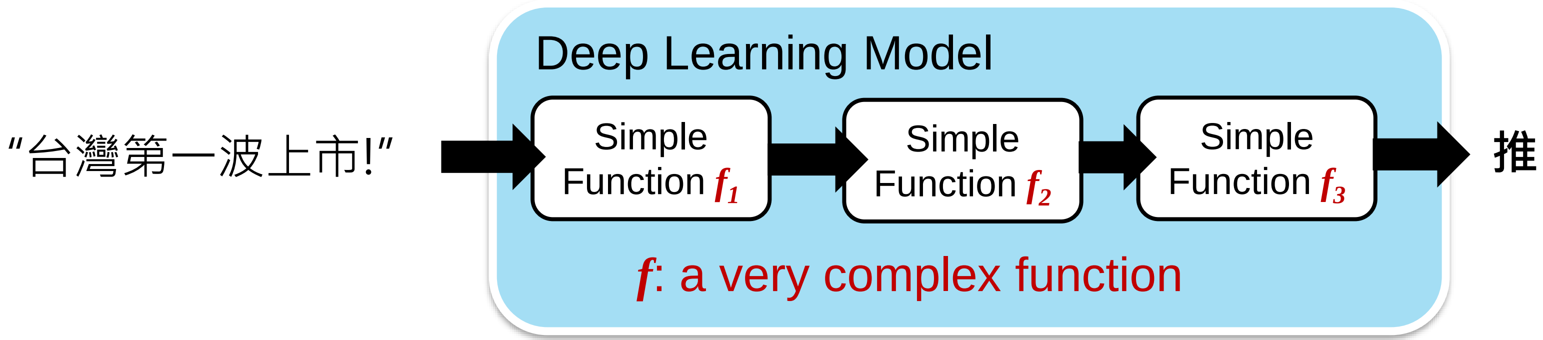
What is Deep Learning?

什麼是深度學習？

A subfield of machine learning

Stacked Functions Learned by Machine

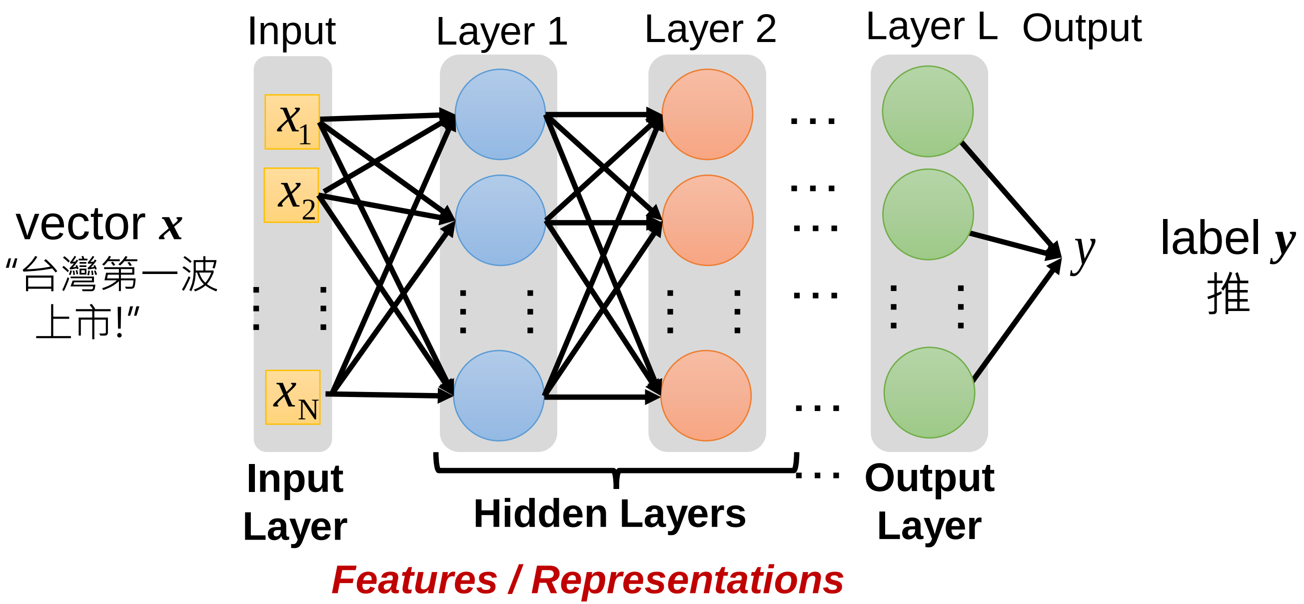
- Production line (生產線)



End-to-end training: what each function should do is learned automatically

Deep learning usually refers to *neural network* based model

Stacked Functions Learned by Machine

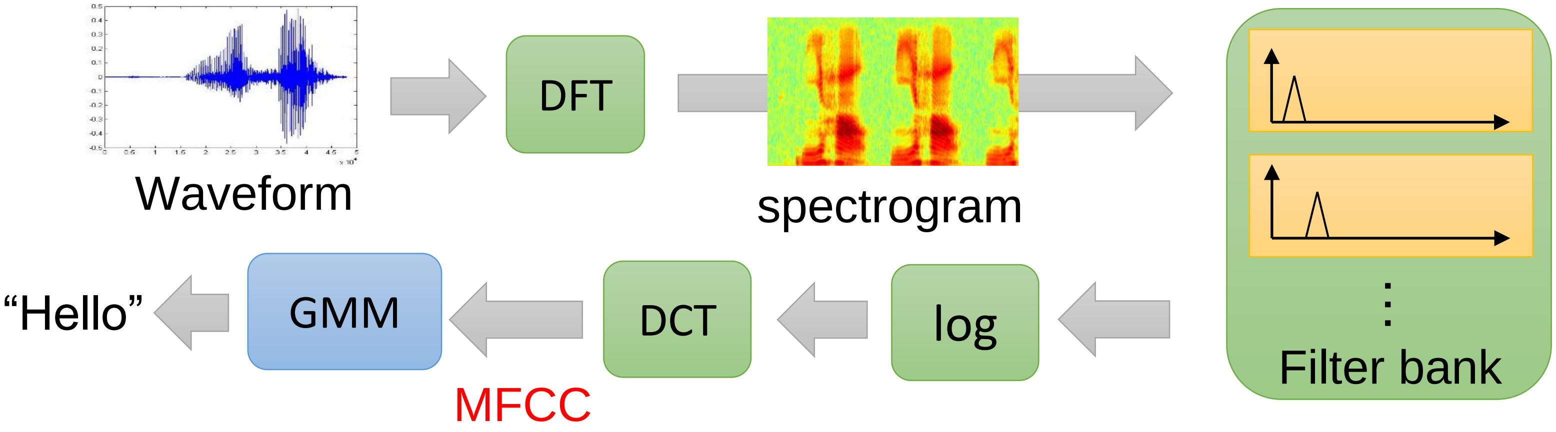


Representation Learning attempts to learn good features/representations

Deep Learning attempts to learn (multiple levels of) representations and an output

