The Introduction To Artificial Intelligence

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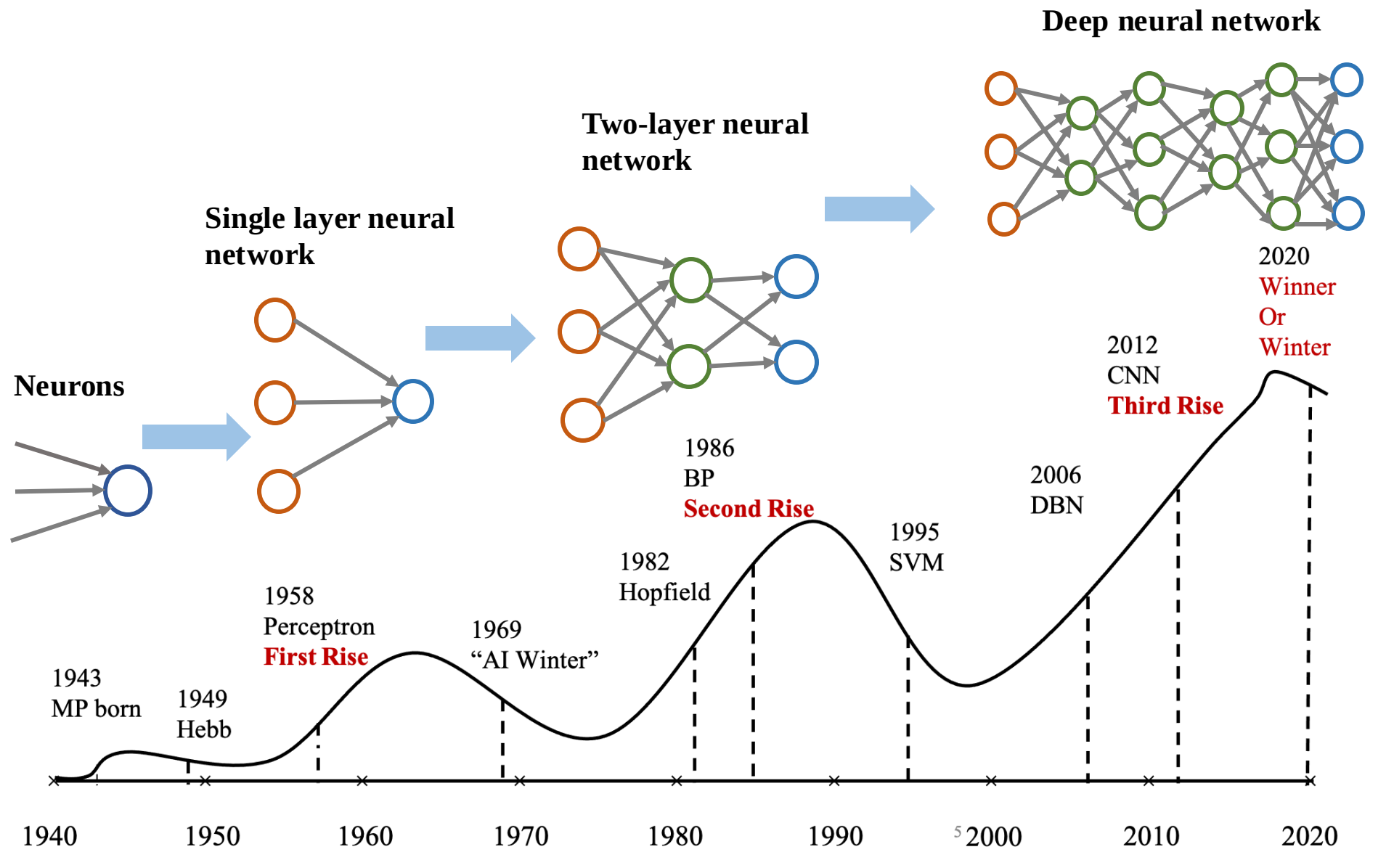
The Introduction to Artificial Intelligence

- Part I Brief Introduction to AI & Different AI tribes
- Part II Knowledge Representation & Reasoning
- Part III AI GAMES and Searching
- Part IV Model Evaluation and Selection
- Part V Machine Learning
- Part VI Neural Networks

Neural Networks

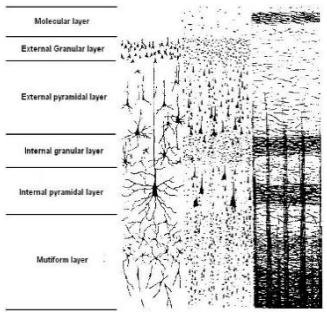
- *Brief review*
- Feedforward Neural Networks
- Recurrent Neural Networks
- The Learning of Neural Networks
- Model Performance: Cost Function
- Steepest Descent Method
- Backpropagation

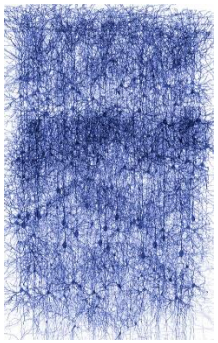
The development history of neural network

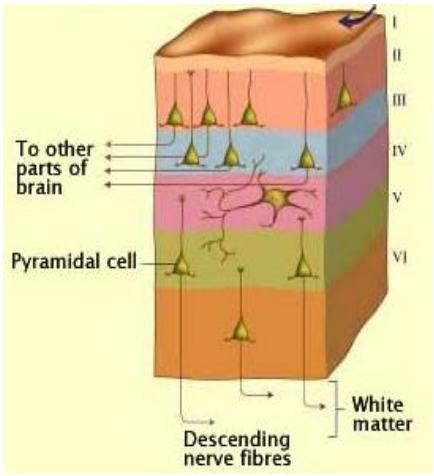


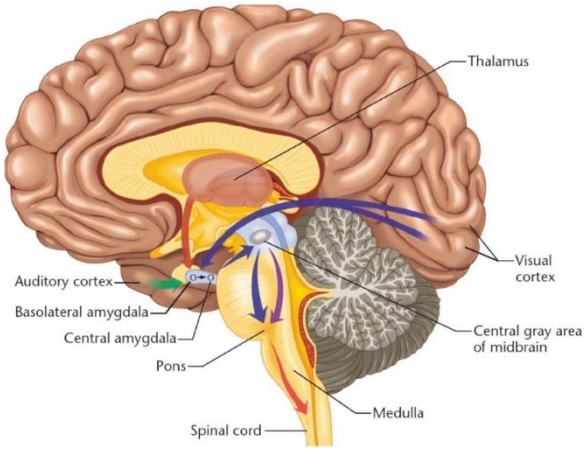
Where does intelligence come from ?

- The brain





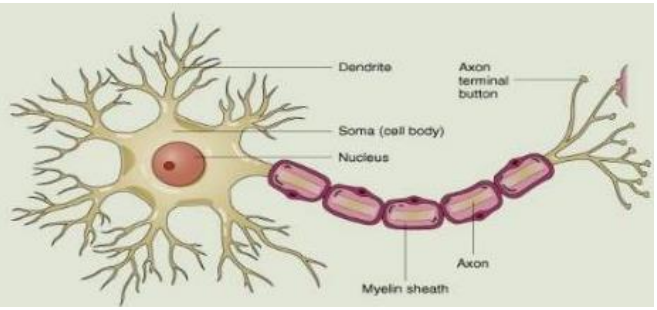


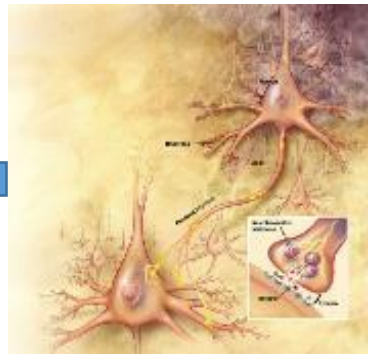


- The typical human neocortex:
  - Stretched flat, the human neocortical sheet is roughly the size of a large dinner napkin.
  - 2mm thick
  - 30 billion neurons
  - A tiny square millimeter contains an estimated 100,000 neurons.
  - 100 trillion synapses.
  - The neocortex plays a key role in most "advanced cognitive functions" such as thinking, memory, planning, perception, language, and attention.

Brief review

- Artificial Neuron





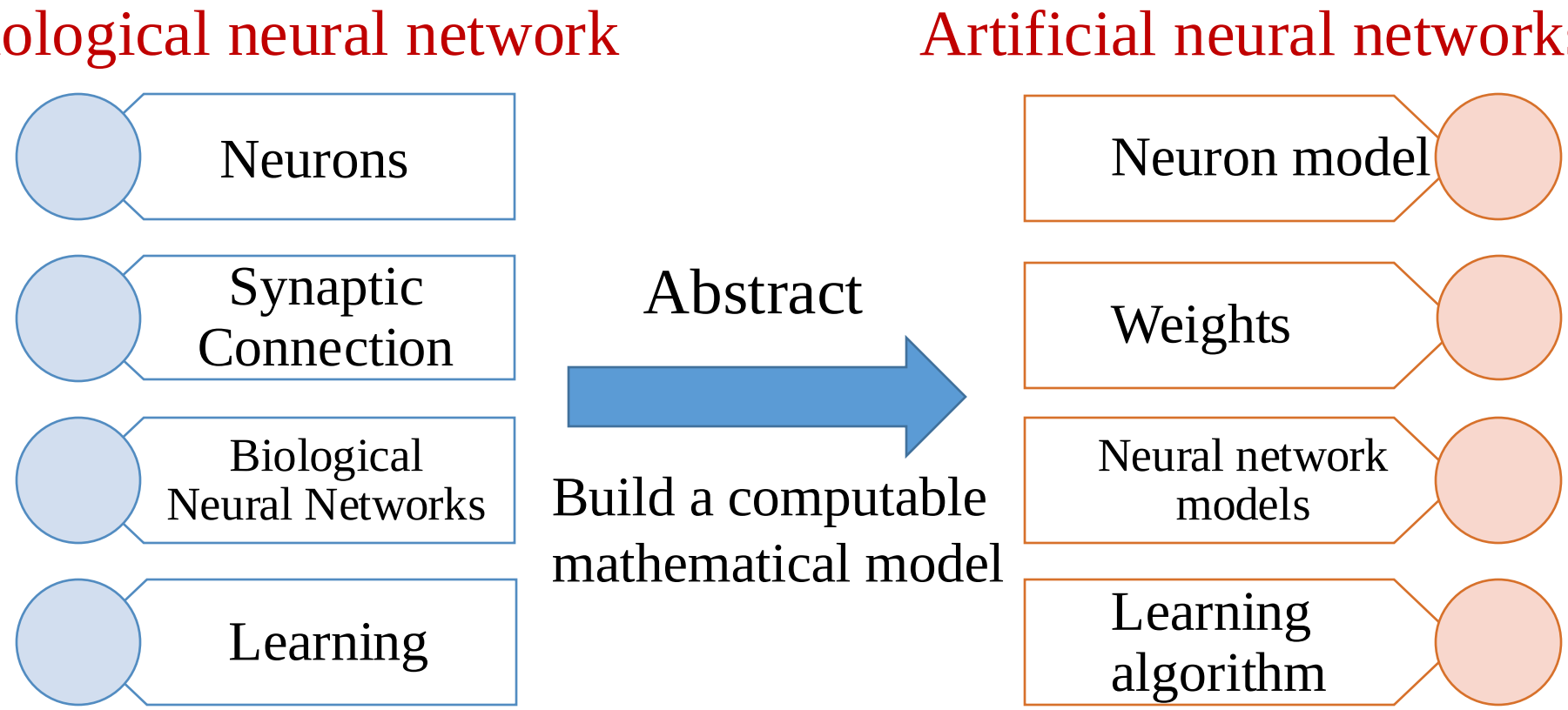
Neurons | Connection between neurons | Neural Networks

Idea: Using computers to simulate the activities of biological neural networks is expected to make machines intelligent

Artificial neural networks

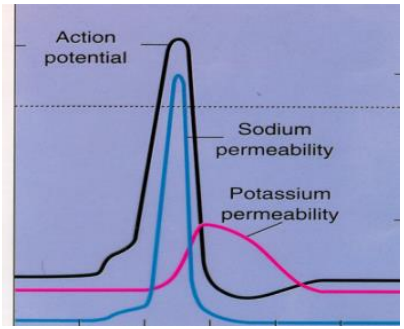
Brief review

- Artificial Neuron

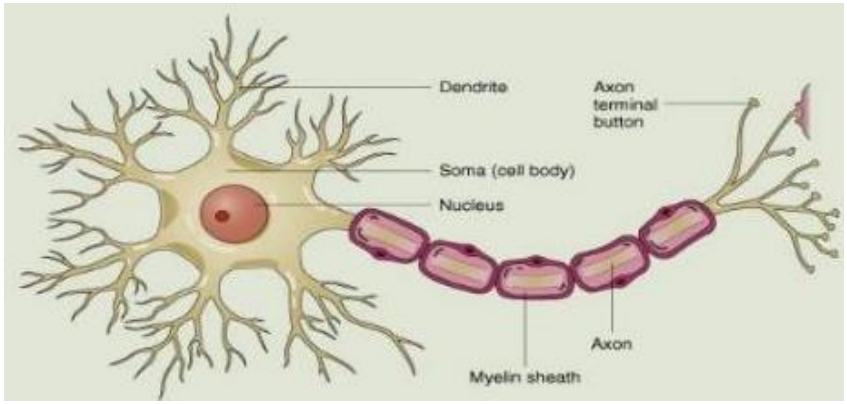


Computational Model of Neural Network

Artificial Neuron



Single neuron structure

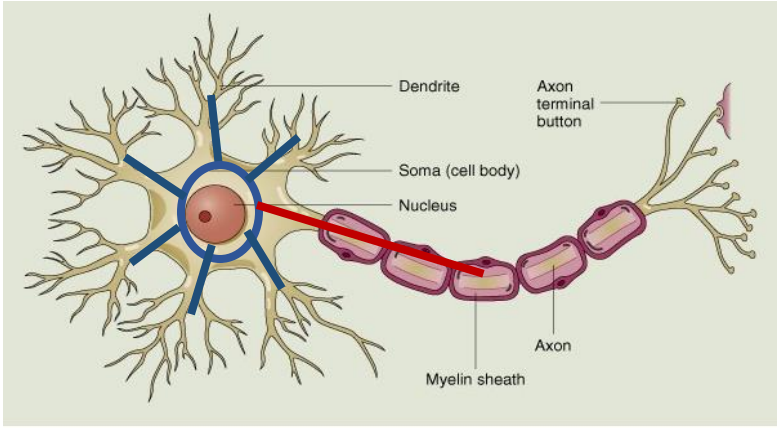


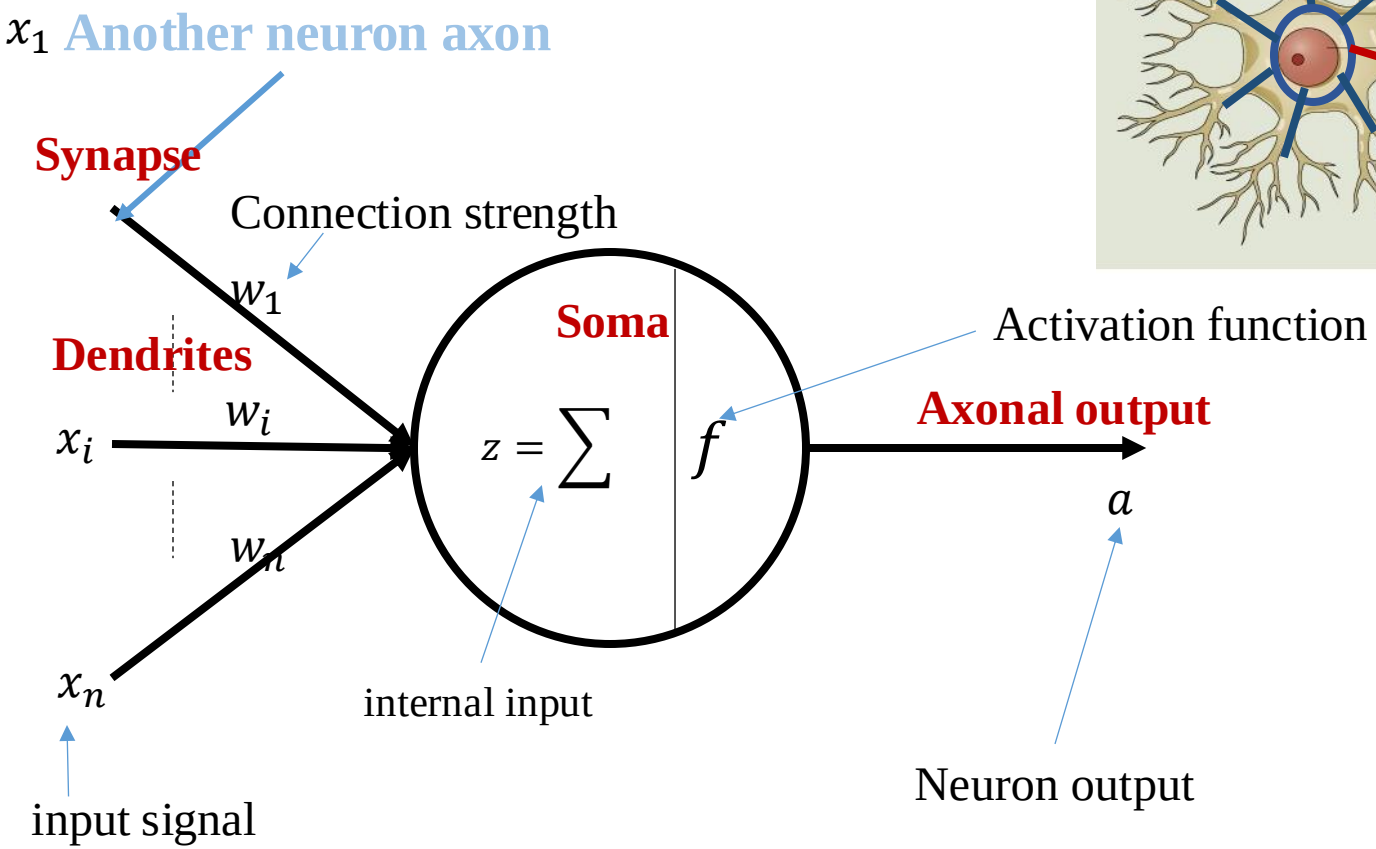
How to abstract?

