CEU
Universidad
San Pablo

Course 4: Neural networks
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Module 2: Data analysis and modelling using Bayesian and neural networks

Advanced Data Analysis and Modelling Summerschool

Madrid
June 26th to July 27th 2006

Summary

- Introduction to Neural Networks
- The Neuron Model
- Perceptron
- Hebb Rule
- Widrow - Hoff Rule
- Backpropagation
- Developing a Neural Network
- Bibliography

Summary

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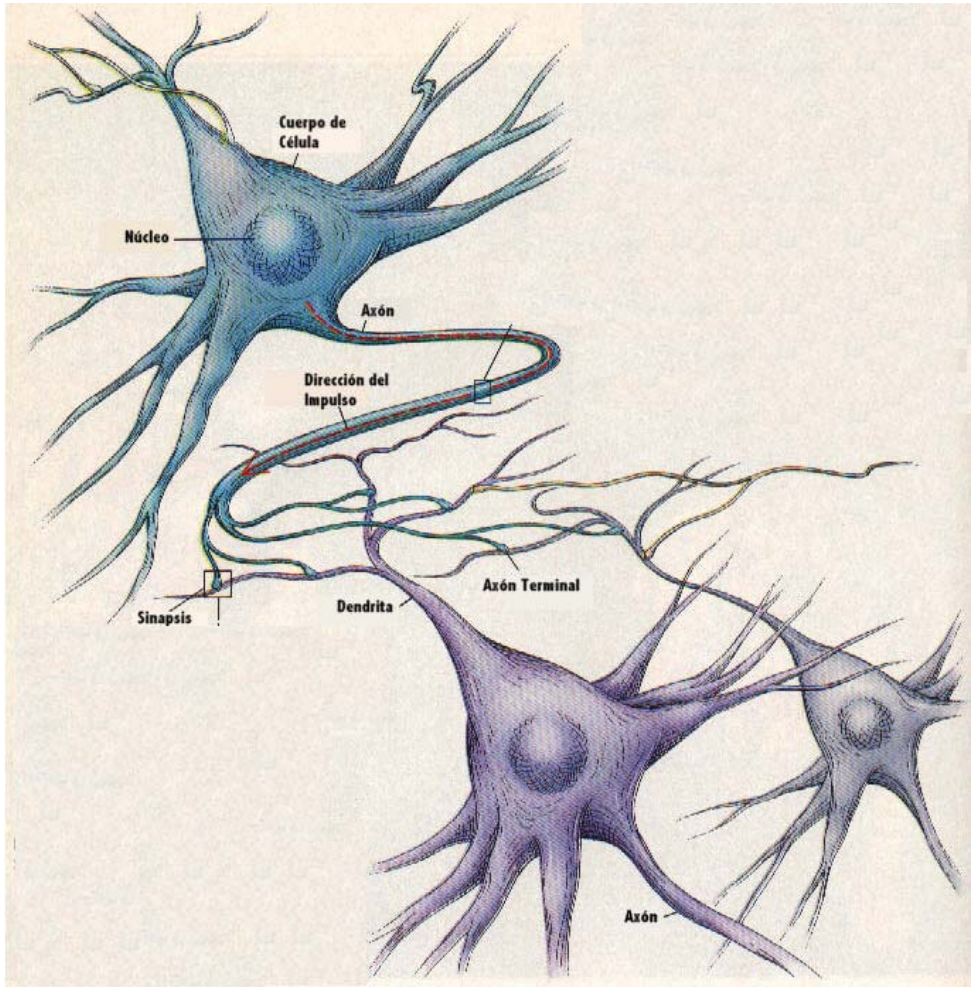
Introduction to Neural Networks: Elemental Neurophysiology

- Las neuronas se pueden considerar como pilas, ya que transmiten diferencias de potencial entre ellas.
- Las dendritas de cada neurona están conectadas a los núcleos de otras neuronas mediante la sinapsis.
- A cada neurona le llegan impulsos excitatorios o inhibitorios, que una vez sumados, son transmitidos a otras neuronas o a otros puntos del organismo.