Deep v.s. Shallow – Speech Recognition

- Shallow Model



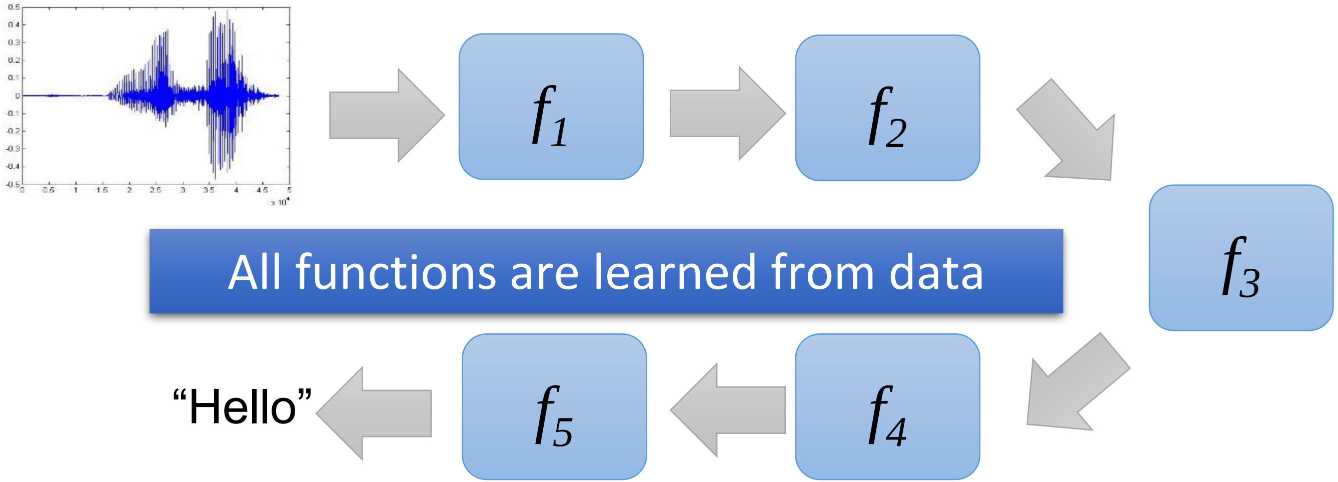
Each box is a simple function in the production line:

:hand-crafted :learned from data

Deep v.s. Shallow – Speech Recognition

"Bye bye, MFCC" - Deng Li in Interspeech 2014

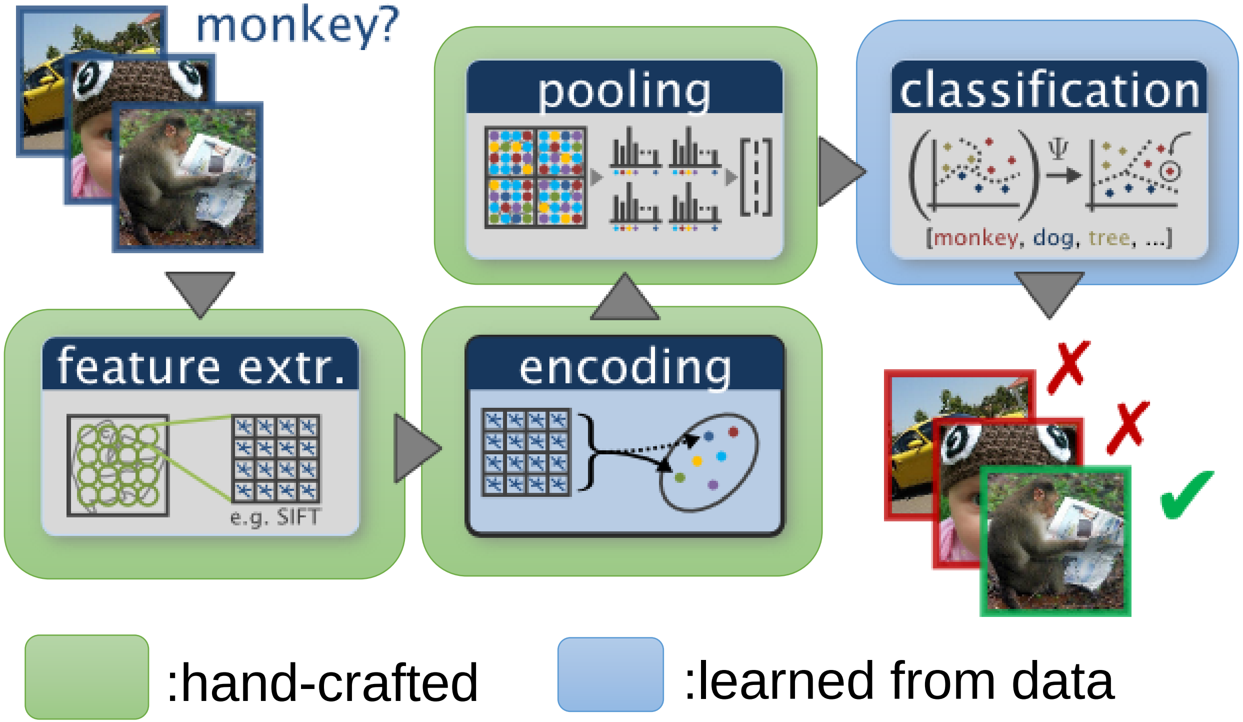
- Deep Model



Less engineering labor, but machine learns more

Deep v.s. Shallow – Image Recognition

- Shallow Model

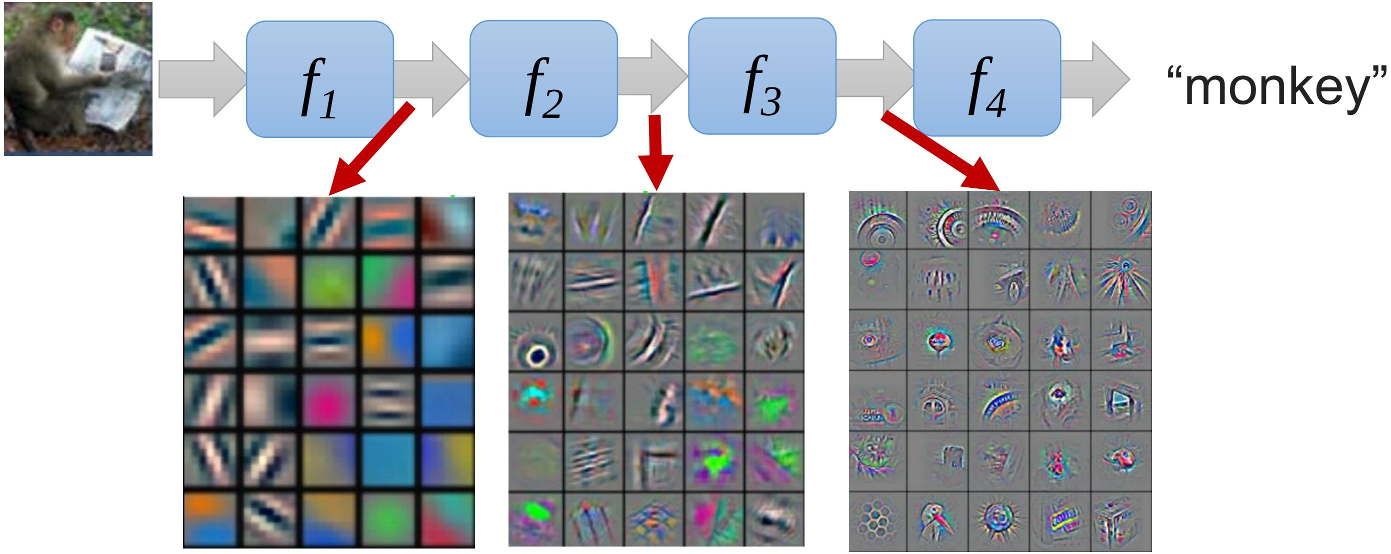


Deep v.s. Shallow – Image Recognition

Reference: Zeiler, M. D., & Fergus, R. (2014). Visualizing and understanding convolutional networks. In *Computer Vision–ECCV 2014* (pp. 818-833)

- Deep Model

All functions are learned from data



Features / Representations

Machine Learning v.s. Deep Learning

Machine Learning

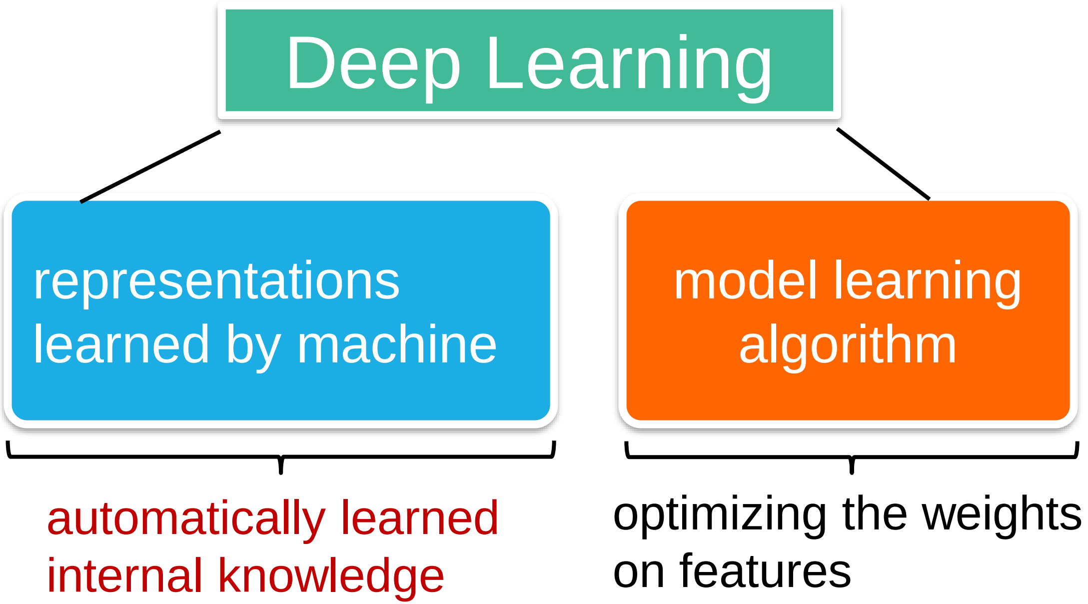
describing your data with features a computer can understand