- Soma, Dendrites, Axons
- Function: Collect and transmit signals
- Dendrites receive multiple inputs
- Soma superimposes input information
- Pulses are generated when information is superimposed to a certain extent
- Single output

Brief review

- Artificial Neuron





Brief review

- Artificial Neuron

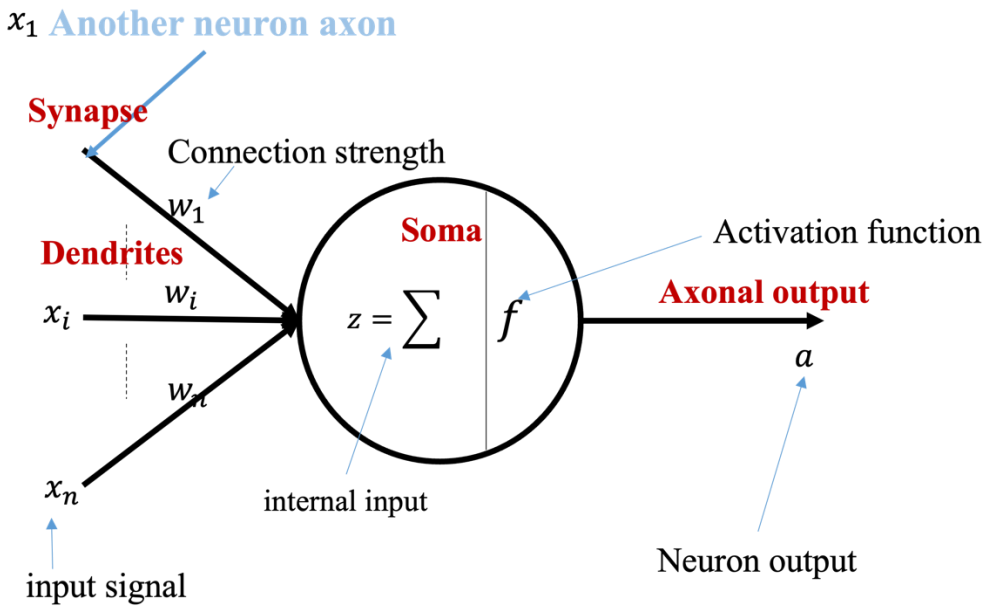
以下哪些是正确的：

$A.\ a = f(z)$

B. $z = w_i x_i$

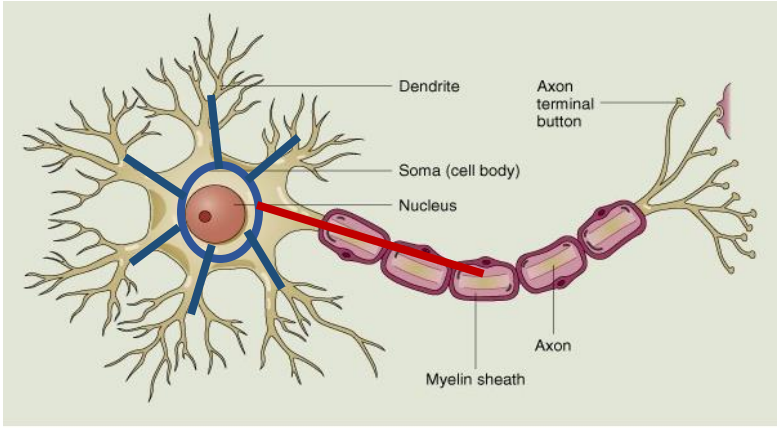
C. $a = f\left(\sum_{i=1}^{R} w_i x_i\right)$

D. $a = f(Wx)$



Brief review

Artificial Neuron



x_1 **Another neuron axon**

Synapse

Connection strength

w_1

Dendrites

x_i w_i

w_n

x_n

Soma

$n = \sum_{i=1}^{n} w_i x_i$ f

Activation function

Axonal output

$a = f(z)$

$a = f\left(\sum_{i=1}^{R} w_i x_i\right)$

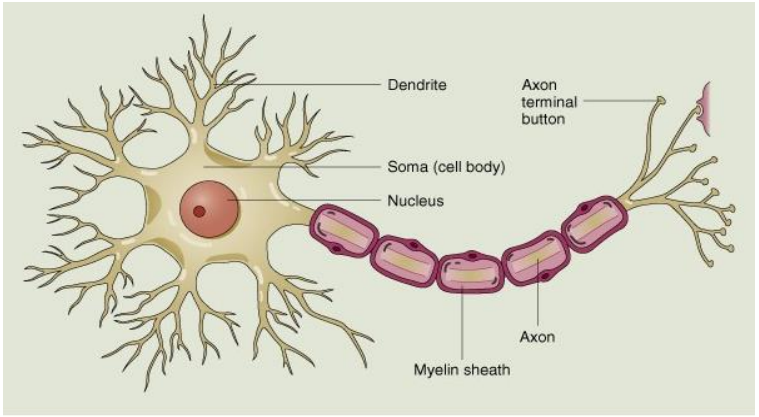
internal input

Neuron output

input signal

Computational Model of Neural Network

- Neural Networks

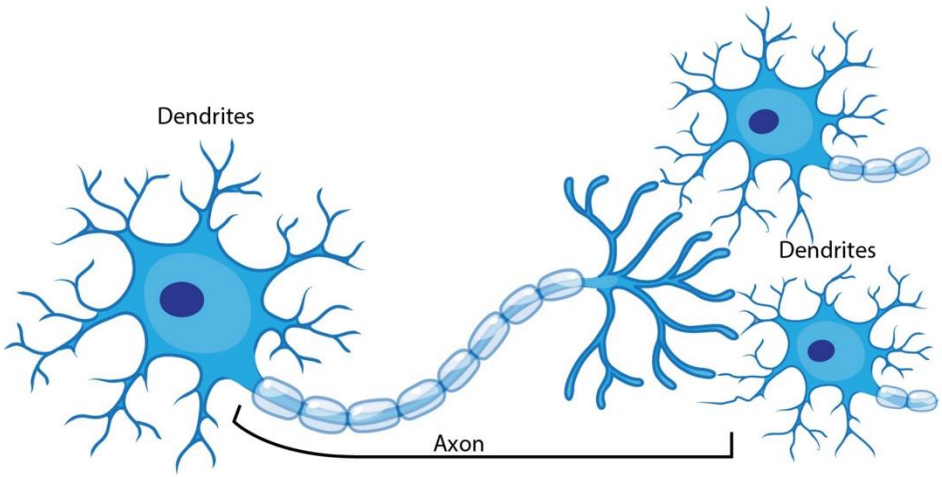


Neurons

Neural Networks

Computational Model of Neural Network

- Neural Networks



Neural Network = Neurons + Connections

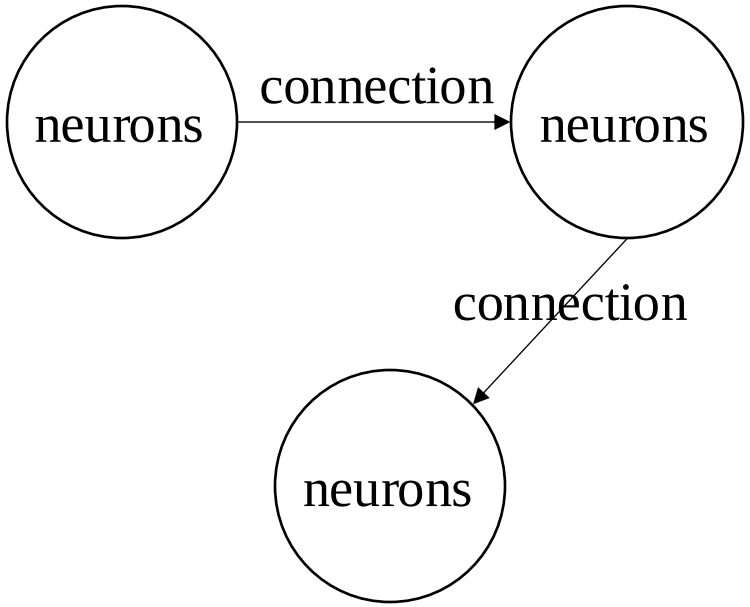
Computational Model of Neural Network

Neural Networks

Feedforward neural network

=

neurons + feedforward connections



Recurrent neural network

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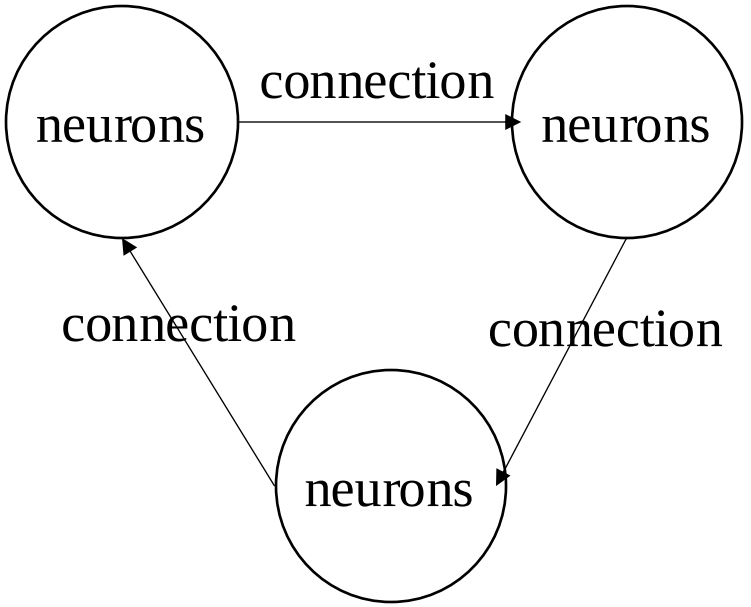
neurons + recurrent connections



Neural Networks

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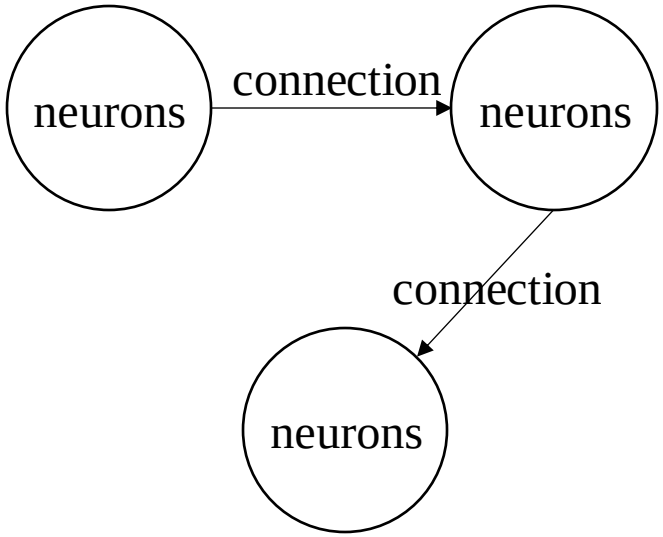
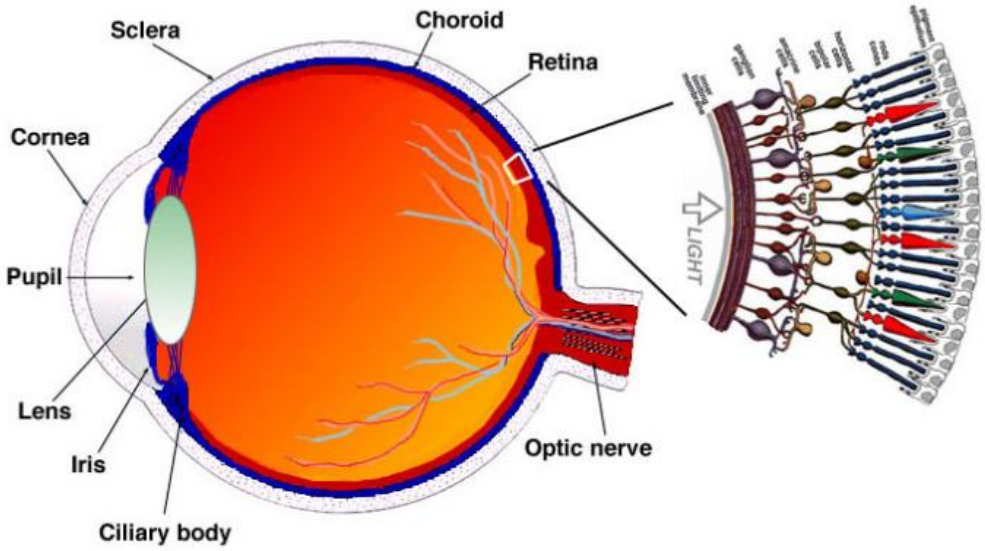
Feedforward Neural Network