Biological Neurons

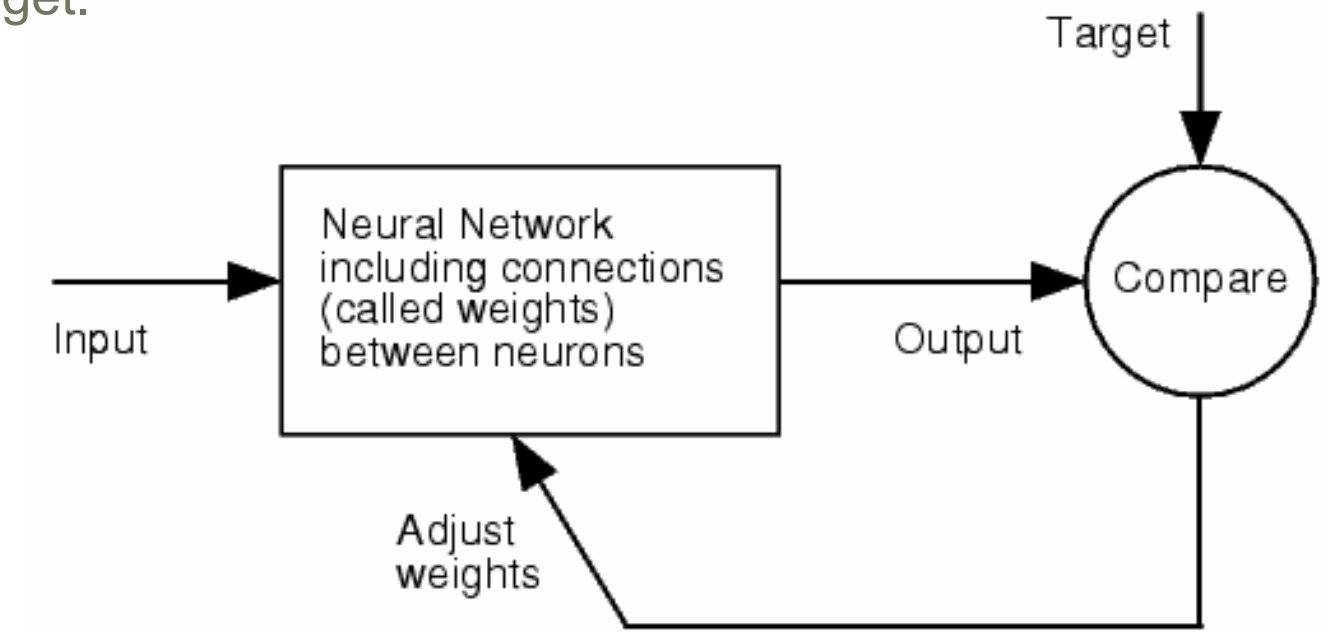
Introduction to Neural Networks

Definition

> Neural networks are composed of simple elements operating in parallel. These elements are inspired by biological nervous systems. As in nature, the network function is determined largely by the connections between elements.

Introduction to Neural Networks

Commonly neural networks are adjusted, or trained, so that a particular input leads to a specific target output. The network is adjusted, based on a comparison of the output and the target, until the network output matches the target.



Introduction to Neural Networks: Advantages

- **Aprendizaje adaptativo**: Capacidad de aprender a realizar tareas basadas en un entrenamiento o experiencia inicial.
- **Autoorganización**: Una red neuronal puede crear su propia organización o representación de la información que recibe mediante una etapa de aprendizaje.
- **Tolerancia a fallos**: La destrucción parcial de una red conduce a una degradación de su estructura; sin embargo algunas capacidades de la red se pueden retener incluso sufriendo algún daño.
- Operación en tiempo real: Los cálculos de una red neuronal pueden ser realizados en paralelo. Se diseñan y fabrican máquinas con hardware especial para obtener esta capacidad.
- Fácil inserción dentro de la tecnología existente: Se pueden obtener chips especializados para introducir la capacidad de las redes neuronales en ciertas tareas.

Introduction to Neural Networks: Comparison

	Brain	Computer
Process speed	$\approx 10^{-2}$ seg. (100 Hz)	$\approx 10^{-8}$ seg. (100 MHz)
Processing stile	parallel	sequential
Number of processors	10^{11}-10^{14}	a few
Connections	10000 by processors	a few
Knowledge	distributed	fixed directions
Failures tolerance	wide	null
Kind of process control	selforganized	centralized

Brain vs Computer

Introduction to Neural Networks: Business Applications

- Aerospace
- Automotive
- Banking
- Credit Card Activity Checking
- Defense
- Electronics
- Entertainment
- Financial
- Industrial
- Insurance
- Insurance
- Manufacturing
- Medical
- Oil and Gas
- Robotics
- Speech
- Securities
- Telecommunications
- Transportation