model learning algorithm

hand-crafted domain-specific knowledge

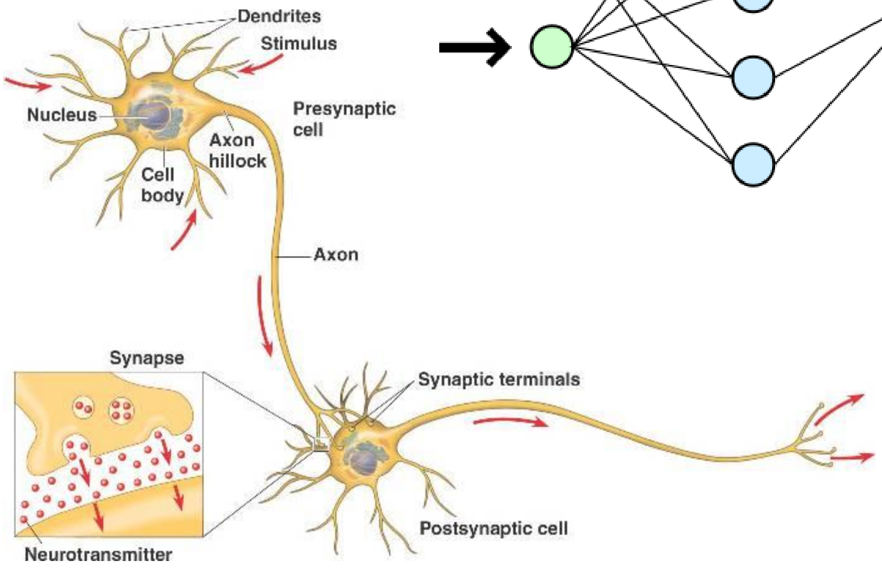
optimizing the weights on features

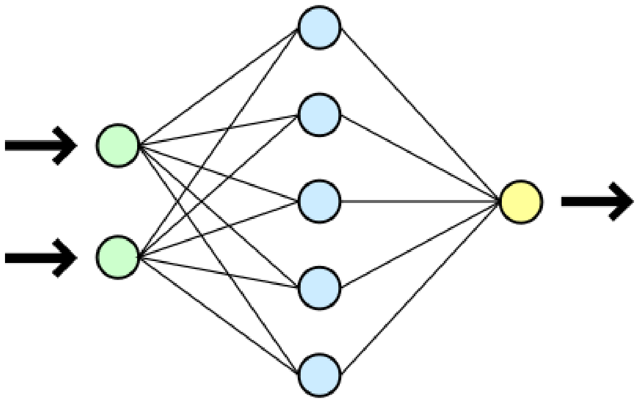
Machine Learning v.s. Deep Learning



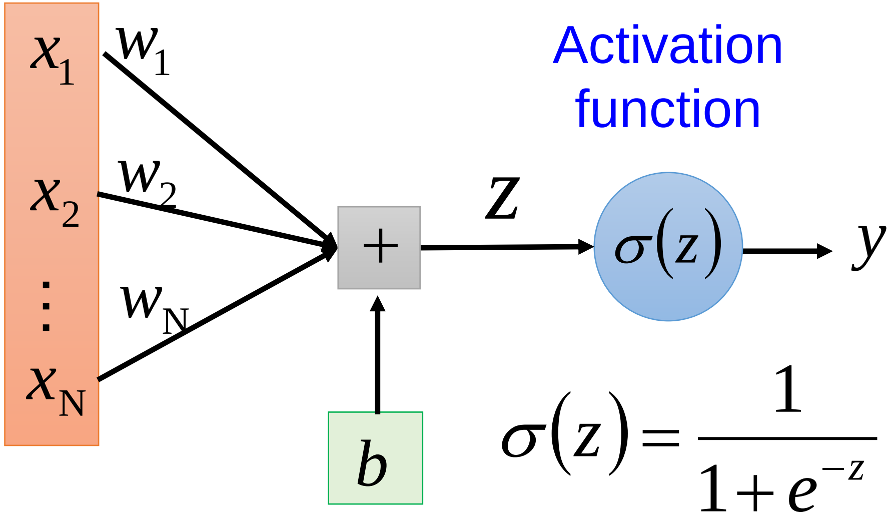
Deep learning usually refers to *neural network* based model

Inspired by Human Brain



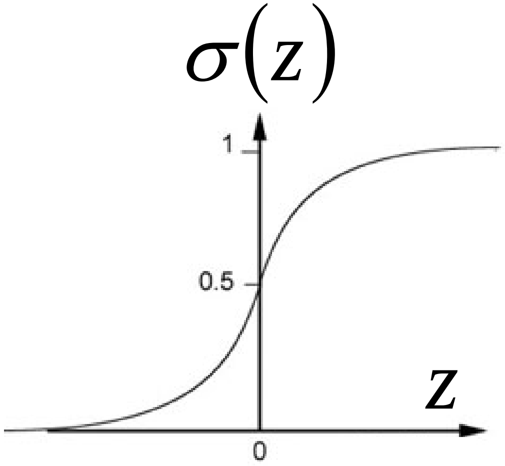


A Single Neuron



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

Sigmoid function

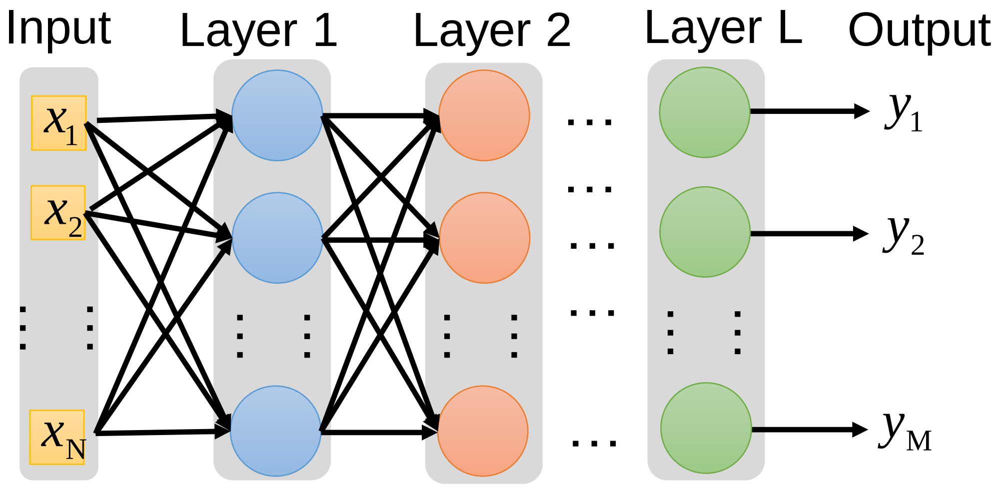


Each neuron is a very simple function

Deep Neural Network

A neural network is a complex function: $f: R^N \to R^M$

- Cascading the neurons to form a neural network

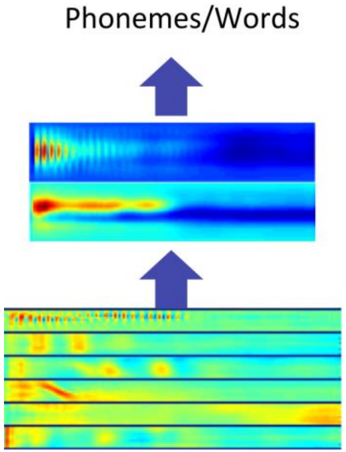


Each layer is a simple function in the production line

History of Deep Learning

- 1960s: Perceptron (single layer neural network)
- 1969: Perceptron has limitation
- 1980s: Multi-layer perceptron
- 1986: Backpropagation
- 1989: 1 hidden layer is “good enough”, why deep?
- 2006: RBM initialization (breakthrough)
- 2009: GPU
- 2010: breakthrough in Speech Recognition (Dahl et al., 2010)
- 2012: breakthrough in ImageNet (Krizhevsky et al. 2012)
- 2015: “superhuman” results in Image and Speech Recognition