Feedforward neural network

=

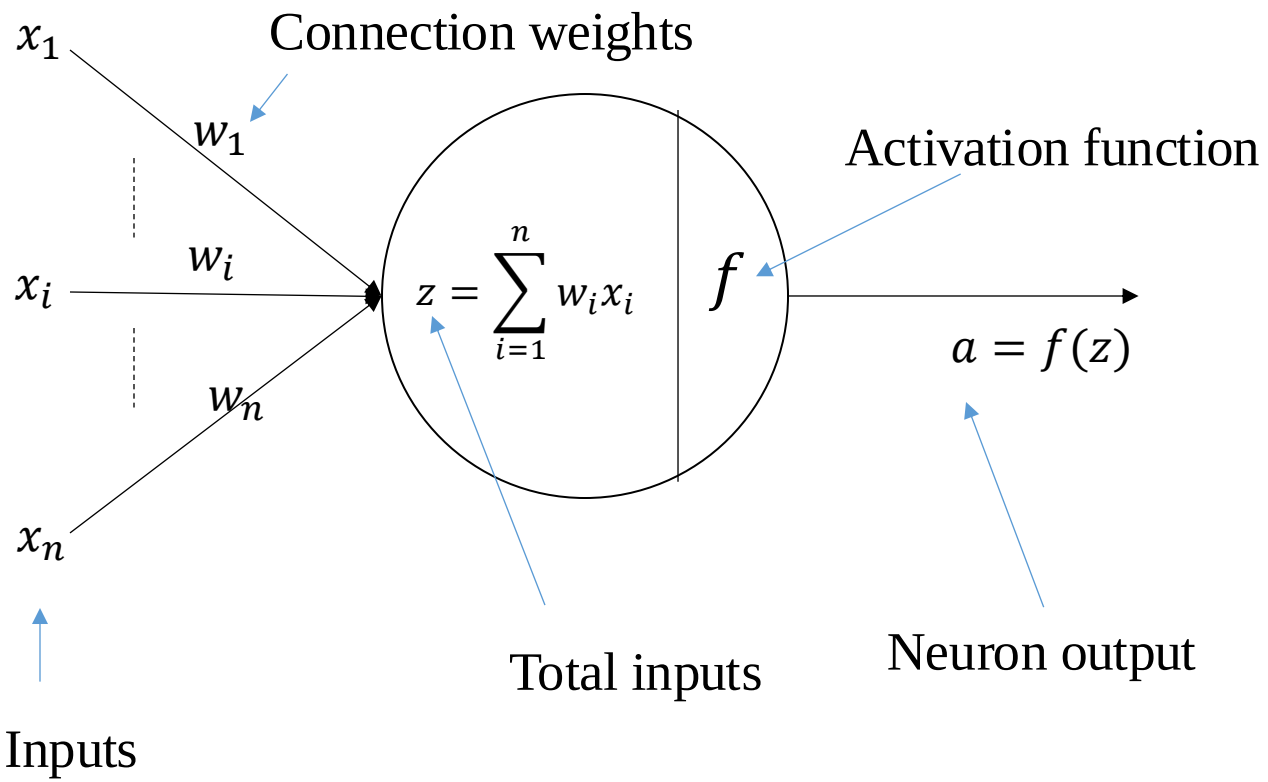
neurons + feedforward connections

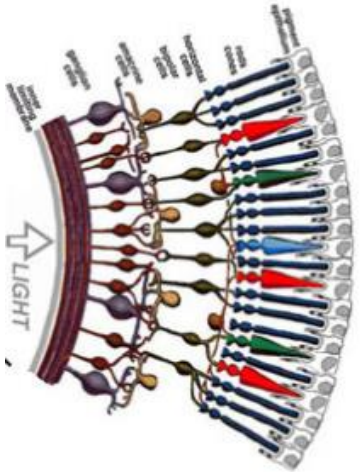


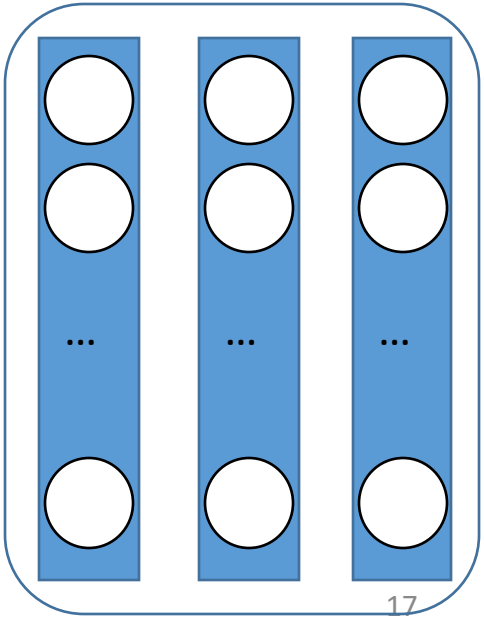


- Feedforward neural network with three layers.
- light-sensing cells – bipolar cells – ganglion cells (光感受细胞-双极细胞-节细胞)
- Neurons receive the outputs of neurons at previous layer as inputs.

Feedforward Neural Network

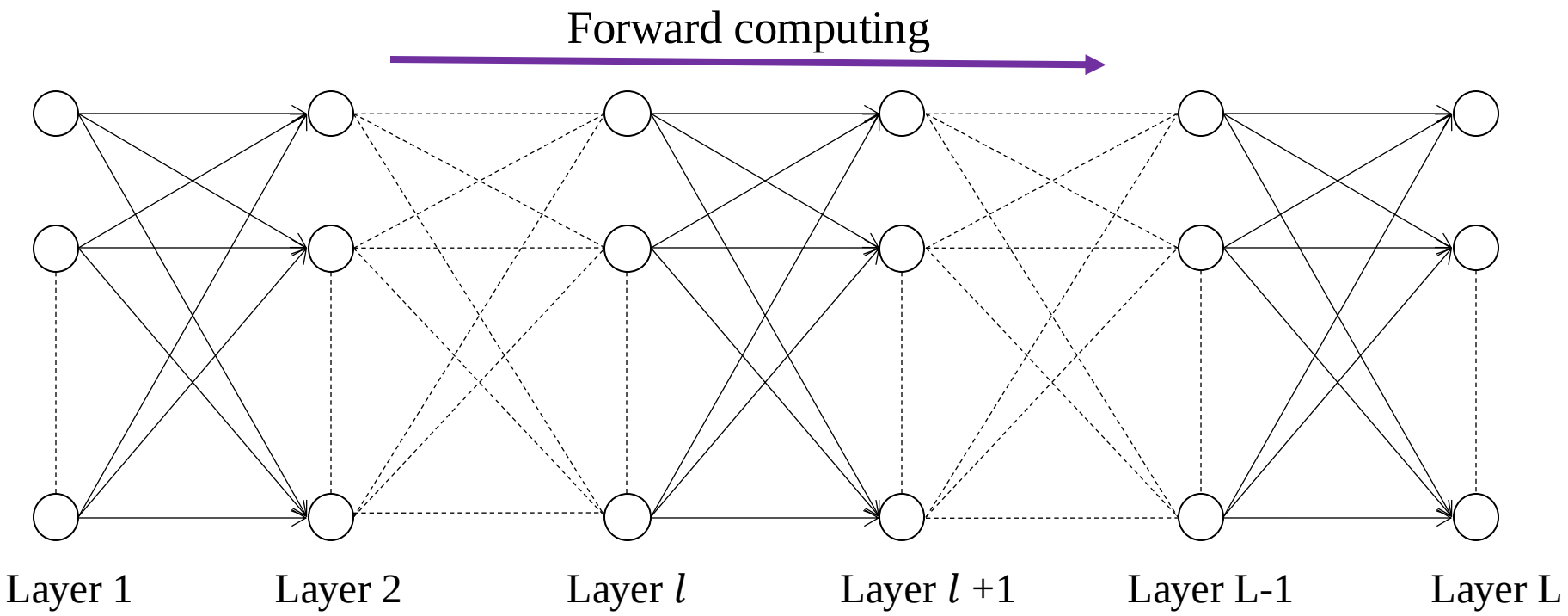




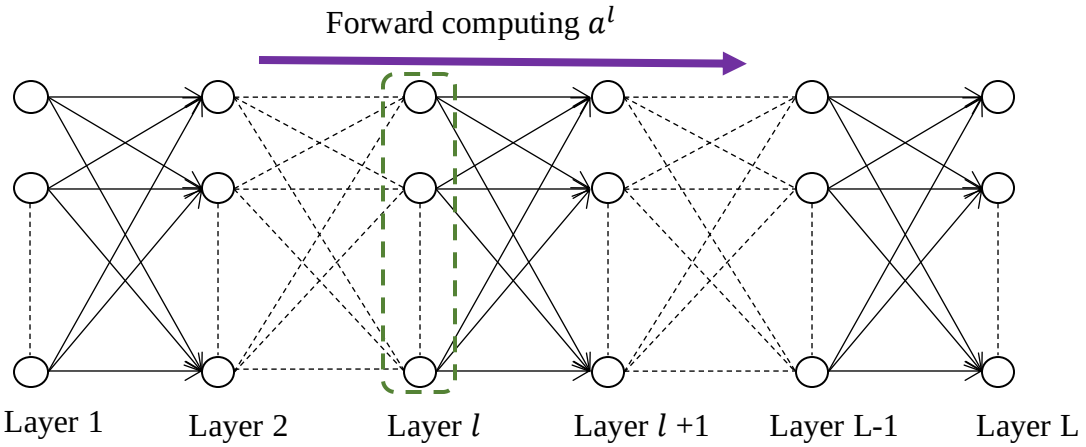


Problem: How are these neurons connected to form a feedforward neural network?

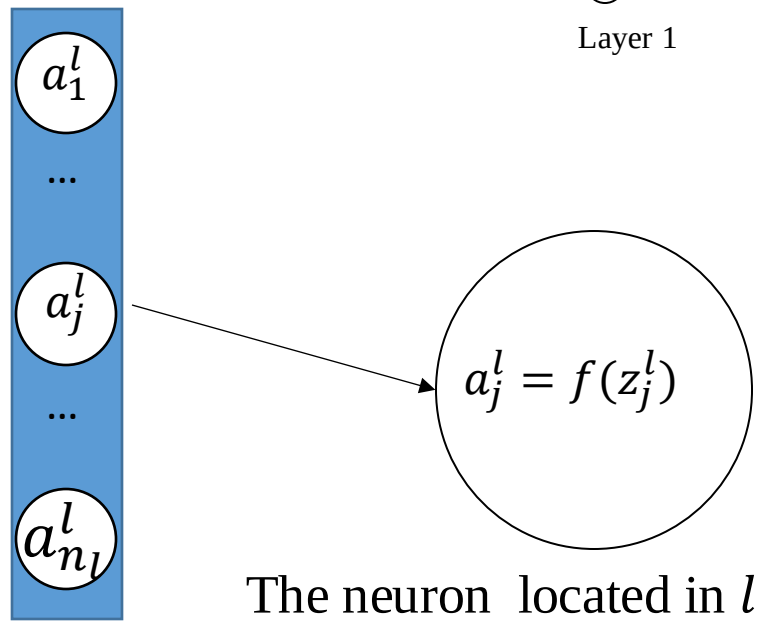
Feedforward Neural Network



Feedforward Neural Network



Layer l contains n_l neurons.



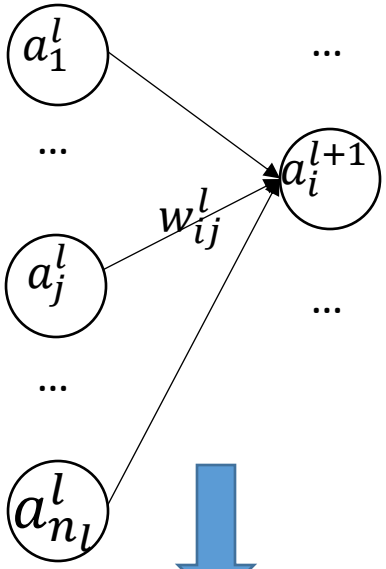
Layer l

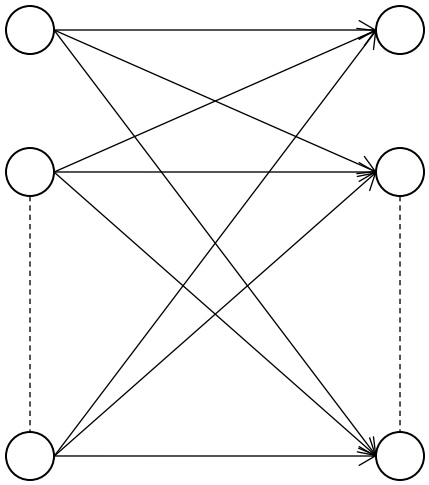
The neuron located in l layer j^{th} place, a_j^l denotes the output value of the neuron.

$$a^l = \begin{bmatrix} a_1^l \\ \dots \\ a_j^l \\ \dots \\ a_{n_l}^l \end{bmatrix}$$

Vector form

Feedforward Neural Network





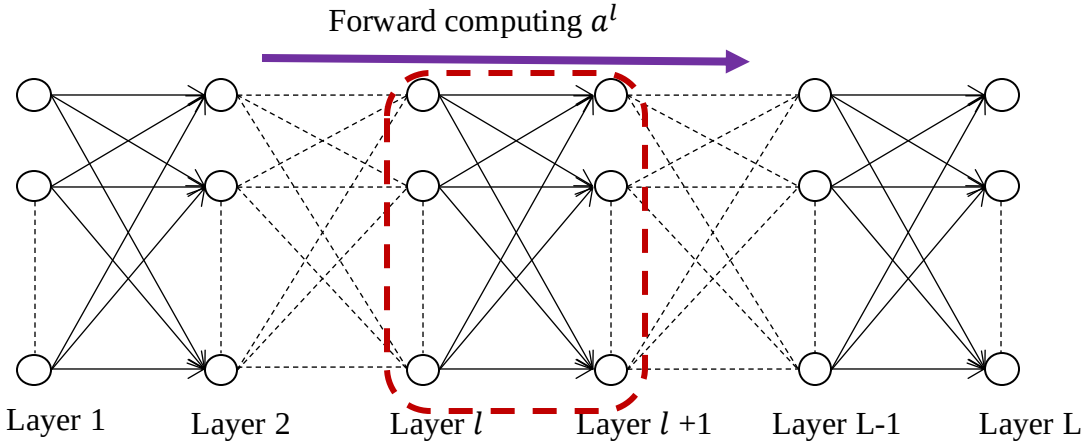
Layer l Layer l +1

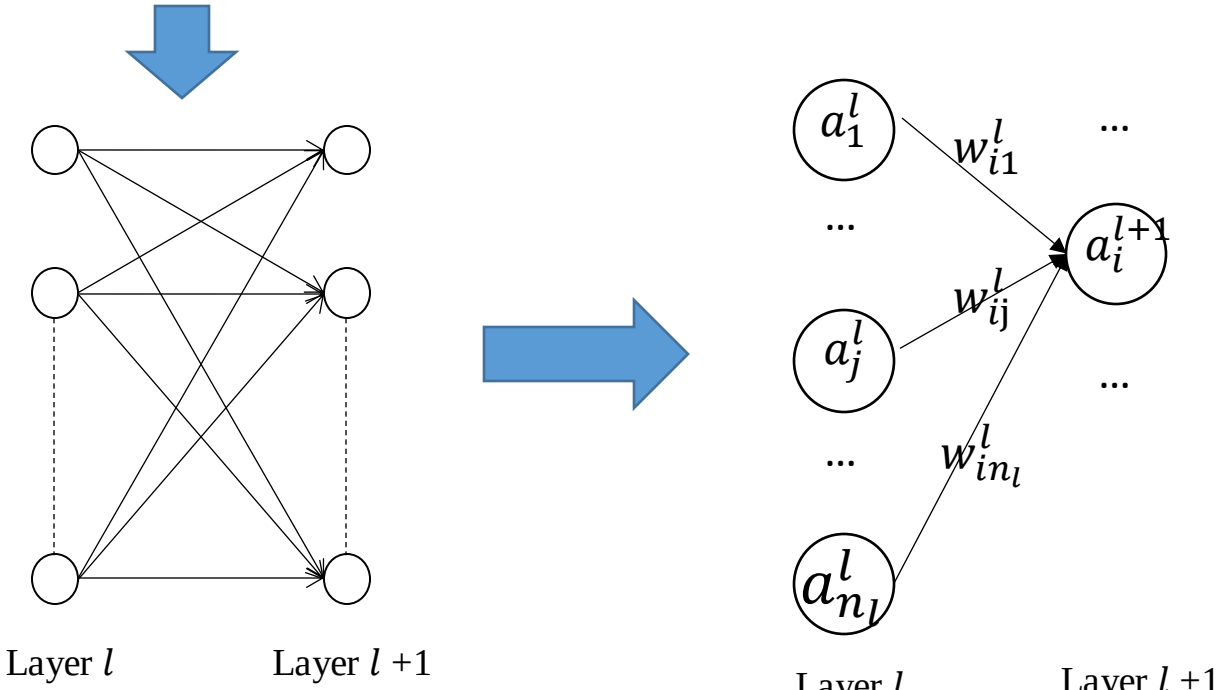
$$W^l = \begin{bmatrix} w_{11}^l & \cdots & w_{1n_l}^l \\ \cdots & w_{ij}^l & \cdots \\ w_{n_{l+1}1}^l & \cdots & w_{n_{l+1}n_l}^l \end{bmatrix}$$

a^l W^l a^{l+1}

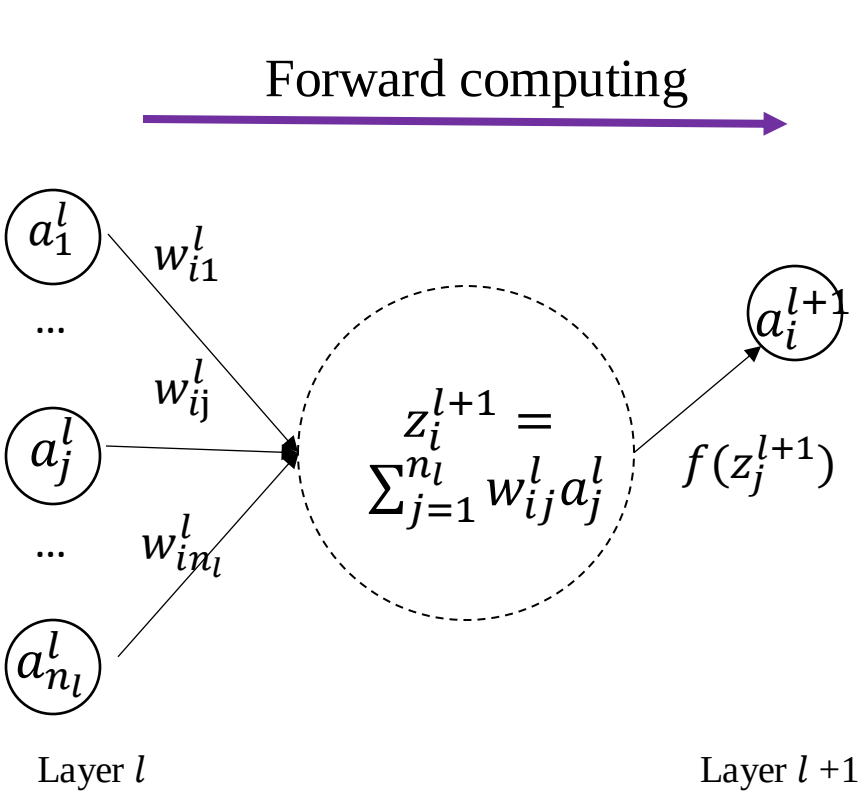
a^l is the input of l +1 layer.

