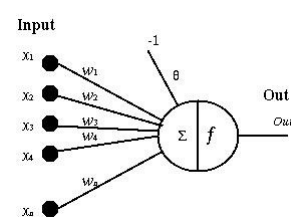
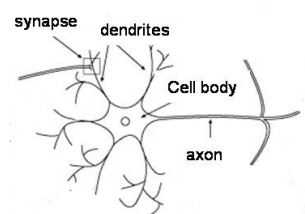


Multilayer Perceptron

1

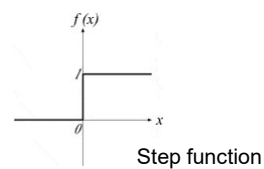
Review of Neuron Model



Its output, in turn, can serve as input to other units.

$$net = w_1x_1 + w_2x_2 + w_3x_3 + \dots + w_nx_n$$

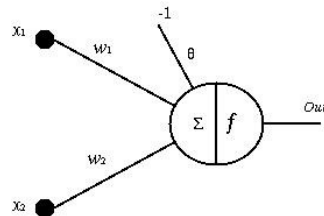
$$out = f(net - \theta)$$



2

Neuron model realizes AND function

A two-input neuron model



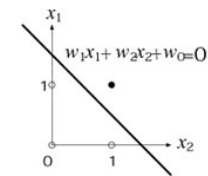
Let $w_1 = 1.0$, $w_2 = 1.0$, $\theta = 1.5$

$f(x) = \text{step}(x)$

then $\text{Out} = \text{step}(w_1x_1 + w_2x_2 - \theta)$

The neuron model realizes logical AND, which is a linear separable problem.

x_1	x_2	Out
0	0	0
0	1	0
1	0	0
1	1	1



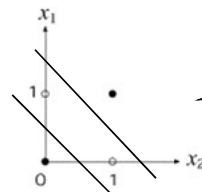
Logical AND

3

Limitation of One Neuron Model

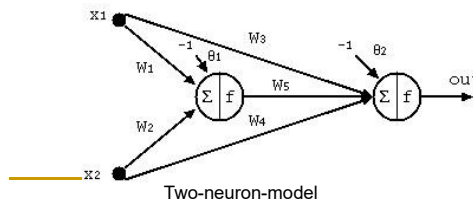
One McCulloch-Pitts neuron model is able to solve linear separable problems such as logical AND, OR, but it is not able to solve problems that are not linear separable such as logical XOR.

However, adding another neuron, the two-neuron-model is able to realize logical XOR.



Not linear separable.

Logical XOR

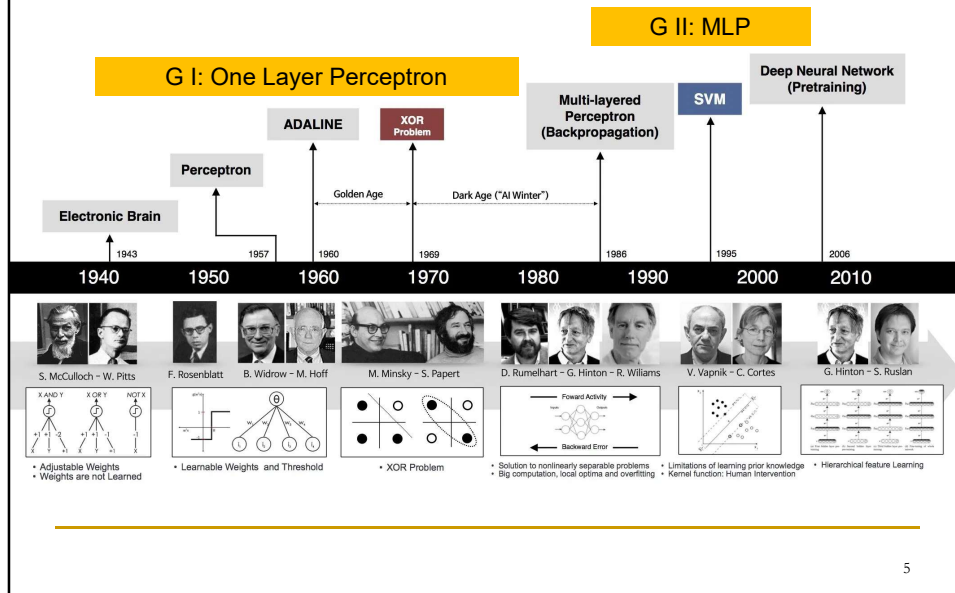


$w_1 = w_2 = w_3 = w_4 = 1$
 $w_5 = -2, \theta_1 = 1.5, \theta_2 = 0.5$
 $f(x) = \text{step}(x)$