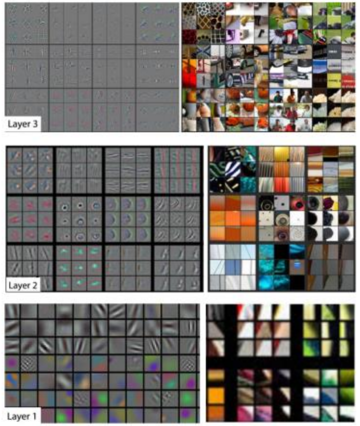
Deep Learning Breakthrough



- First: Speech Recognition

Acoustic Model	WER on RT03S FSH	WER on Hub5 SWB
Traditional Features	27.4%	23.6%
Deep Learning	18.5% (-33%)	16.1% (-32%)

- Second: Computer Vision



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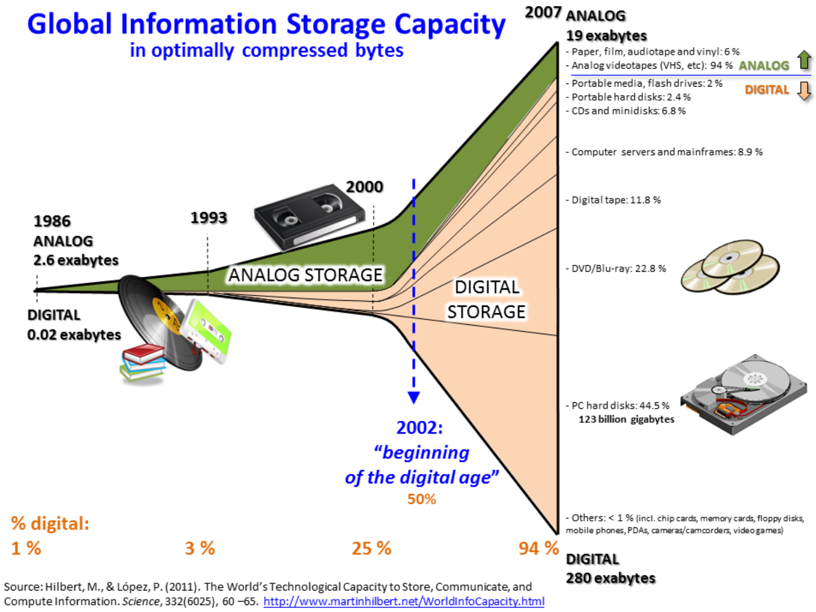
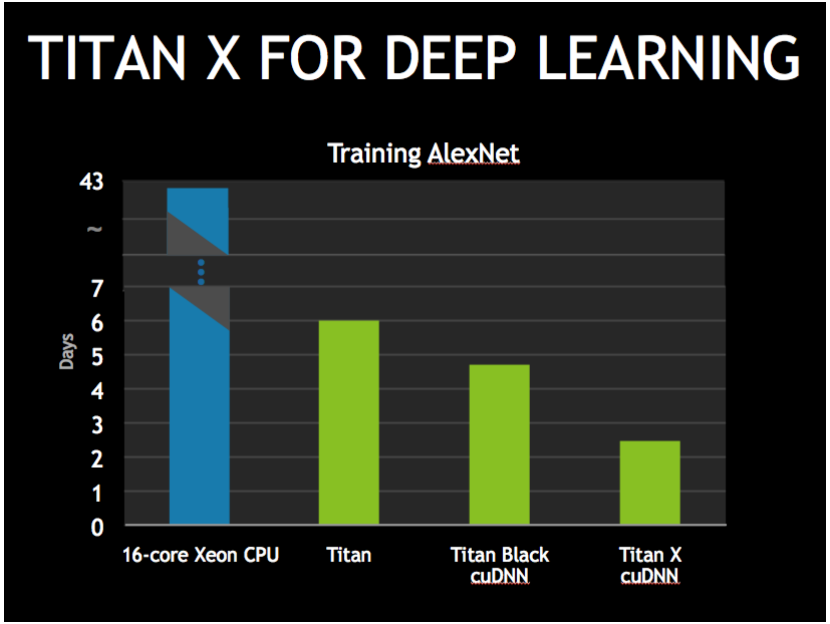
Why does deep learning show breakthrough in applications after 2010?

Reasons why Deep Learning works



Big Data



GPU

Why to Adopt GPU for Deep Learning?

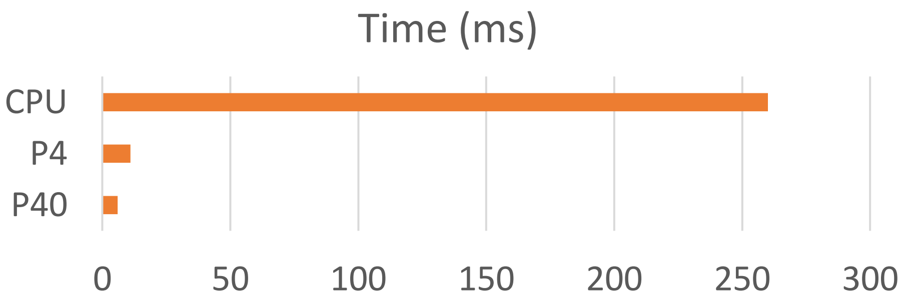
- GPU is like a brain
- Human brains create *graphical imagination* for *mental thinking*

台灣好吃牛肉麵

Why Speed Matters?