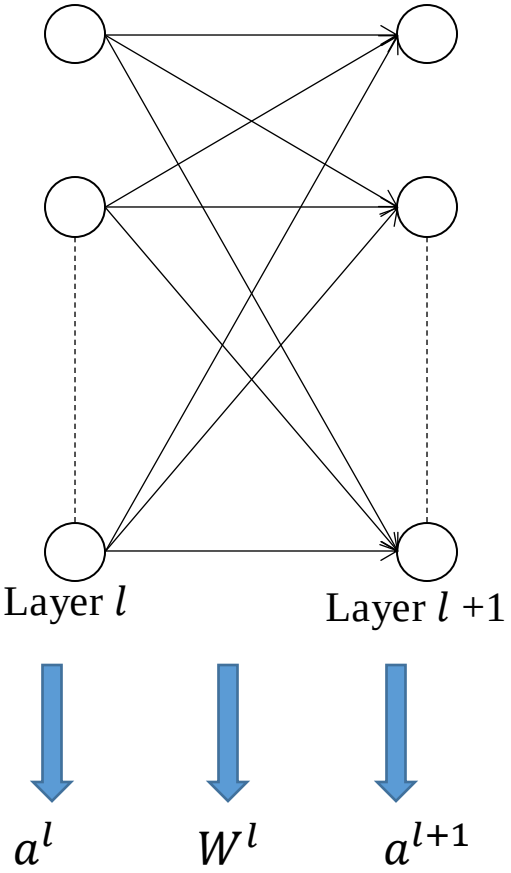
Feedforward Neural Network





Feedforward Neural Network





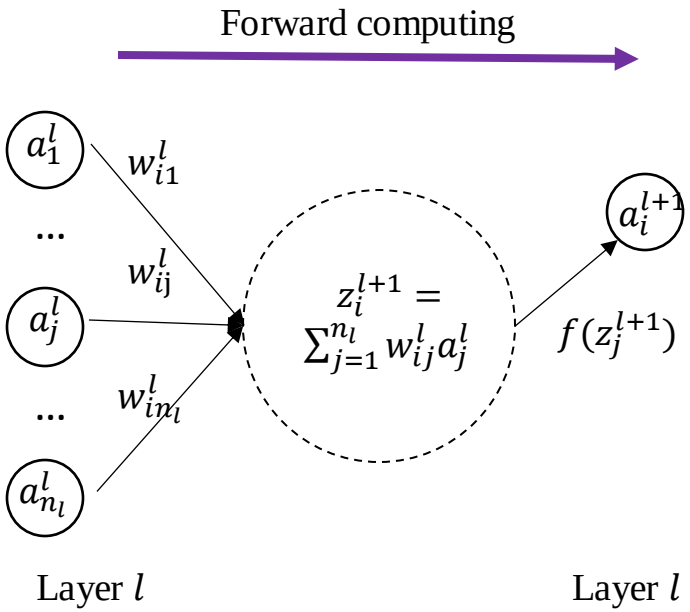
Component form

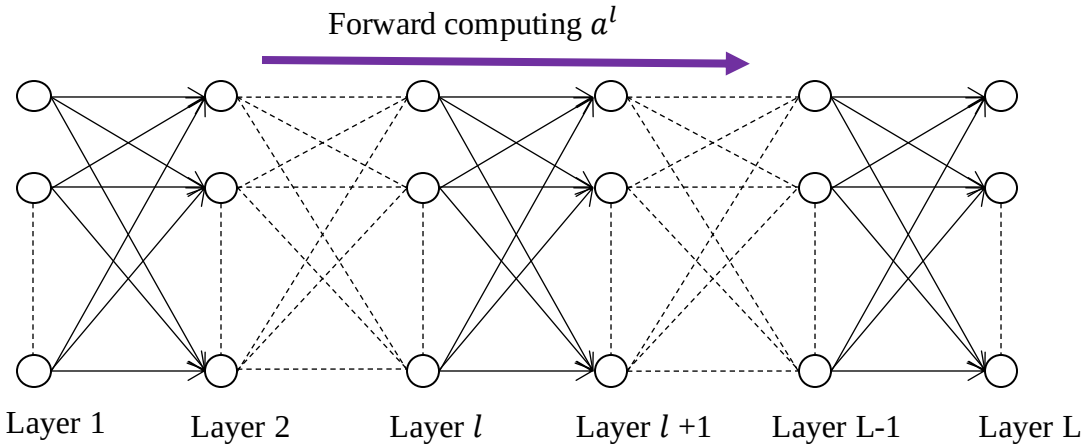
$$\begin{cases} a_i^{l+1} = f(z_i^{l+1}) \\ z_i^{l+1} = \sum_{j=1}^{n_l} w_{ij}^l a_j^l \end{cases}$$

Vector form

$$\begin{cases} a^{l+1} = f(z^{l+1}) \\ z^{l+1} = W^l a^l \end{cases}$$

Feedforward Neural Network





Algorithm:

Input W^l, a^l

for l = 1:L, run function:

$a^{l+1} = fc(W^l, a^l)$

return

Function $fc(W^l a^l)$

For i = 1: n_{l+1}

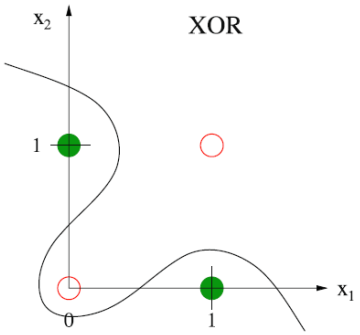
$z_i^{l+1} = \sum_{j=1}^{n_l} w_{ij}^l a_j^l$

$a_i^{l+1} = f(z_i^{l+1})$

end

Feedforward Neural Network

Example: XOR Problem



$\begin{bmatrix}0\\1\end{bmatrix}$ $\begin{bmatrix}1\\0\end{bmatrix}$

$\begin{bmatrix}0\\0\end{bmatrix}$ $\begin{bmatrix}1\\1\end{bmatrix}$

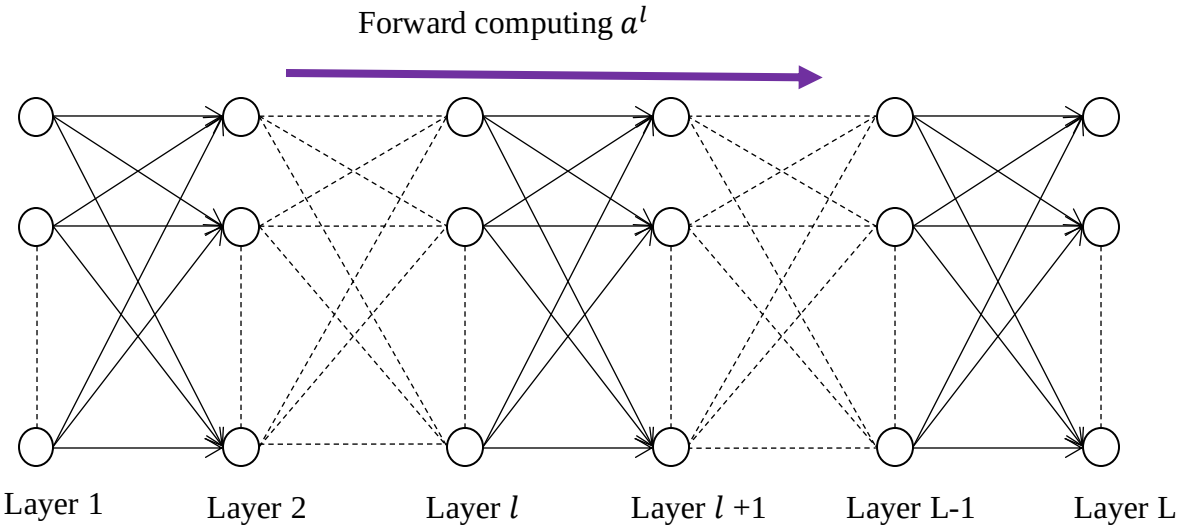
$$F\left(\begin{bmatrix}x_1\\x_2\end{bmatrix}\right) = f[f(2x_1 + 2x_2 - 1) + f(-x_1 - x_2 + 1.5) - 1.5]$$

$$f(s) = \begin{cases}1, & s \geq 0\\ 0, & otherwise\end{cases}$$

→ 1

→ 0

Problem: Could build a feedforward neural network to complete F ?



Feedforward Neural Network

- Example: XOR Problem

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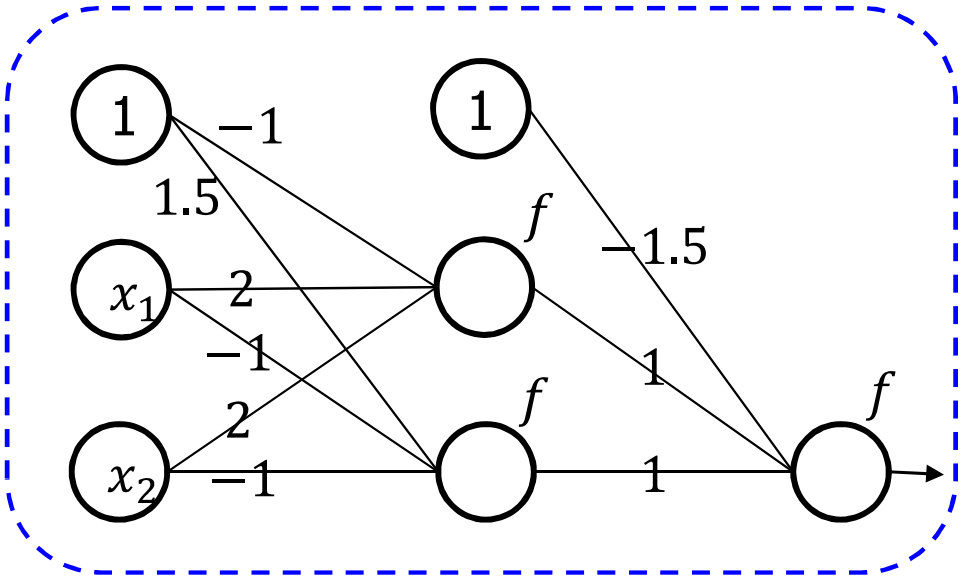
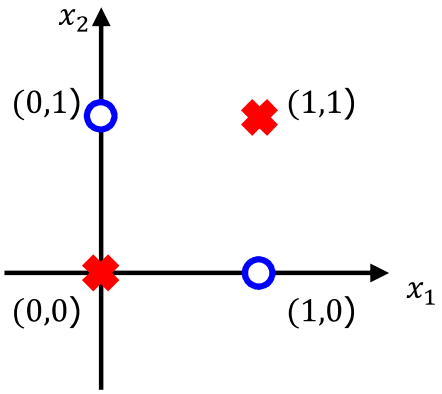


1
或
0

Feedforward Neural Network

- Example: XOR Problem



$$\begin{bmatrix}0\\1\end{bmatrix} \quad \begin{bmatrix}1\\0\end{bmatrix}$$

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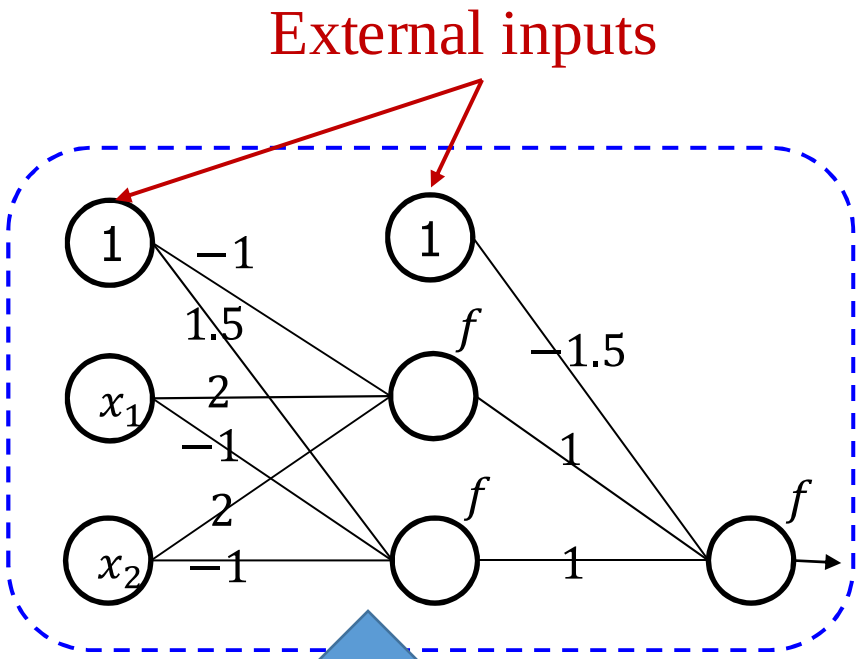

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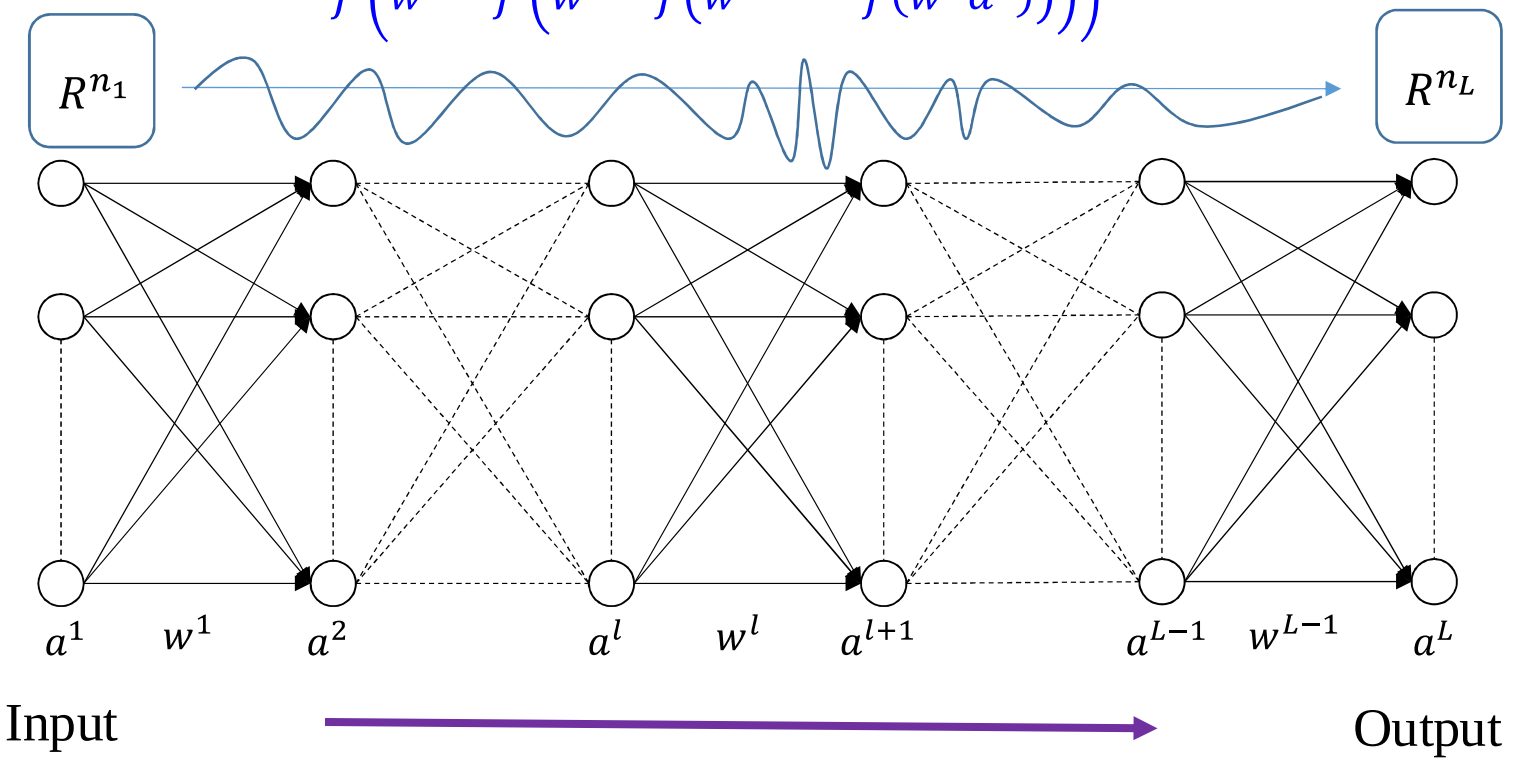
$$f(s) = \begin{cases}1, & s \geq 0\\ 0, & otherwise\end{cases}$$