4

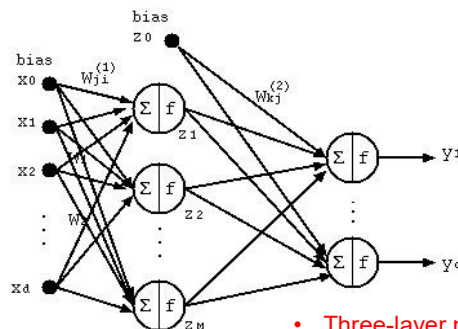
Neural Network History

G III: DNN



5

Multilayer Perceptron



$$\begin{aligned}
 y_k(t) &= f_2(net_k(t)) \\
 &= f_2\left(\sum_{j=0}^M w_{kj}^{(2)} z_j(t)\right) \\
 &= f_2\left(\sum_{j=0}^M w_{kj}^{(2)} f_1(net_j(t))\right) \\
 &= f_2\left(\sum_{j=0}^M w_{kj}^{(2)} f_1\left(\sum_{i=0}^d w_{ji}^{(1)} x_i(t)\right)\right)
 \end{aligned}$$

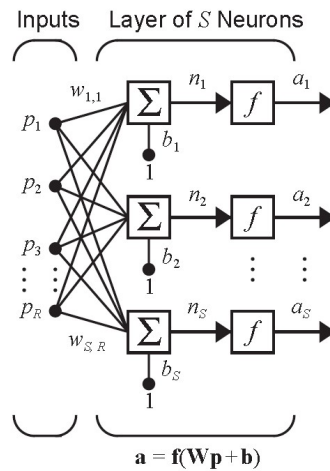
- Three-layer neural network
- Two-layer perceptron

- Neuron, unit, node
- Artificial neuron model
- Perceptron

One neuron model has limited approximation ability. But a multilayer neural network has universal approximation ability.

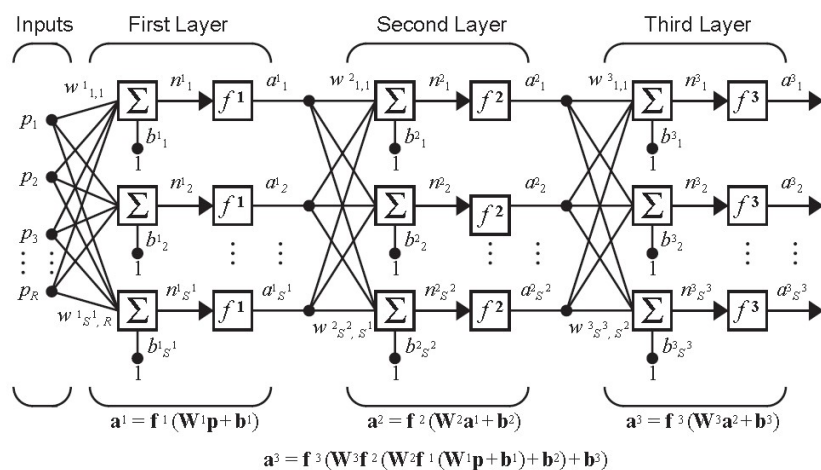
6

Multilayer Perceptron (cont'd)



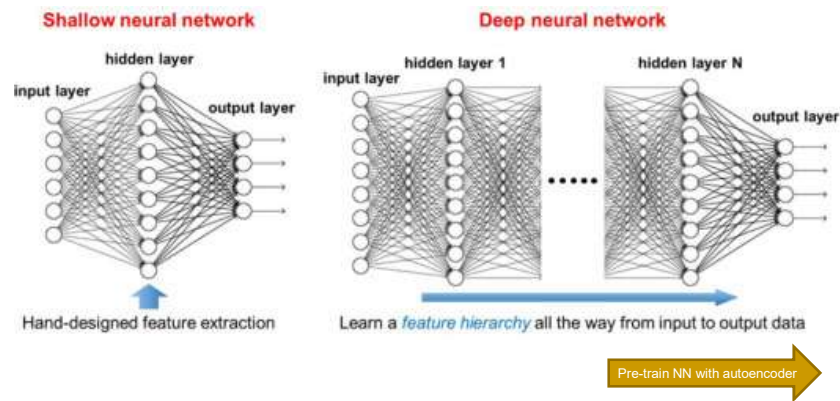
7

Multilayer Perceptron (cont'd)