- Training time
  - Big data increases the training time
  - Too long training time is not practical

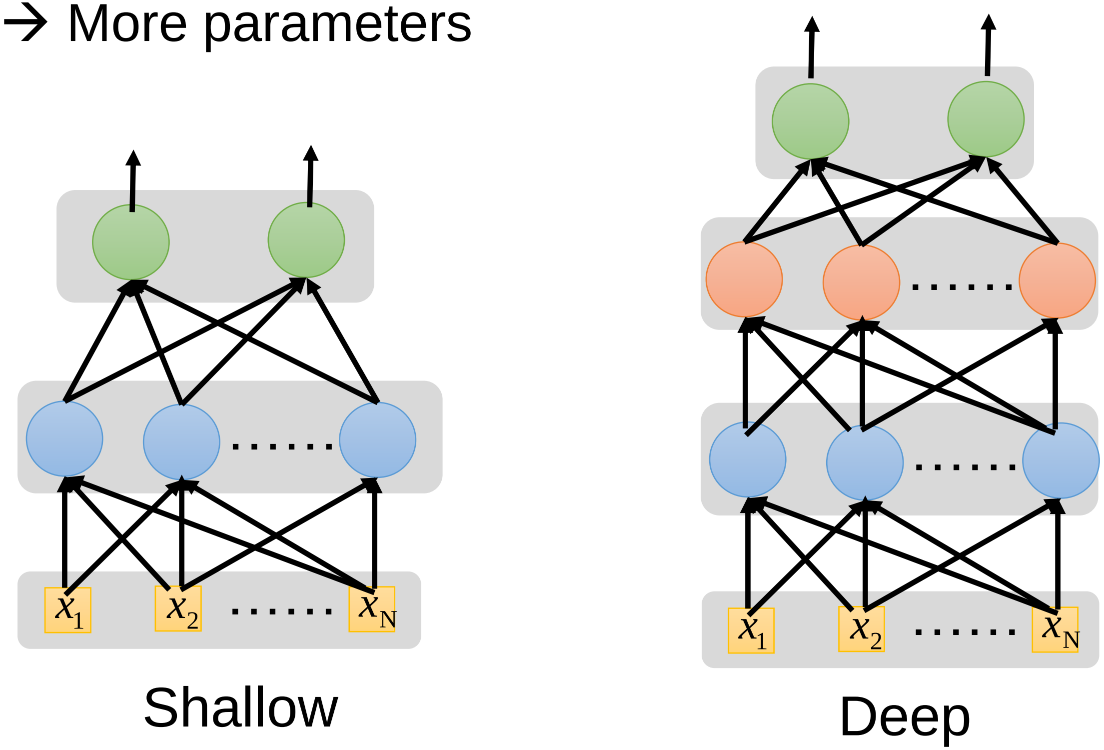
- Inference time
  - Users are not patient to wait for the responses



GPU enables the real-world applications using the computational power

Why Deeper is Better?

- Deeper → More parameters

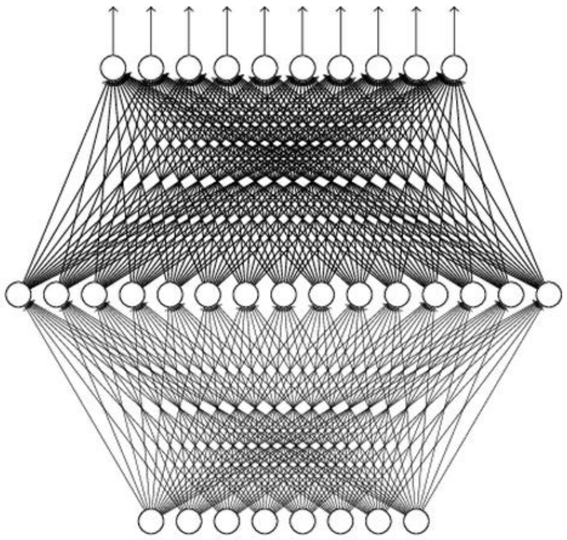


Universality Theorem

- Any continuous function f

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

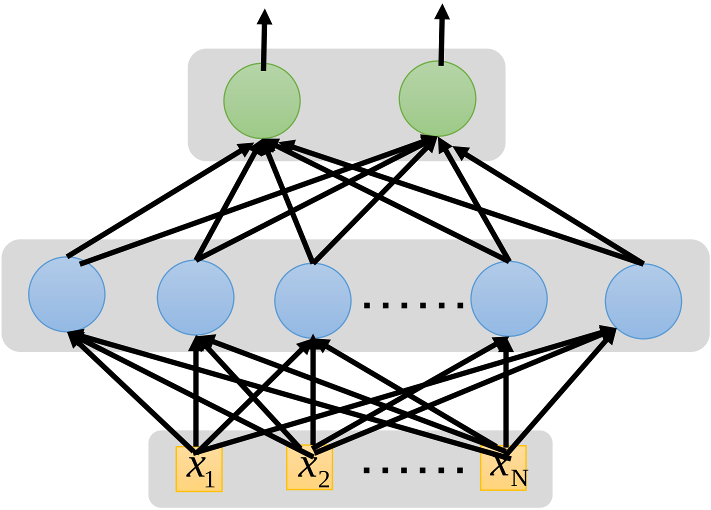
- can be realized by a network with only hidden layer

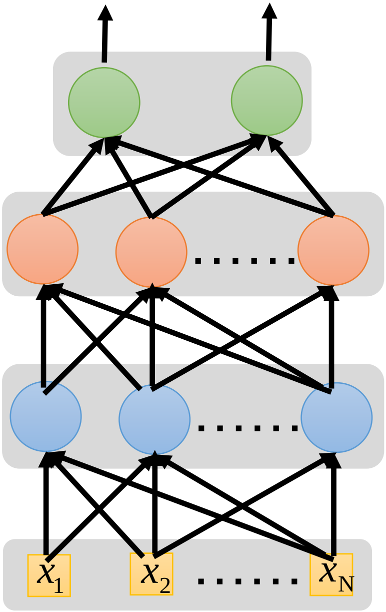


Why “deep” not “fat”?