Feedforward Neural Network

In fact, FNN is a nonlinear mapping from R^{n_1} space to R^{n_L} space.

$$a^L = f(w^{L-1}a^{L-1}) = f\left(w^{L-1}f\left(w^{L-2}f\left(w^{L-3}\cdots f(w^1a^1)\right)\right)\right)$$

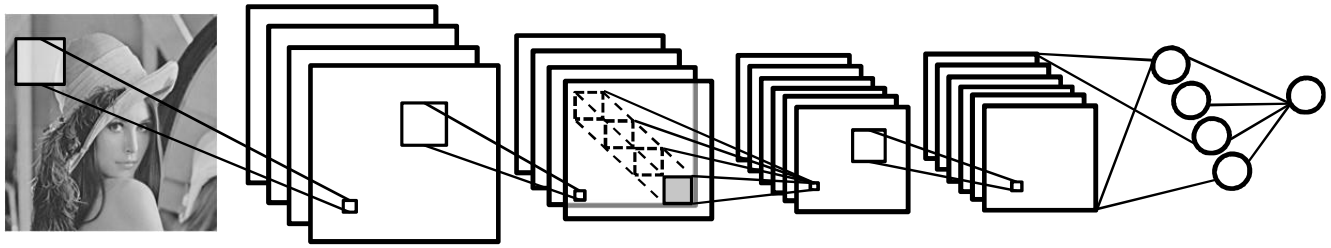
$$f\left(w^{L-1}f\left(w^{L-2}f\left(w^{L-3}\cdots f(w^1a^1)\right)\right)\right)$$

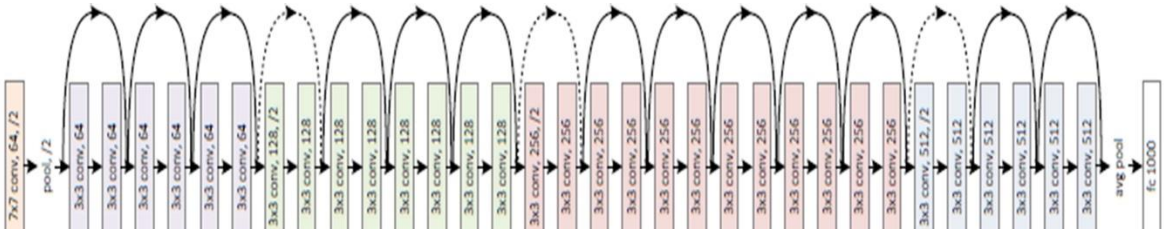


Feedforward Neural Network

FNN

- The feedforward neural network is described by nonlinear mapping and is suitable for spatial correlation data analysis.
- Based on the topology of feedforward neural network, a variety of feedforward neural network models are developed.





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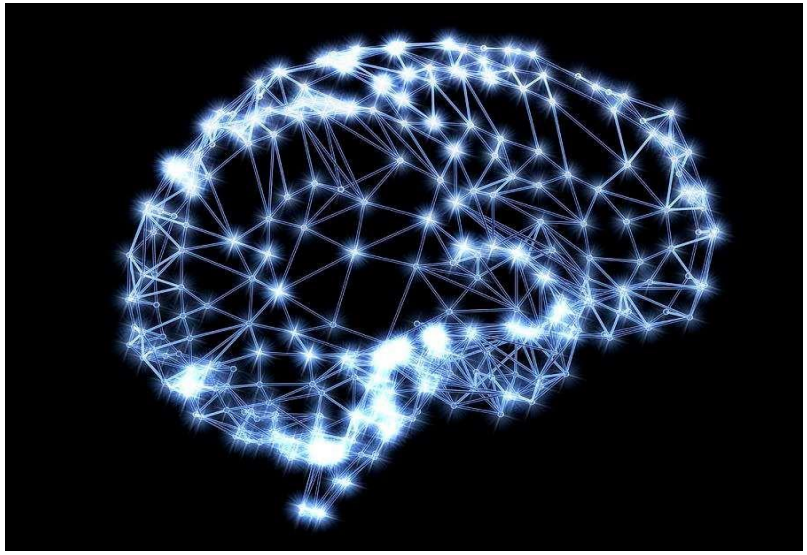

Recurrent neural network

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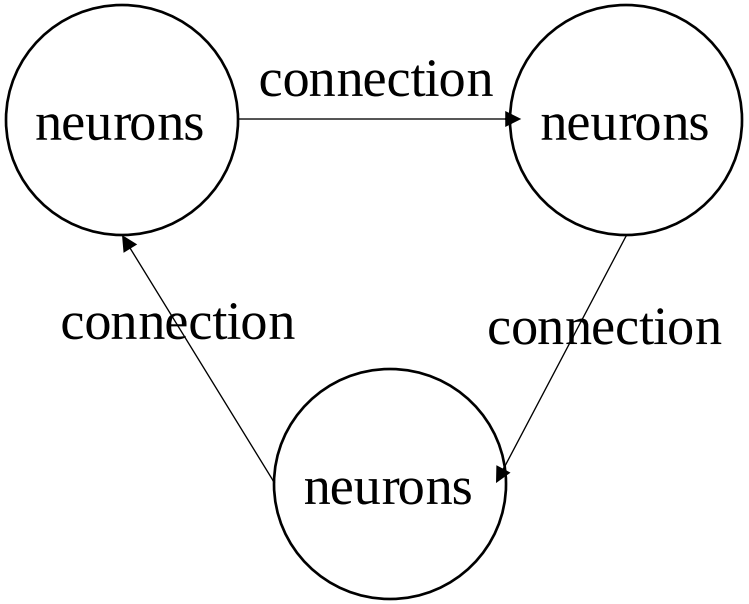
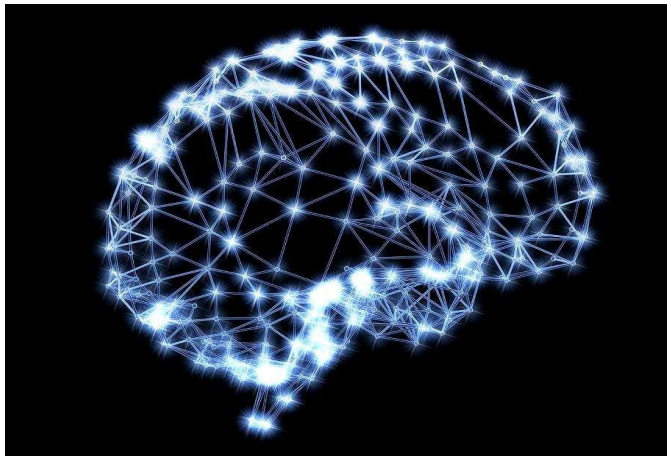
neurons + recurrent connections

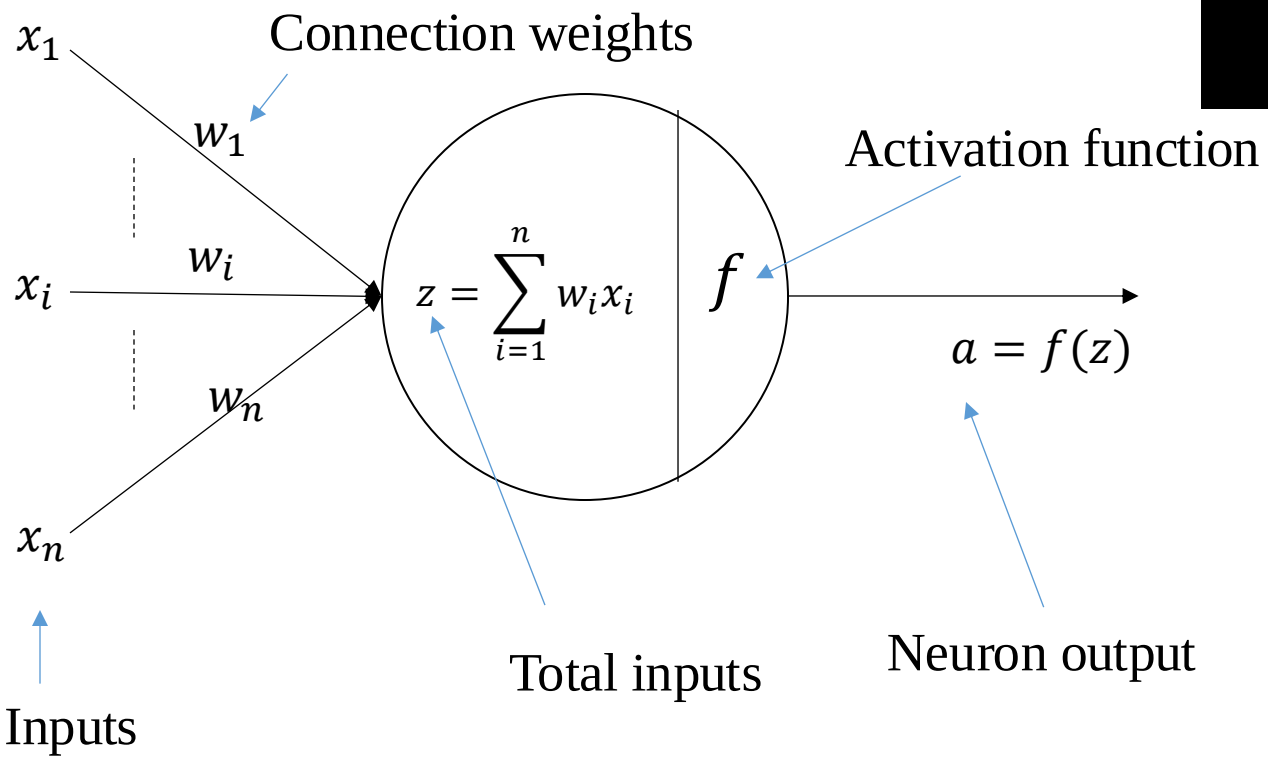


RNNs ---- with feedback connections

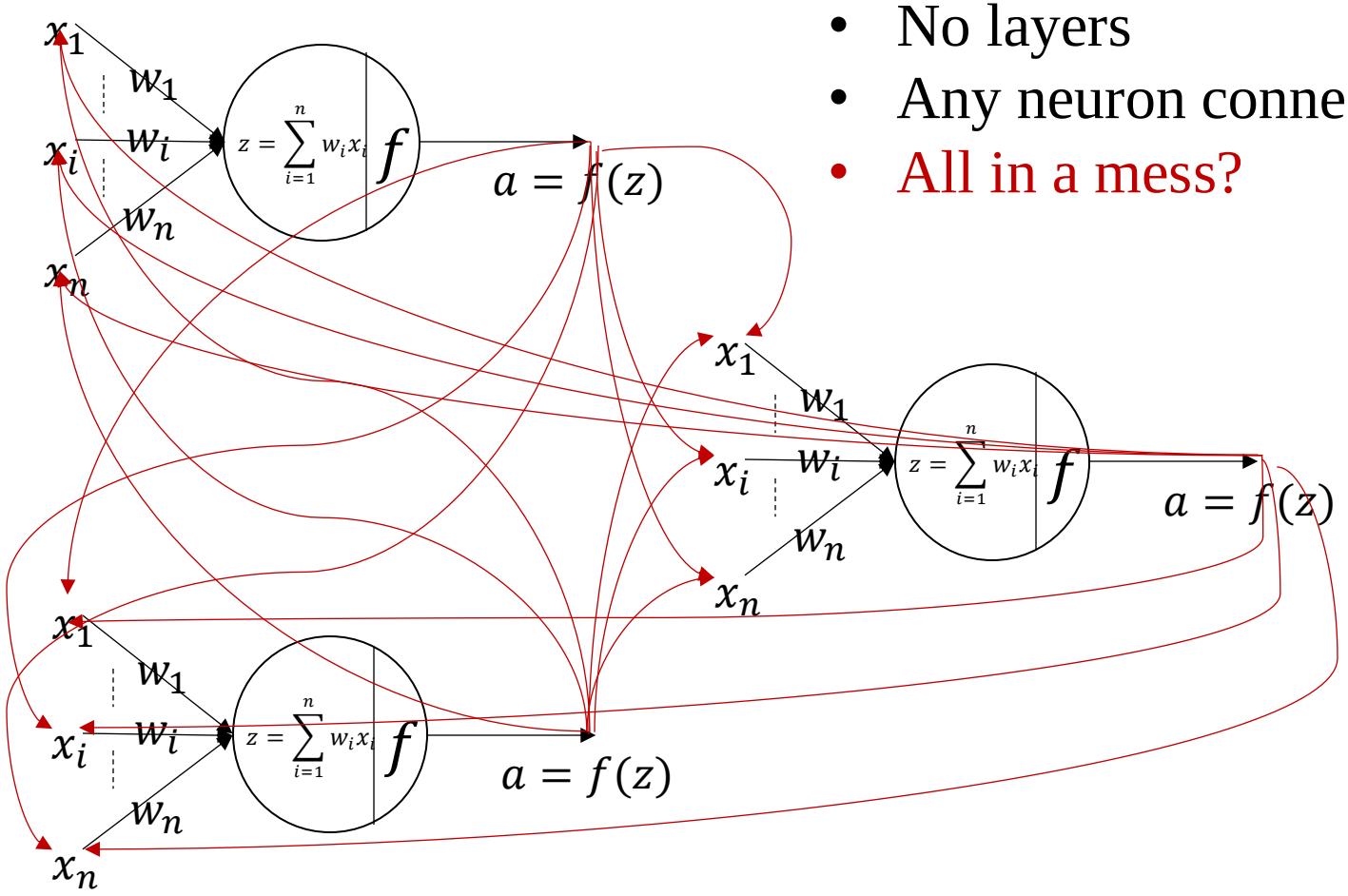
Recurrent Neural Networks

RNN = neurons + recurrent connections



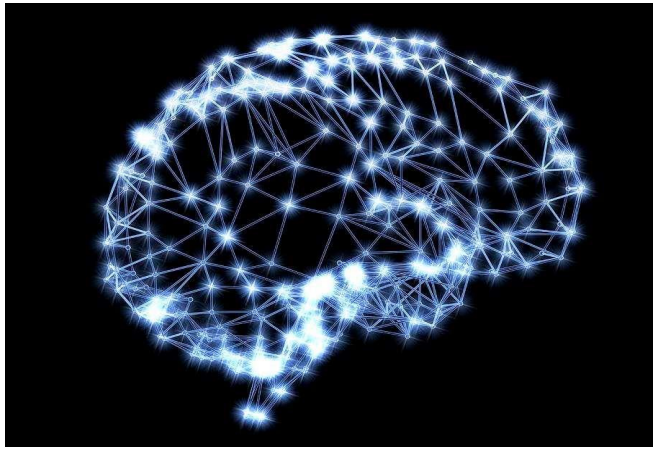


Recurrent Neural Networks

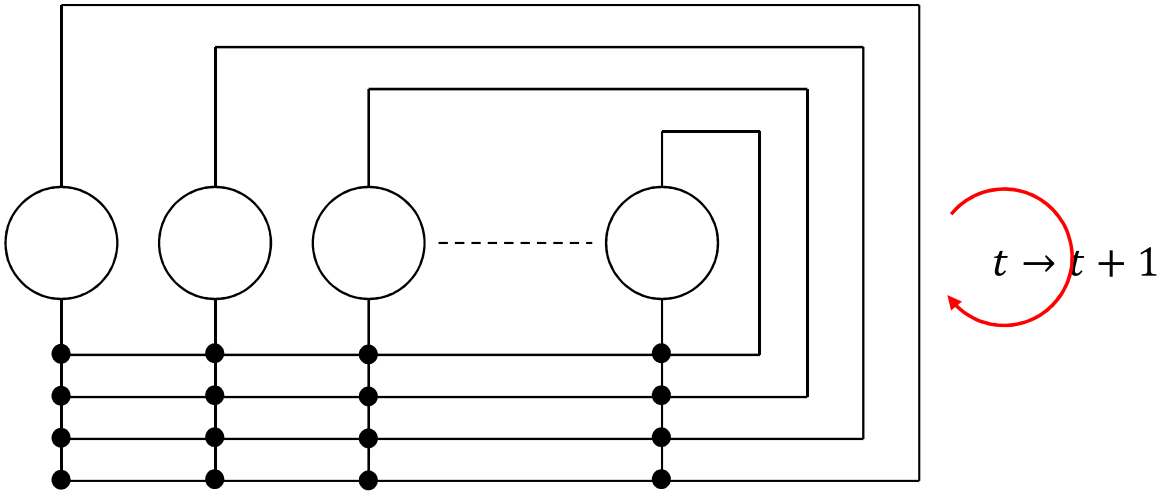


- No layers
- Any neuron connects to any others
- All in a mess?