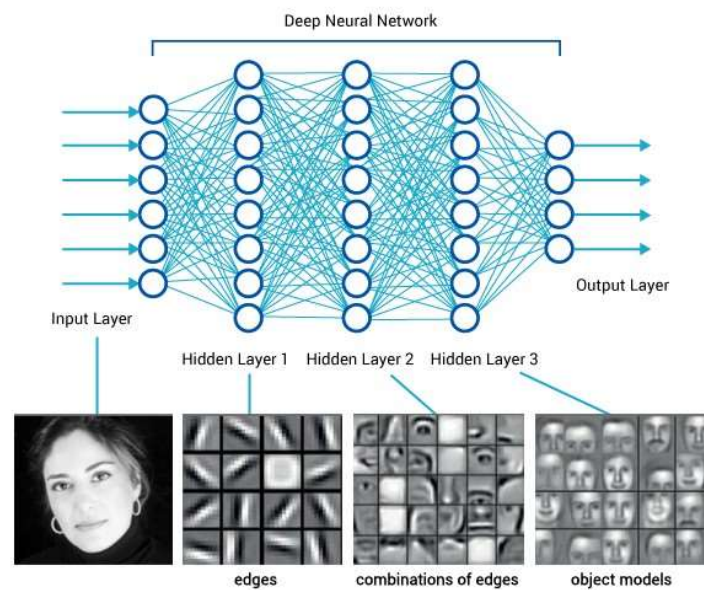
8

Shallow and Deep Neural Networks (1/2)



9

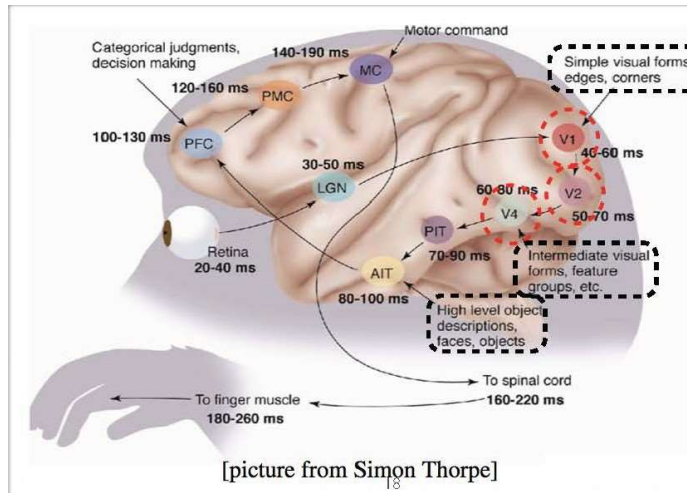
Shallow and Deep Neural Networks (2/2)



10

Biological Inspiration of DNN

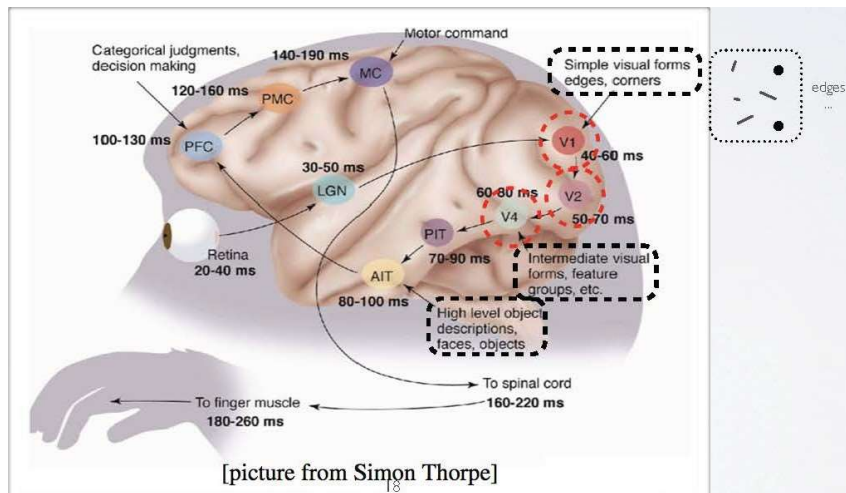
- Parallel with the visual cortex



11

Biological Inspiration of DNN (cont'd)