Fat + Shallow v.s. Thin + Deep

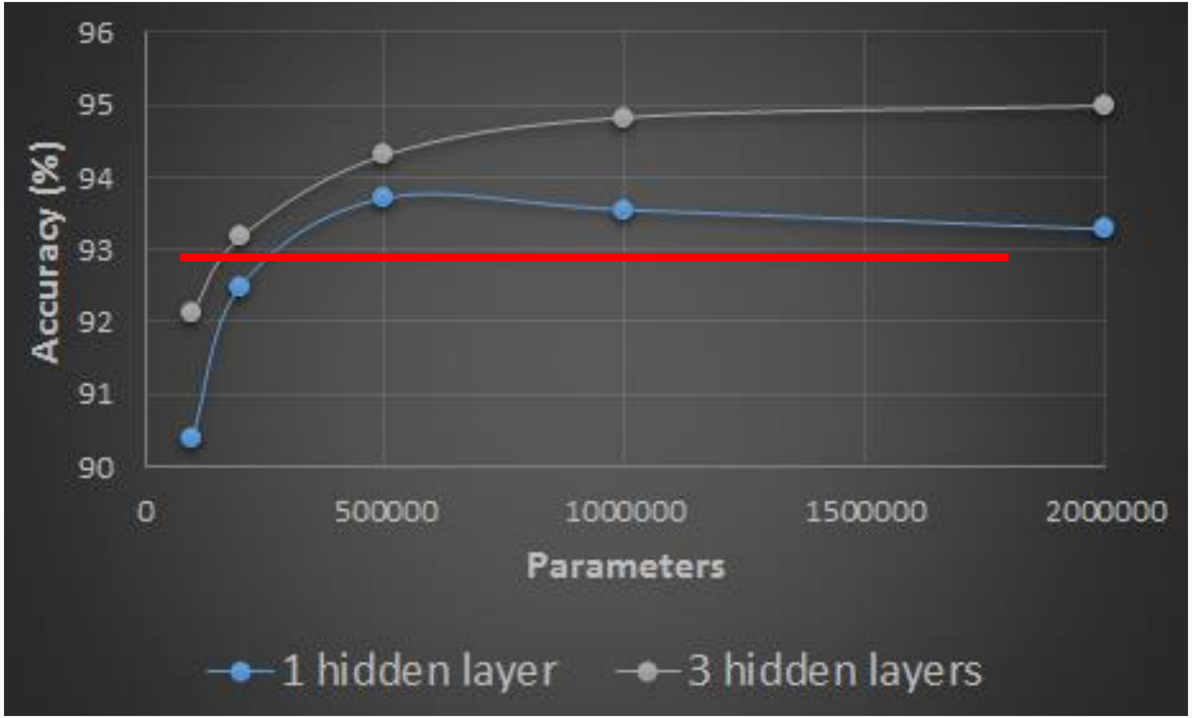
- Two networks with the same number of parameters





Fat + Shallow v.s. Thin + Deep

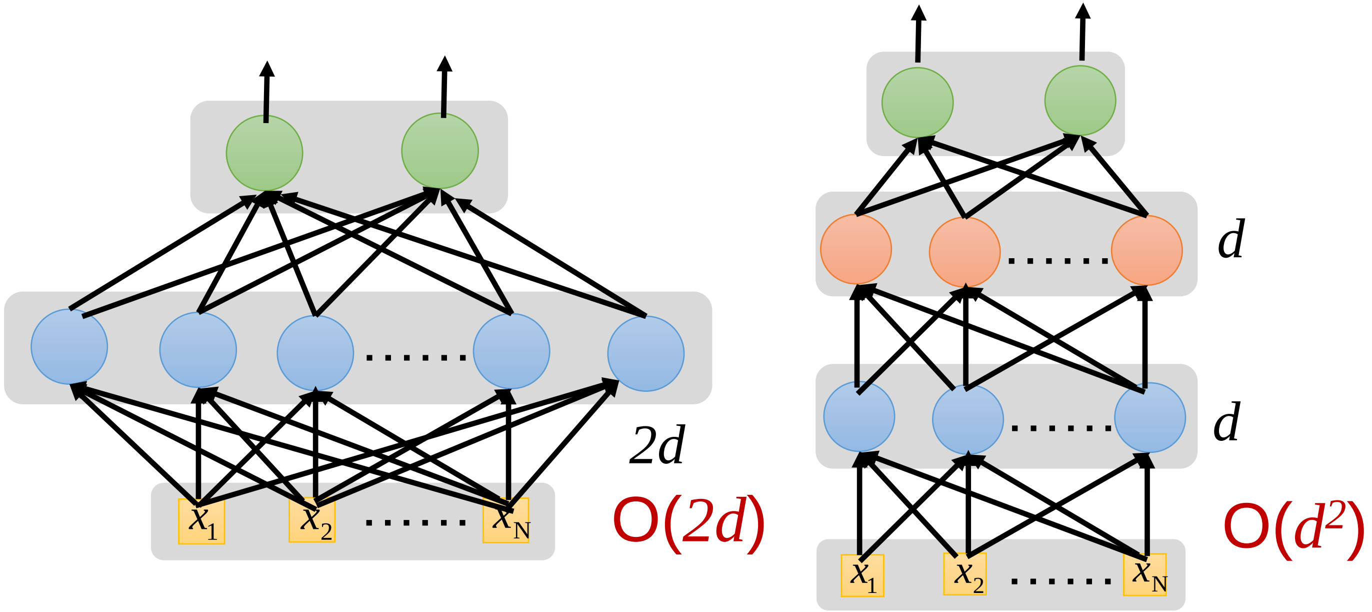
Hand-Written Digit Classification



The deeper model uses less parameters to achieve the same performance

Fat + Shallow v.s. Thin + Deep

- Two networks with the same number of parameters



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How to Apply?

如何應用深度學習？

How to Frame the Learning Problem?

- The learning algorithm f is to map the input domain X into the output domain Y

$$f : X \to Y$$

- Input domain: word, word sequence, audio signal, click logs
- Output domain: single label, sequence tags, tree structure, probability distribution

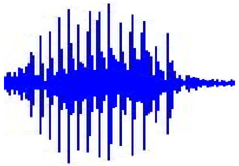
Output Domain – Classification

- Sentiment Analysis

“這規格有誠意!” ⟶ +

“太爛了吧~” ⟶ -

- Speech Phoneme Recognition



⟶ /h/

- Handwritten Recognition

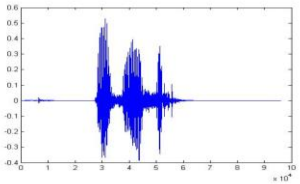
⟶ 2

Output Domain – Sequence Prediction

- POS Tagging

“推薦我台大後門的餐廳” → 推薦/VV 我/PN 台大/NR 後門/NN 的/DEG 餐廳/NN

- Speech Recognition



→ “大家好”

- Machine Translation

“How are you doing today?” → “你好嗎?”

Learning tasks are decided by the output domains

Input Domain – How to Aggregate Information

- Input: word sequence, image pixels, audio signal, click logs
- Property: continuity, temporal, importance distribution
- Example
  - CNN (convolutional neural network): local connections, shared weights, pooling
    - AlexNet, VGGNet, etc.
  - RNN (recurrent neural network): temporal information

Network architectures should consider the input domain properties

How to Frame the Learning Problem?