Recurrent Neural Networks

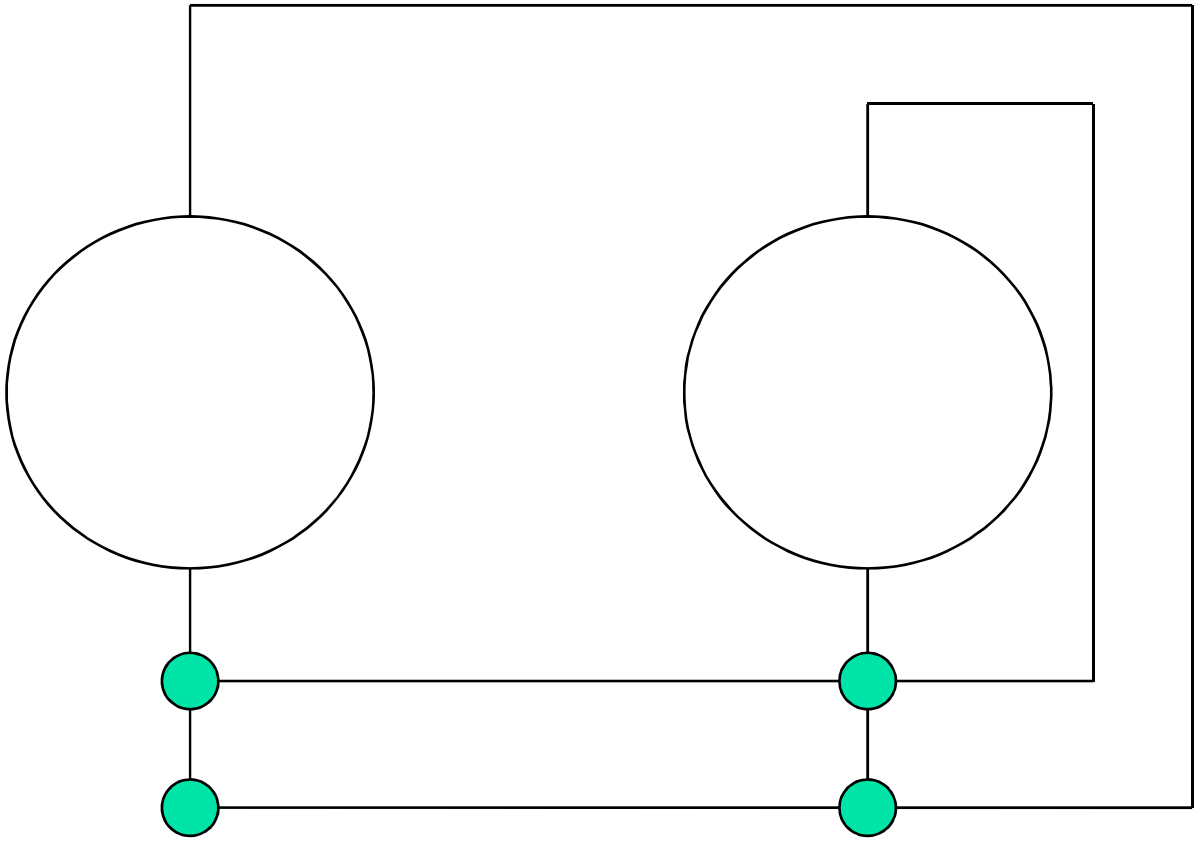


Topology Structure

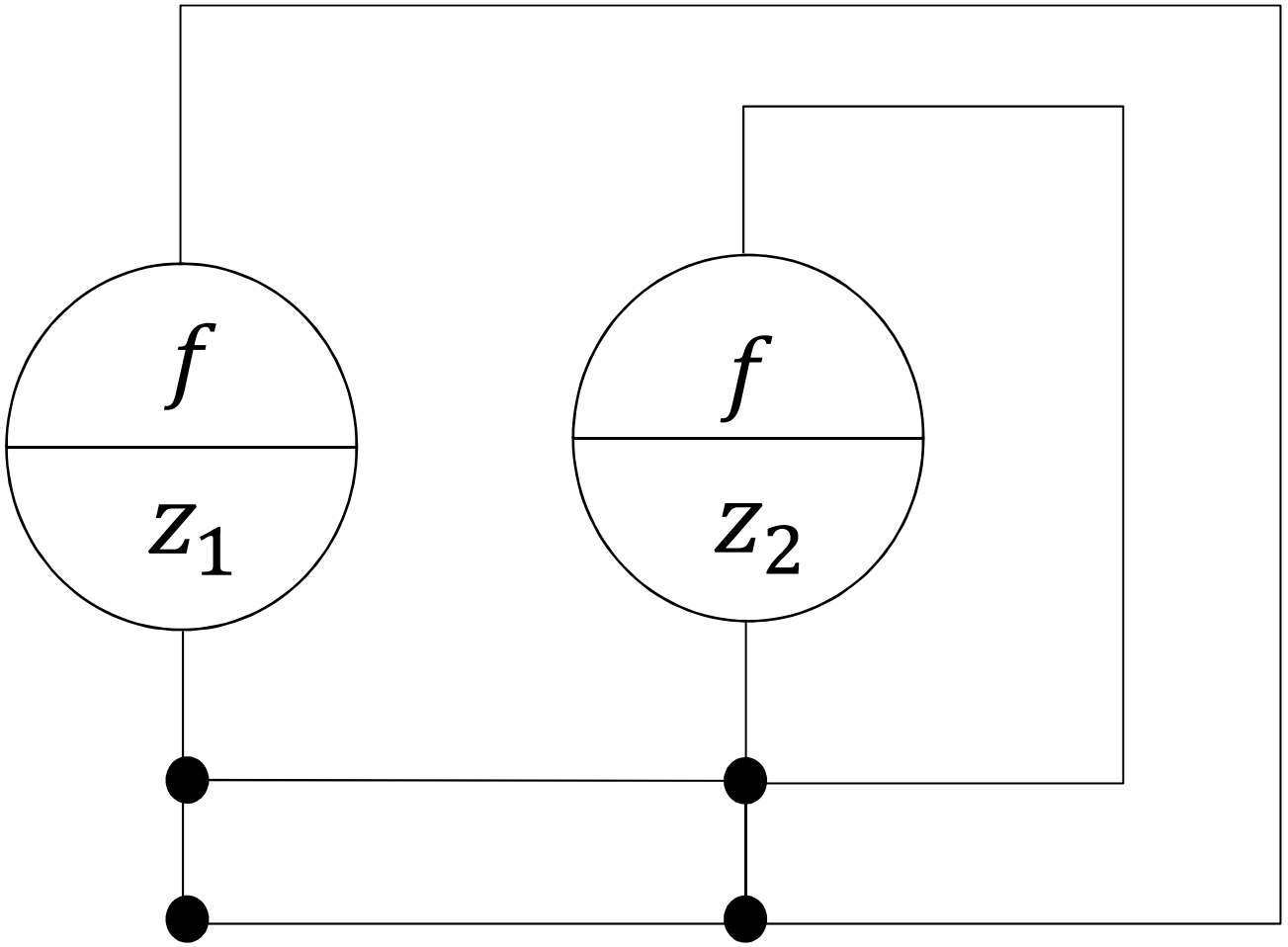


Problem: how to develop computational model of the RNNs ?