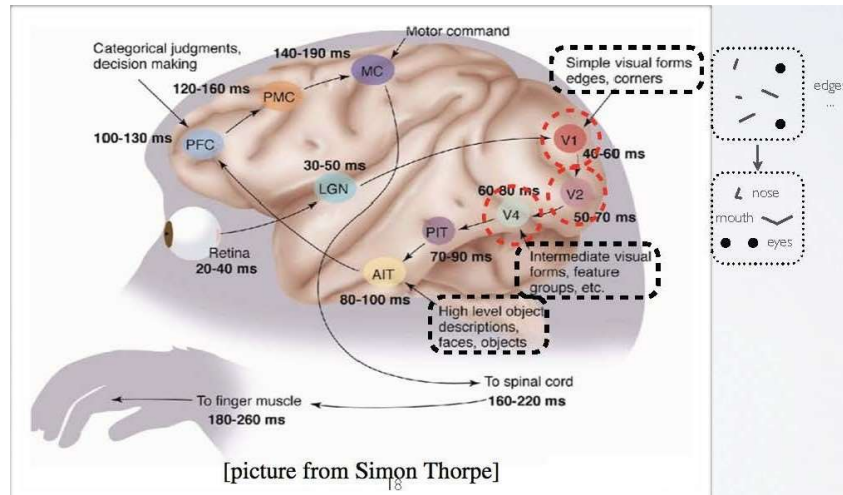
- Parallel with the visual cortex



12

Biological Inspiration of DNN (cont'd)

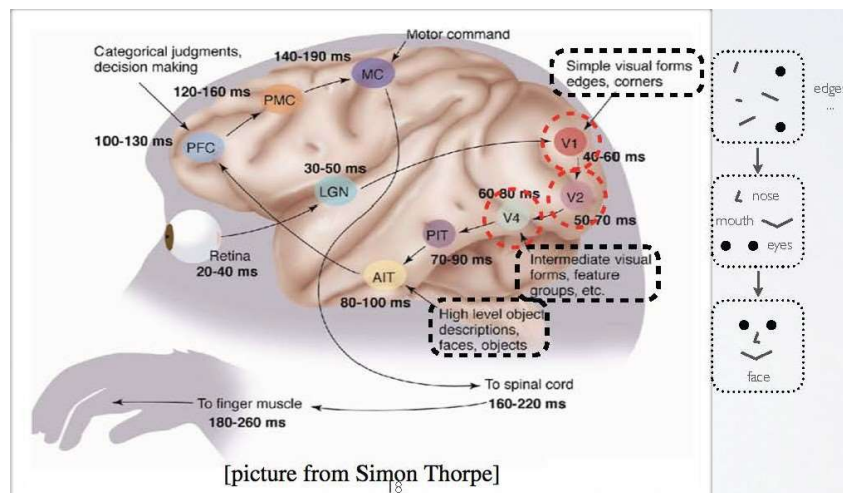
- Parallel with the visual cortex



13

Biological Inspiration of DNN (cont'd)

- Parallel with the visual cortex

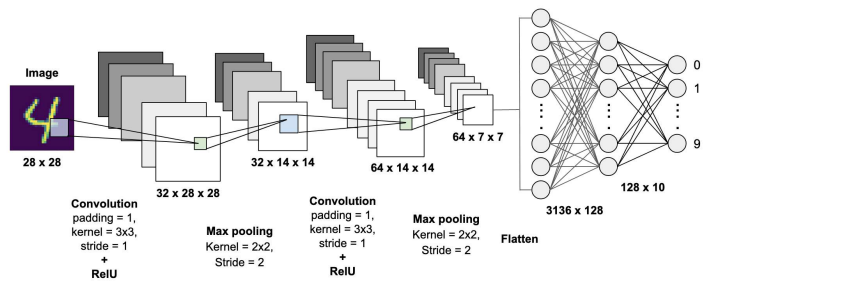


14

Other Neural Networks

Convolutional Neural Network

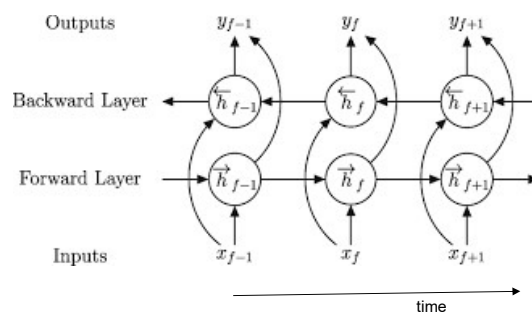
- Localized connection
- Shared weights



15

Other Neural Networks (cont'd)

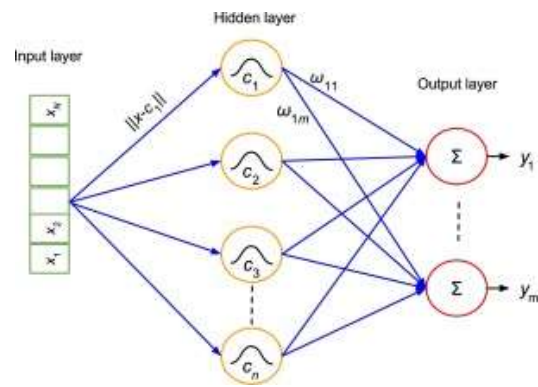
Recurrent Neural Network



16

Other Neural Networks (cont'd)

- RBF Neural Network



- Local receptive field
- Distance measure