- The learning algorithm f is to map the input domain X into the output domain Y

$$f : X \rightarrow Y$$

- Input domain: word, word sequence, audio signal, click logs
- Output domain: single label, sequence tags, tree structure, probability distribution

Network design should leverage input and output domain properties

"Applied" Deep Learning

Deep Learning

representations learned by machine

model learning algorithm

automatically learned internal knowledge

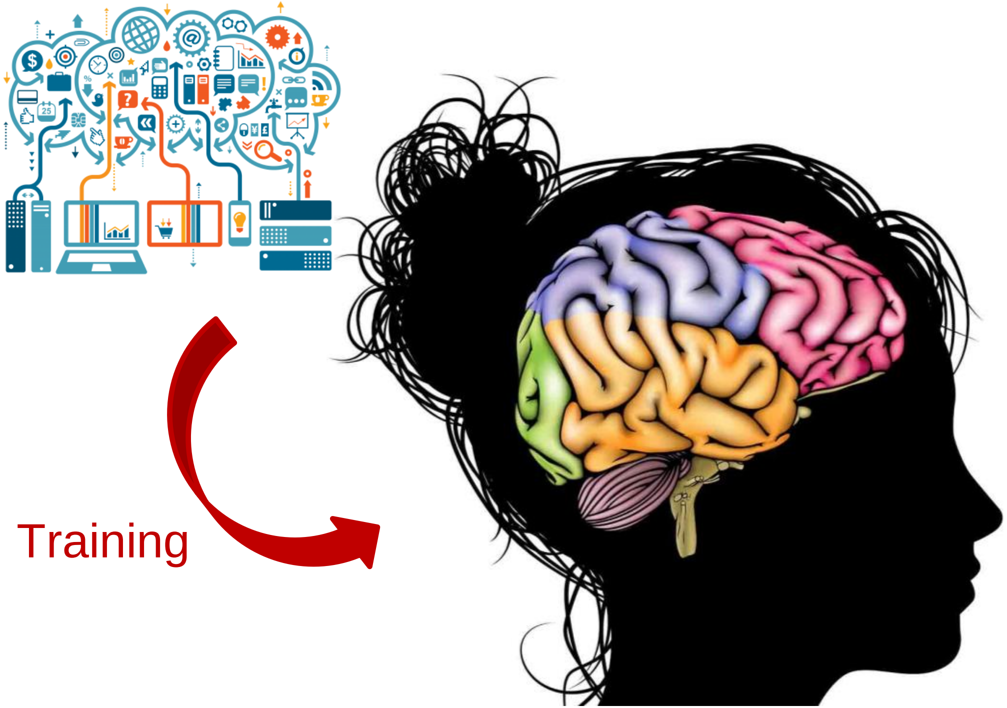
optimizing the weights on features

How to frame a task into a learning problem and design the corresponding model

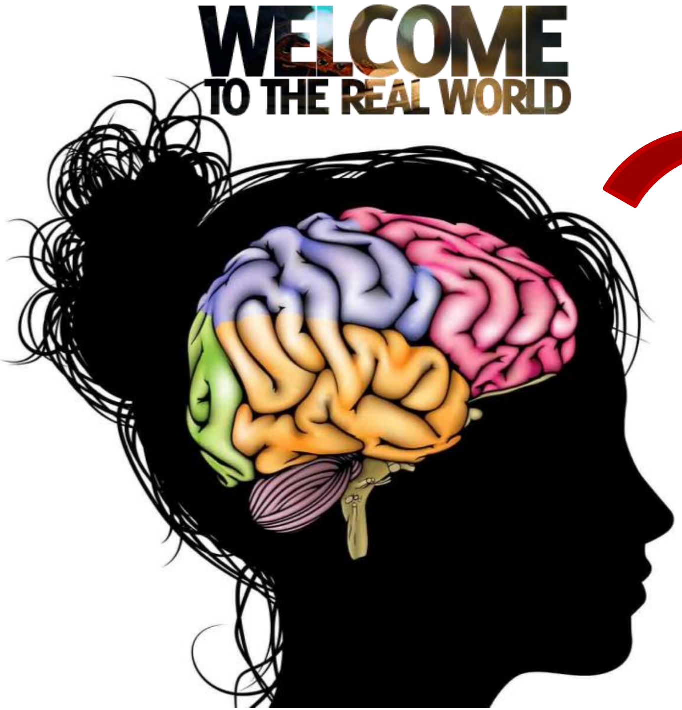
Core Factors for Applied Deep Learning

1. Data: big data
2. Hardware: GPU computing
3. Talent: design algorithms to allow networks to work for the specific problems

Concluding Remarks

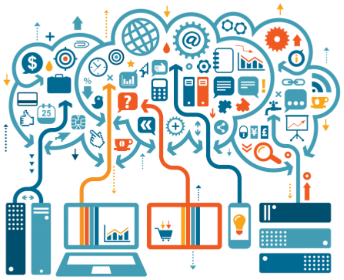


Concluding Remarks

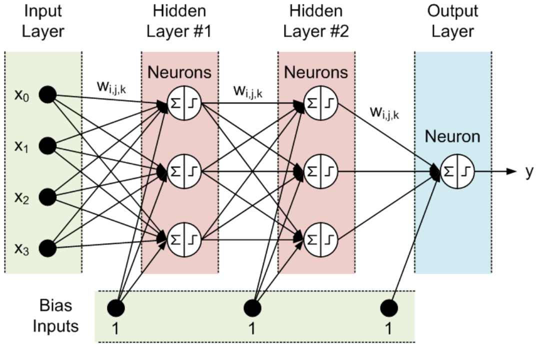


Inference

Concluding Remarks



Inference



Training

Main focus: how to apply deep learning to the real-world problems

Reference

- Reading Materials
  - Academic papers will be put in the website
- Deep Learning
  - Goodfellow, Bengio, and Courville, “Deep Learning,” 2016. http://www.deeplearningbook.org
  - Michael Nielsen, “Neural Networks and Deep Learning” http://neuralnetworksanddeeplearning.com

Thanks!

Any questions ?

You can find the course information at

- http://adl.miulab.tw
- adl-ta@csie.ntu.edu.tw
- slido: #ADL2022
- YouTube: Vivian NTU MiuLab