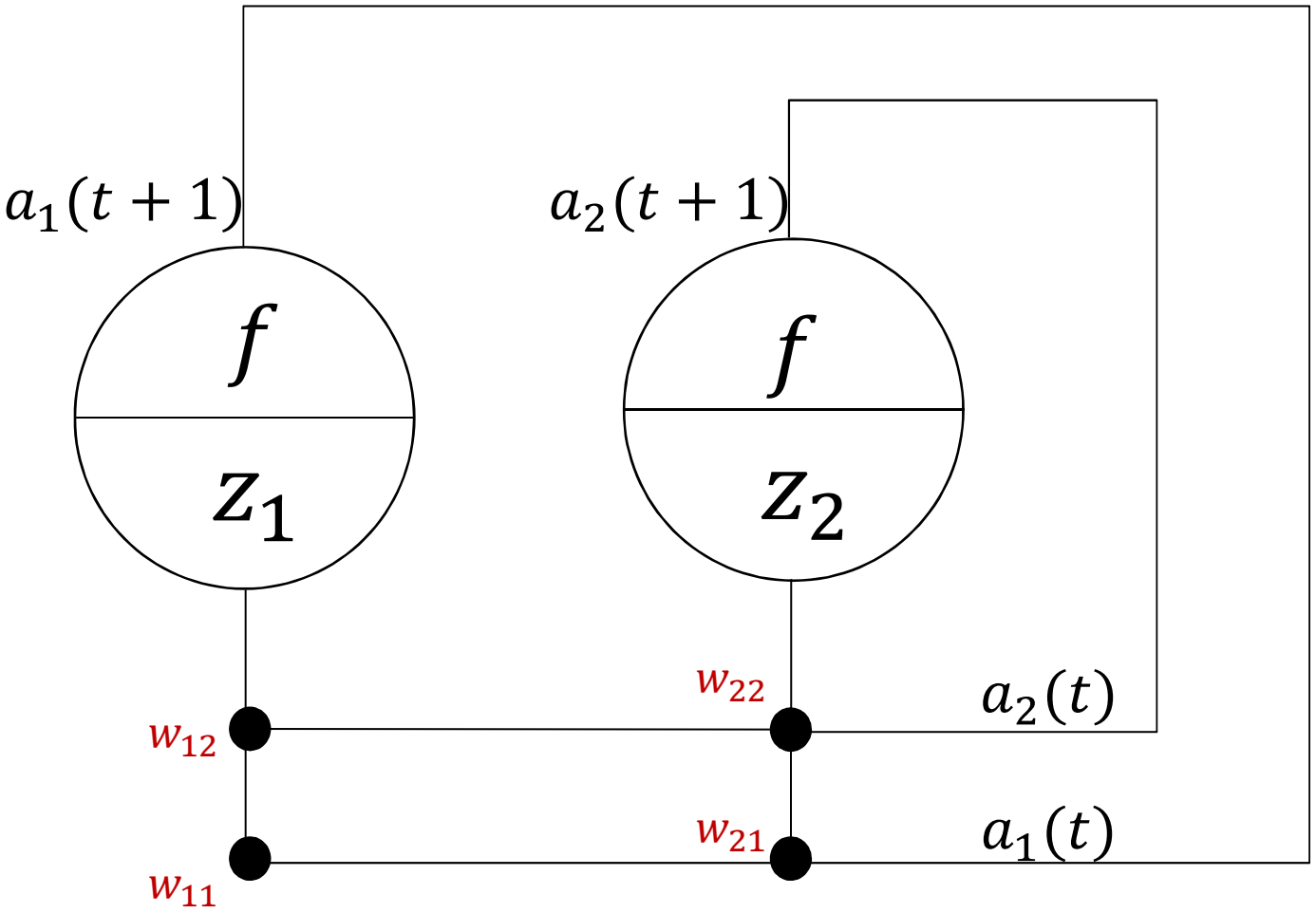
Recurrent Neural Networks



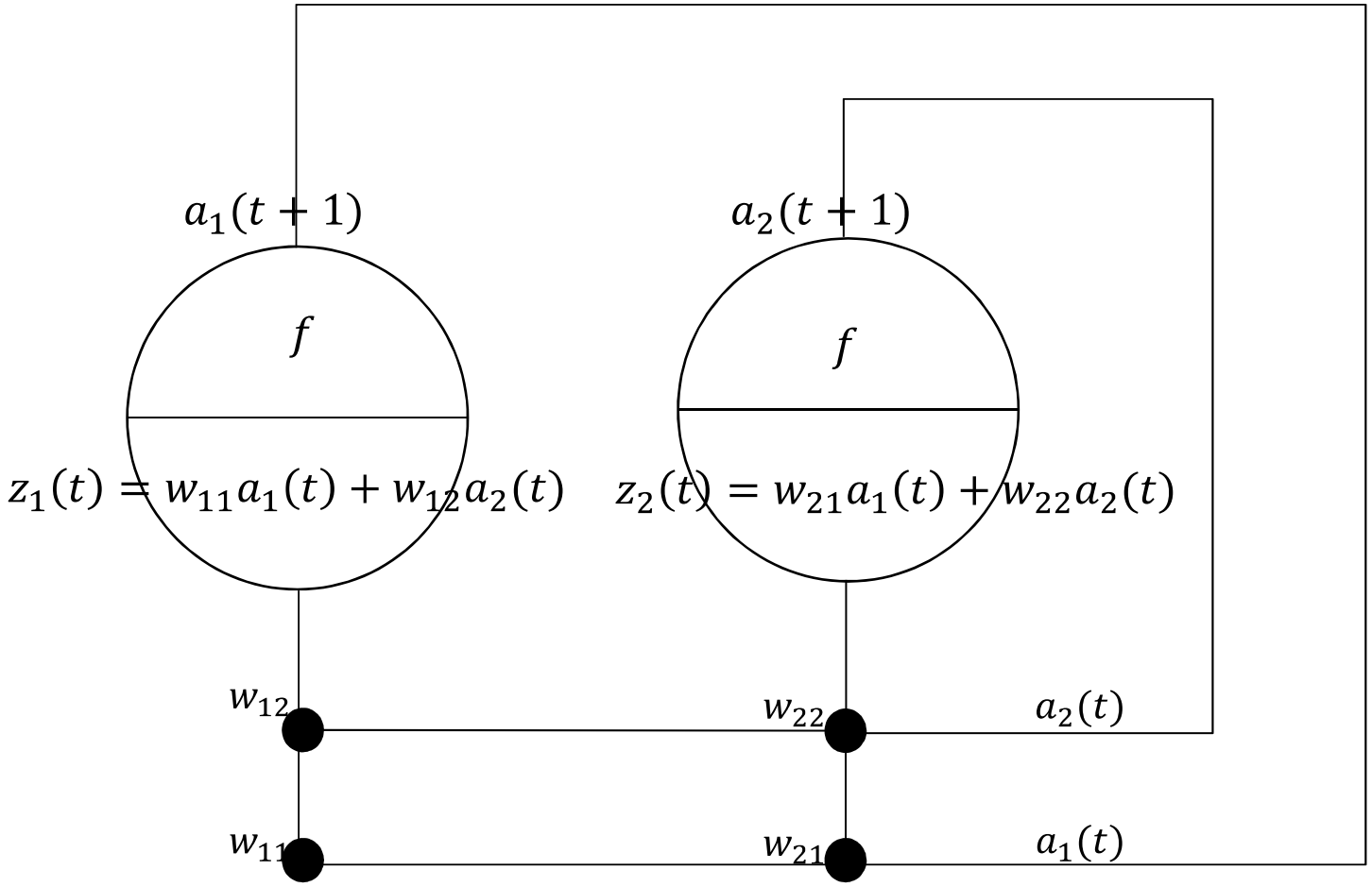
Recurrent Neural Networks



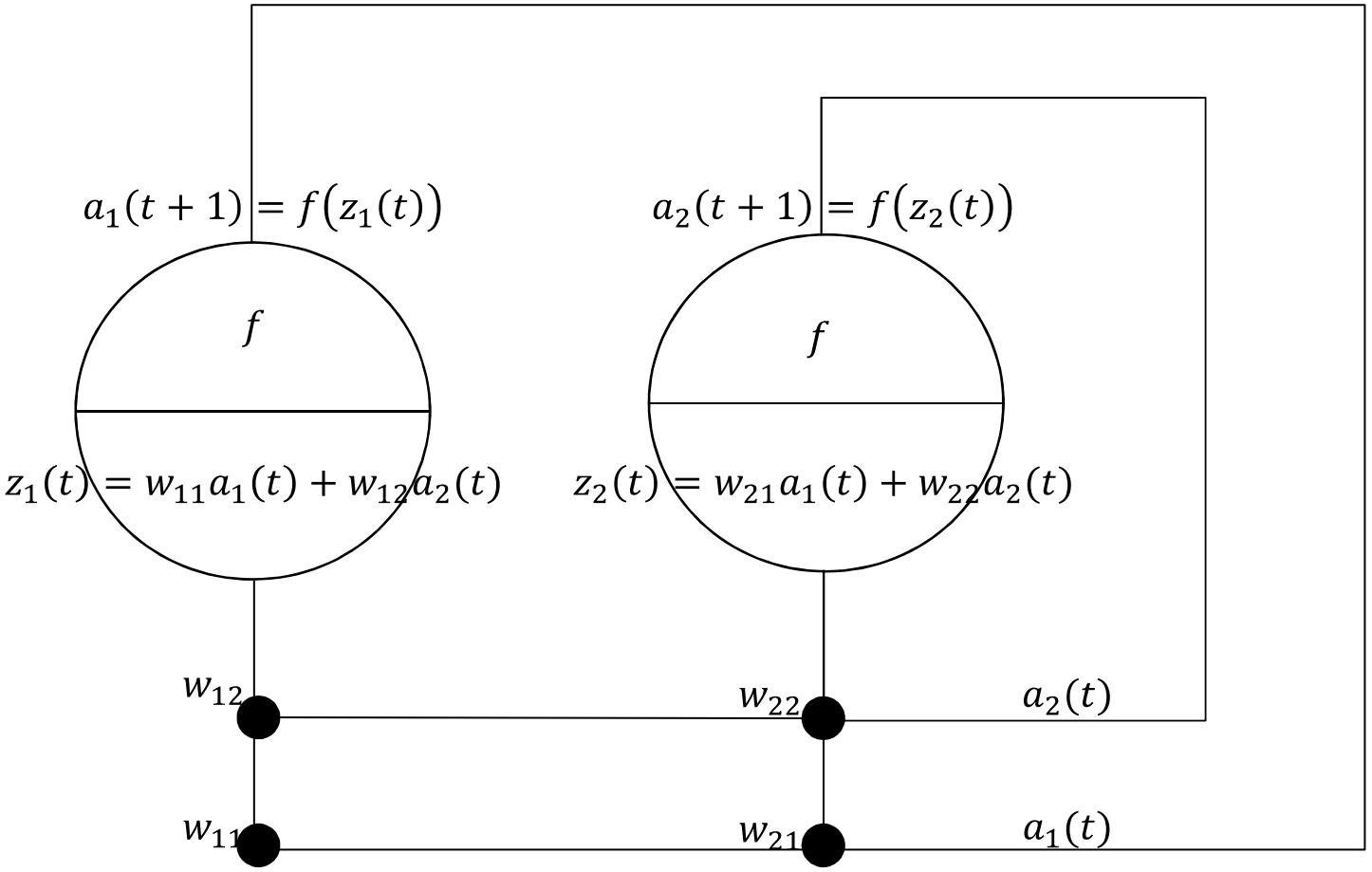
Recurrent Neural Networks



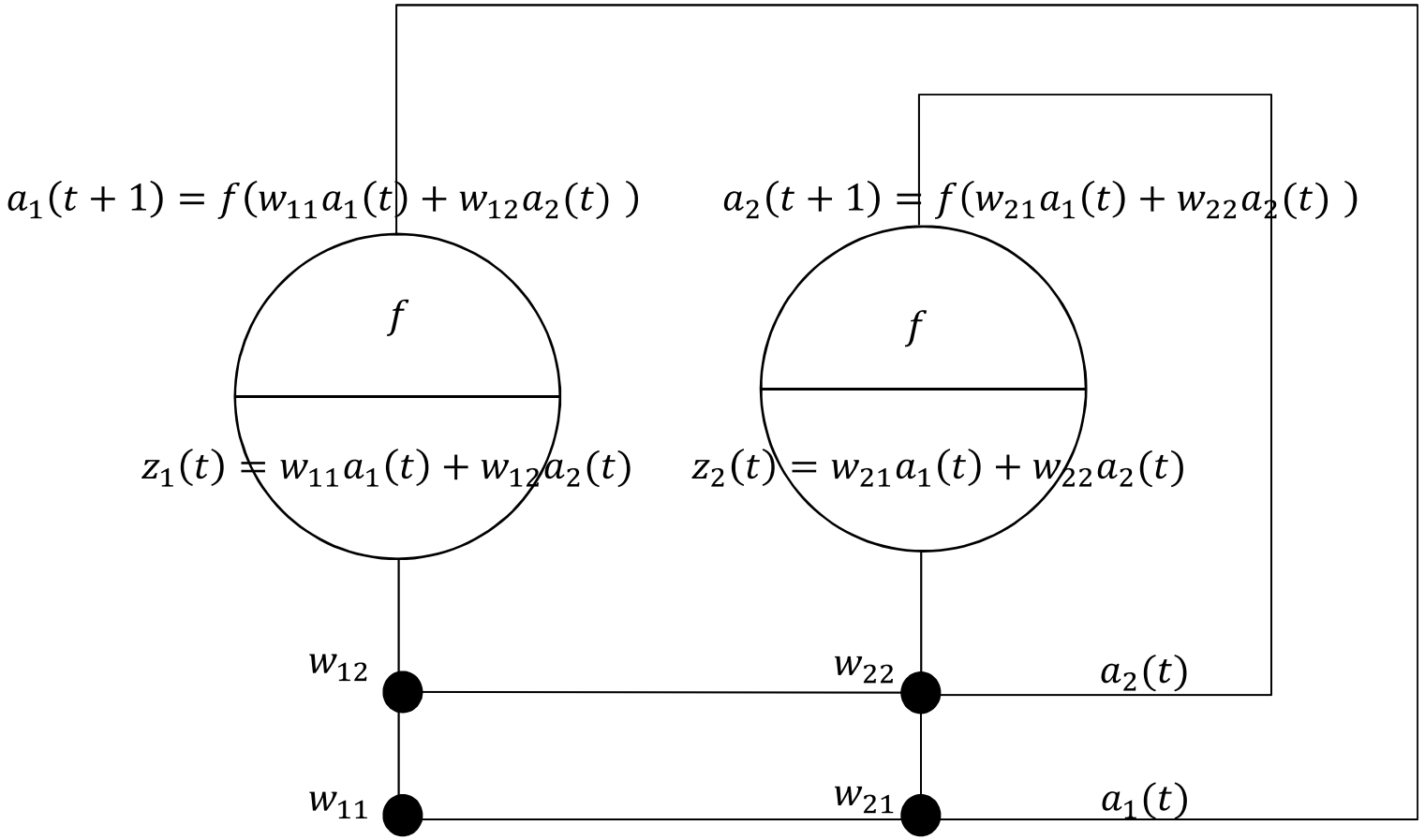
Recurrent Neural Networks



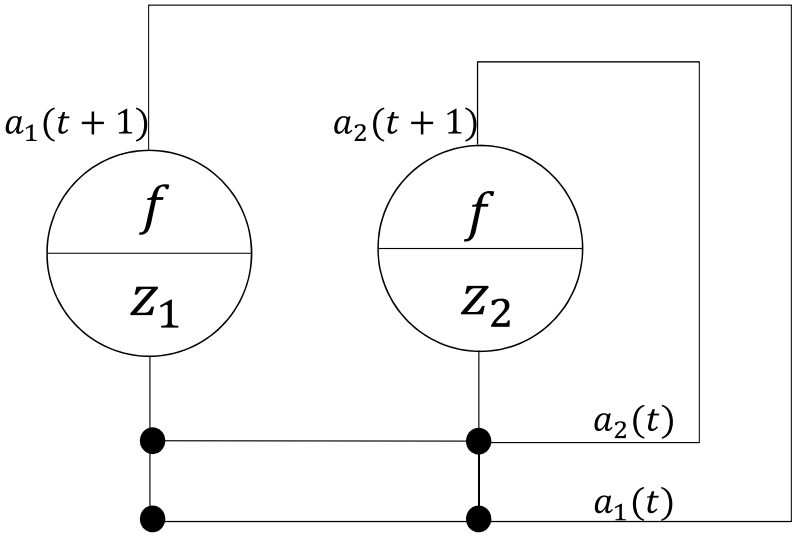
Recurrent Neural Networks



Recurrent Neural Networks



Recurrent Neural Networks



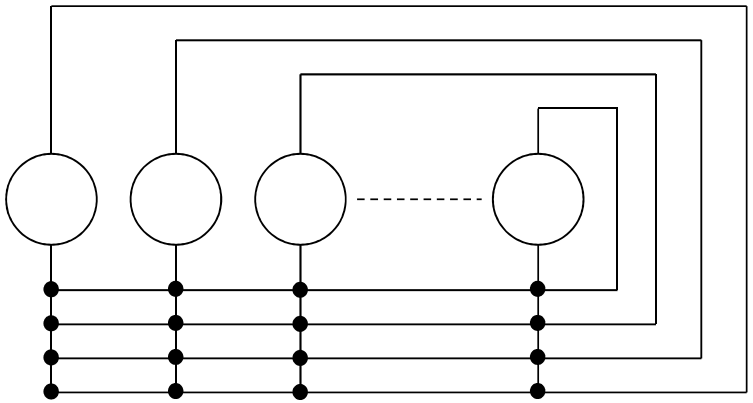
RNNs – Computational Neural Networks Model:

$$\begin{cases} a_1(t+1) = f\left(w_{11}a_1(t) + w_{12}a_2(t)\right) \\ a_2(t+1) = f\left(w_{21}a_1(t) + w_{22}a_2(t)\right) \end{cases}$$

Recurrent Neural Networks

Computational Model of RNNs:

$$a_i(t+1) = f\left(\sum_{j=1}^{n} w_{ij} a_j(t)\right)$$



Vector form:

$$a(t+1) = f(Wa(t))$$

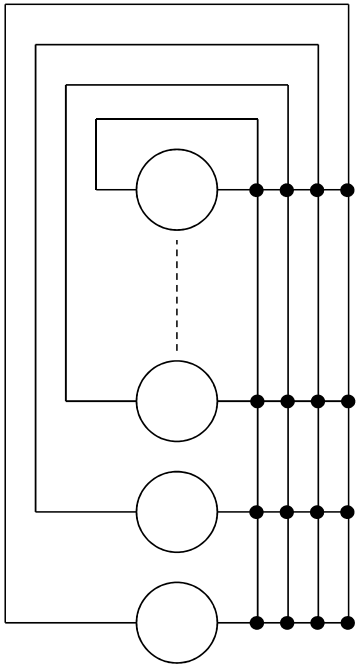
$$W = \begin{bmatrix} w_{11} & \cdots & w_{1n} \\ \vdots & \ddots & \vdots \\ w_{n1} & \cdots & w_{nn} \end{bmatrix}, a(t) = \begin{bmatrix} a_1(t) \\ \vdots \\ a_n(t) \end{bmatrix}$$

$t \rightarrow t+1$

The time changes in discrete manner.

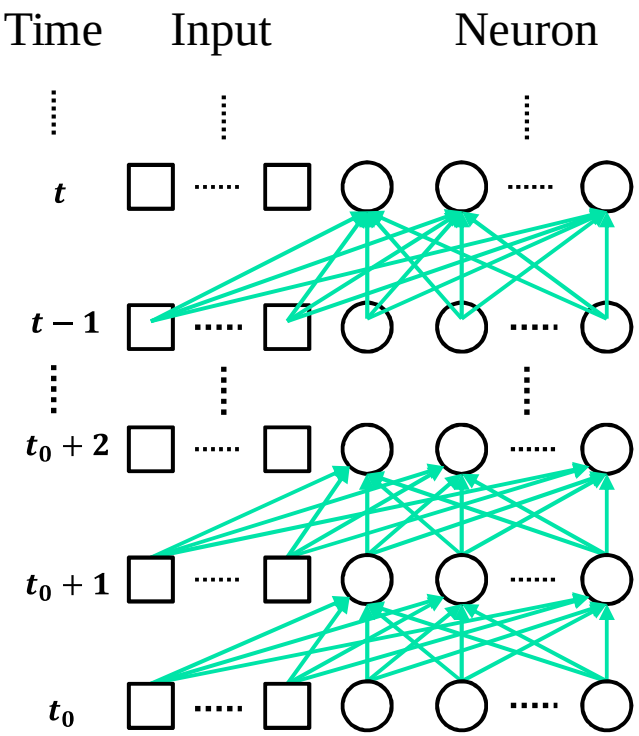
This model is a discrete time dynamic system.

Recurrent Neural Networks



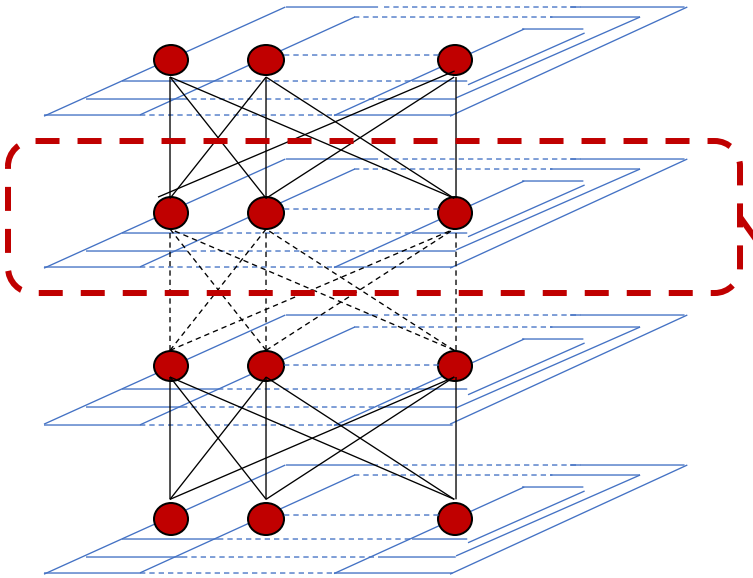
RNN could be expanded in time dimension.

With expanding in time, this networks could have infinite layers.



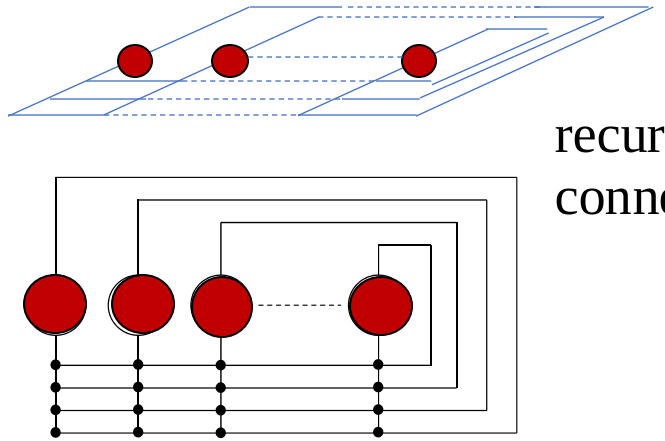
Recurrent Neural Networks

- Multiple recurrent layers connected by a forward connection
- The neurons within the recurrent layer are connected by recurrent connections



RNNs

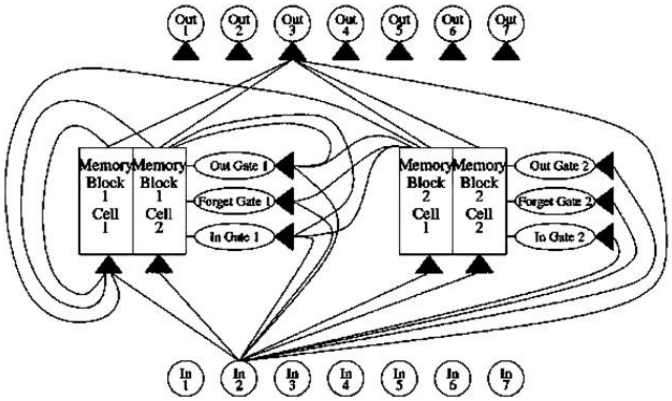
Through the recurrent connection, the RNN can maintain certain internal states and form memory.



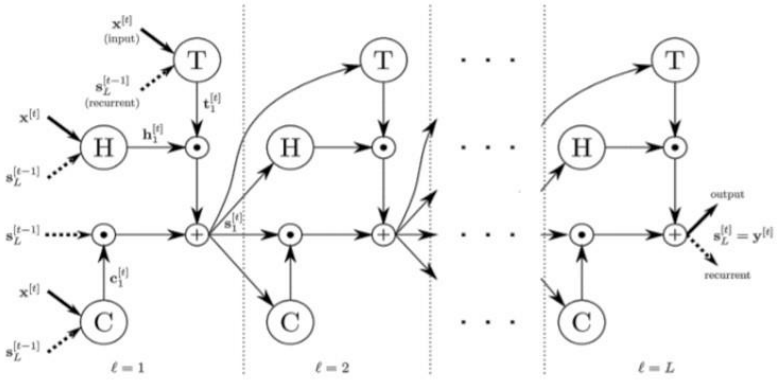
Recurrent Neural Networks

RNN

- The recurrent neural network is described by the dynamic system and is suitable for spatiotemporal correlation data analysis.
- Based on the topological structure of recurrent neural network, a variety of recurrent neural network models are developed.



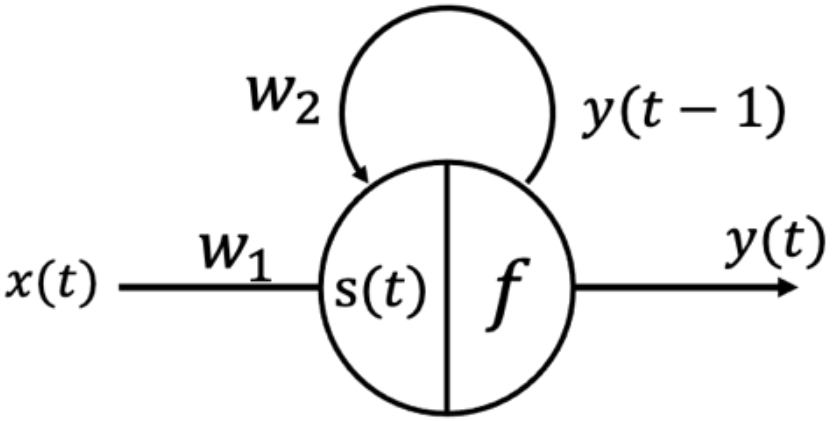
LSTM



Recurrent High-way

Have a try

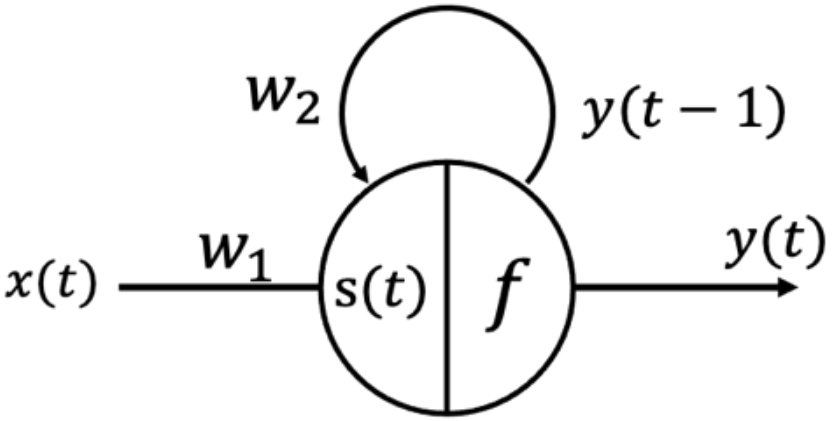
1. 给定以下回复式神经网络结构，其中包含两个权重 w_1和w_2，和激活函数$f(s) = s$:



(1) 确定该网络的前向计算。

Have a try

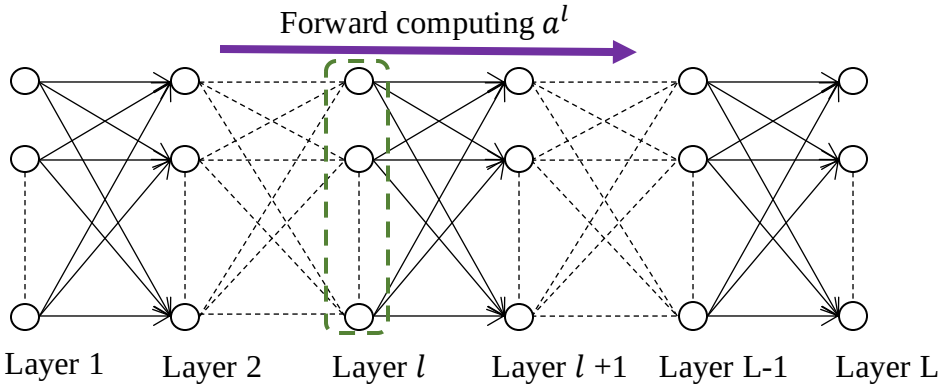
1. 给定以下回复式神经网络结构，其中包含两个权重 w_1和w_2，和激活函数$f(s) = s$:



(1) 确定该网络的前向计算。

$$y(t) = f(s(t)),$$
$$s(t) = x(t)w_1 + y(t-1)w_2$$

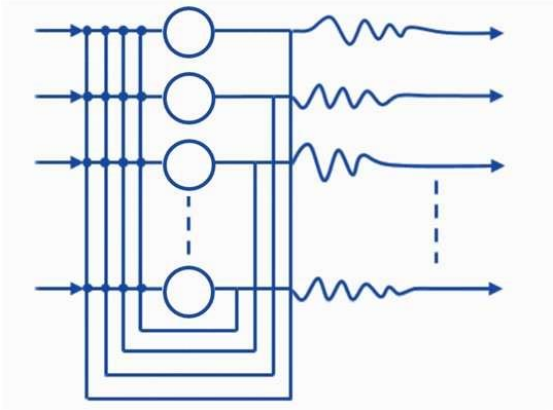
FNNs VS. RNNs



no recurrent connection

FNNs

- Extract the spatial features of static data
- Describe spatial correlation



with recurrent connection

RNNs

- Memory mechanism
- Extract spatiotemporal features of time sequence data
- Describe time correlation

Neural Networks

- Brief review
- Feedforward Neural Networks
- Recurrent Neural Networks
- *The Learning of Neural Networks*
- Model Performance: Cost Function
- Steepest Descent Method
- Backpropagation

The Learning of Neural Networks

- Knowledge is acquired by learning.
  - Three human learning models:

Learning with teacher

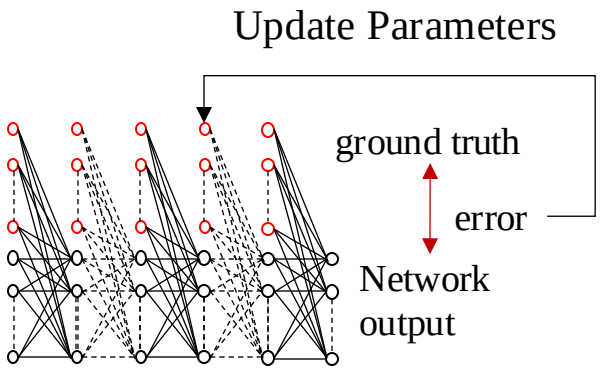
Reinforcement learning

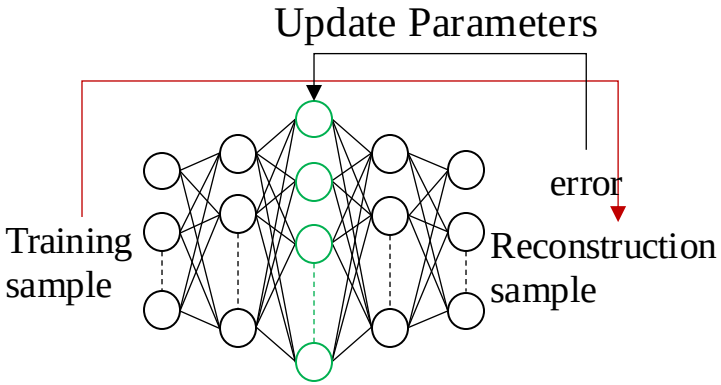
Learning without teacher

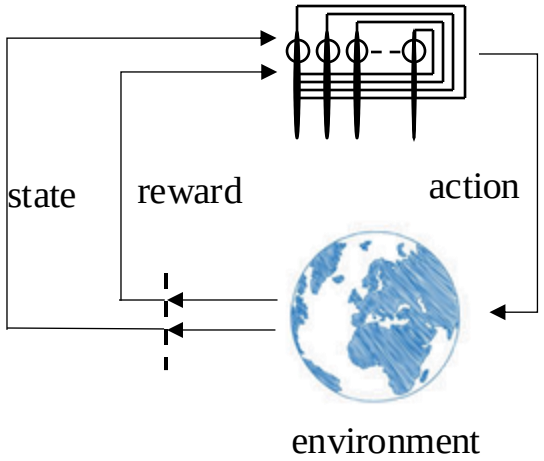
Learning: establishment of new connections and the modification of existing connections

The Learning of Neural Networks

- Learning is to change the connections by some rules.
- Similar with the three learning model of human:







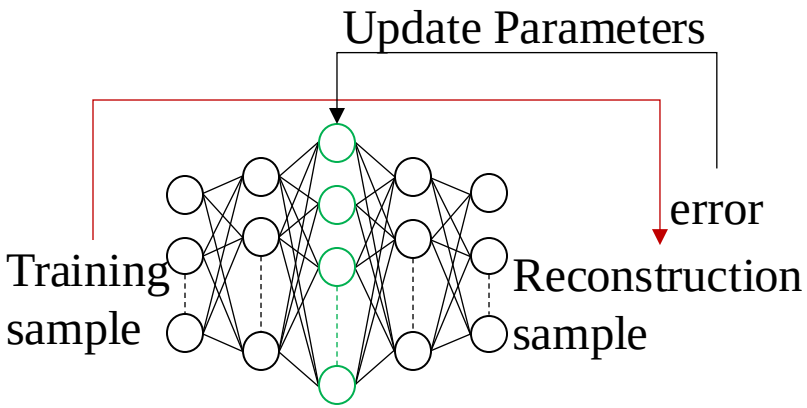
Supervised Learning: Update the network parameters according to the error between the target output and the actual network output of the training sample

Unsupervised learning: For non-label samples, the network parameters are updated by reconstructing these samples.

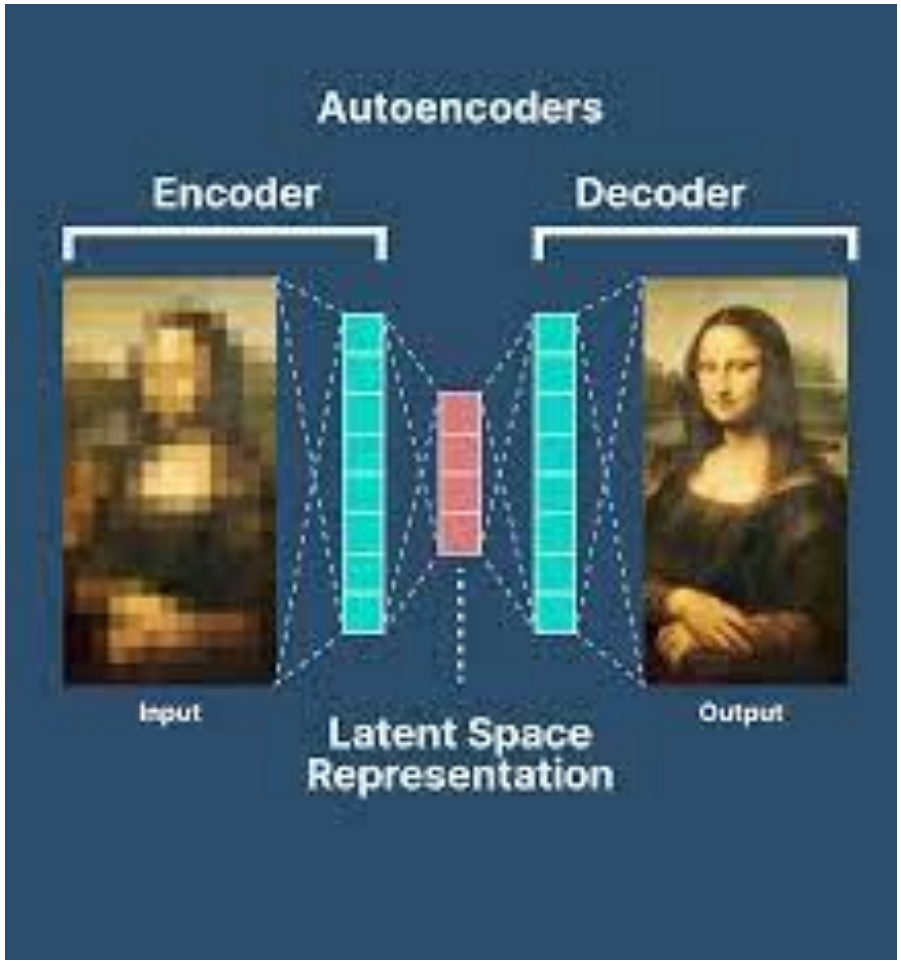
Reinforcement learning: Update network parameters with the goal of maximizing rewards during interactions with the environment

The Learning of Neural Networks

Unsupervised Learning



Unsupervised learning: For non-label samples, the network parameters are updated by reconstructing these samples.

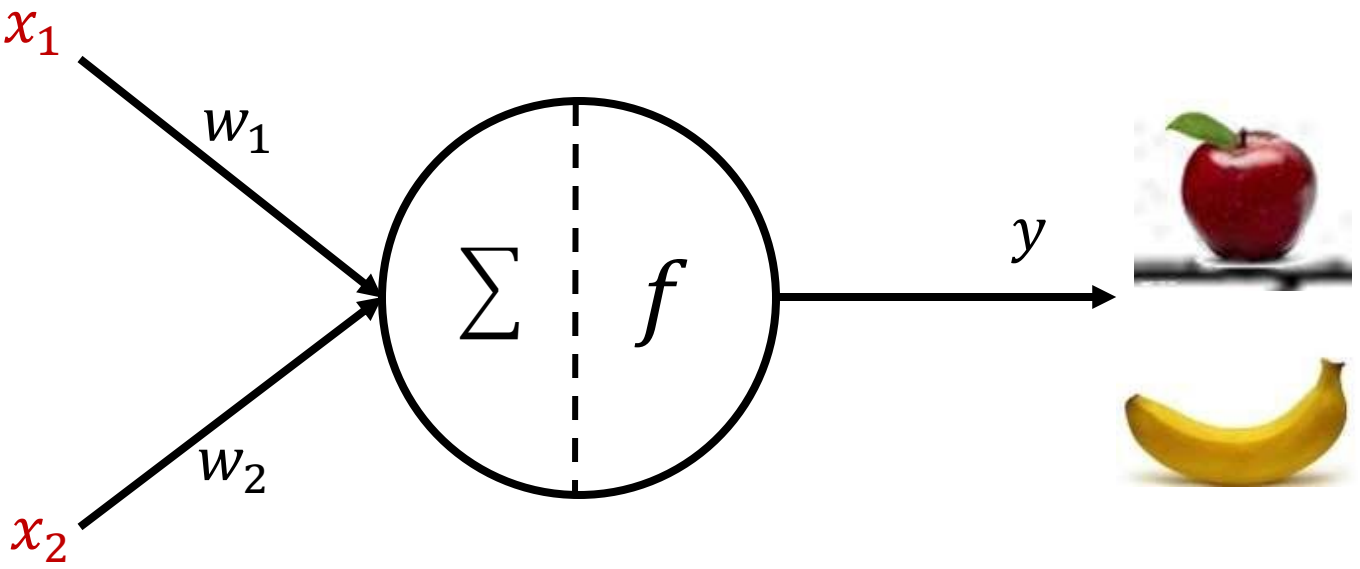


The Learning of Neural Networks

- Supervised Learning

Feature: red, round

Feature: yellow, strip



The Learning of Neural Networks

- Supervised Learning