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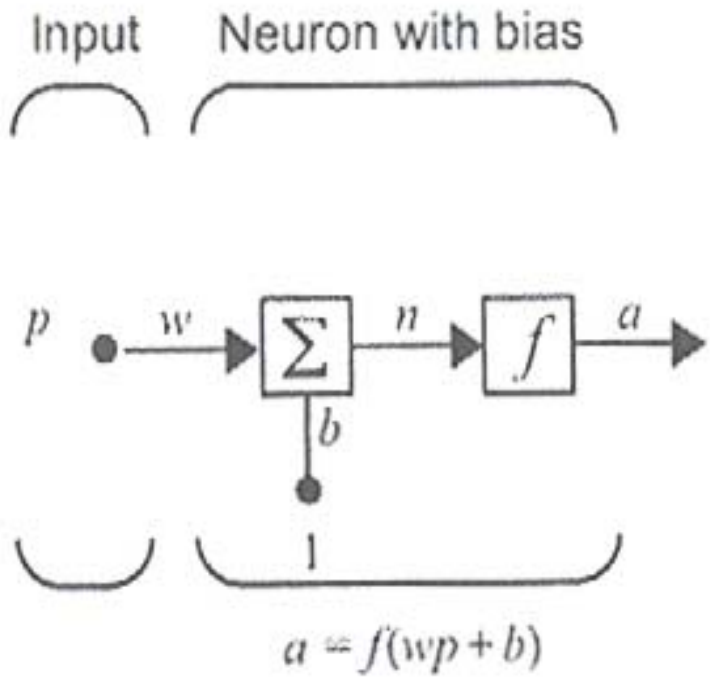
The Neuron Model: Single-Input Neuron

- p input (single or vector)
- w weight
- b bias
- n net input
- f transfer function
- a output (single or vector)



The Neuron Model: Transfer functions (I)

Name	Input/output Relation	Icon	Function
Hard Limit	$a = 0 \quad n < 0$ $a = 1 \quad n \geq 0$		hardlim
Symmetrical Hard Limit	$a = -1 \quad n < 0$ $a = +1 \quad n \geq 0$		hardlims
Linear	$a = n$		purelin
Saturating Linear	$a = 0 \quad n < 0$ $a = n \quad 0 \leq n \leq 1$ $a = 1 \quad n > 1$		satlin

The Neuron Model: Transfer functions (II)

Name	Input/output Relation	Icon	Function
Symmetric Saturating Linear	$a = -1 \quad n < -1$ $a = n \quad -1 \le n \le 1$ $a = 1 \quad n > 1$		satlins
Log-Sigmoid	$a = \frac{1}{1+e^{-n}}$		logsig
Hyperbolic Tangent Sigmoid	$a = \frac{e^{n}-e^{-n}}{e^{n}+e^{-n}}$		tansig
Positive Linear	$a = 0 \quad n < 0$ $a = n \quad 0 \le n$		poslin
Competitive	$a = 1$ neuron with max n $a = 0$ all other neurons		compet

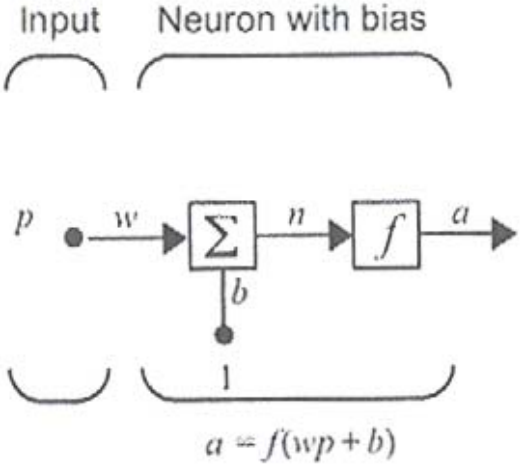
The Neuron Model: Example

w = 2.3 (weight)

p = 2 (input)

b = -3 (bias)

net input : n = wp + b = 1.6



¿Which is output with the following transfer functions?

a) HARD LIMIT Function

a = Hardlim(1.6) = 1.0

b) LINEAR Function

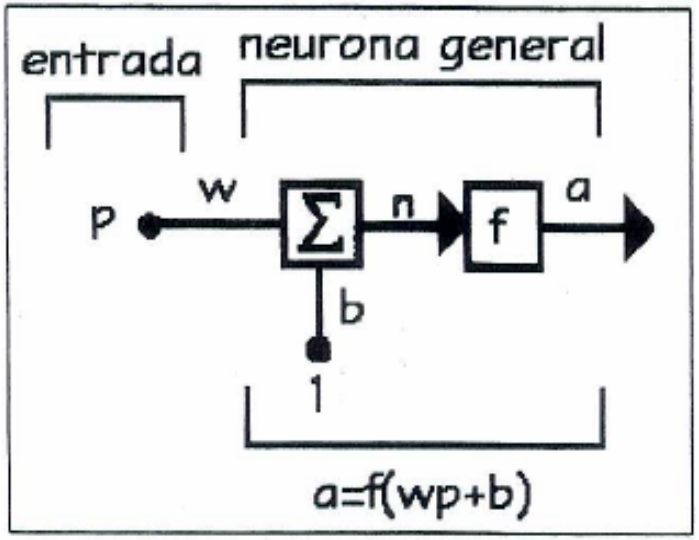
a = Linear (1.6) = 1.6

c) LOG-SIGMOIDEA Function

a = Sigmoid (1.6) = $1/(1+e^{-1.6}) = 0.832$

The Neuron Model:

f: función de transferencia



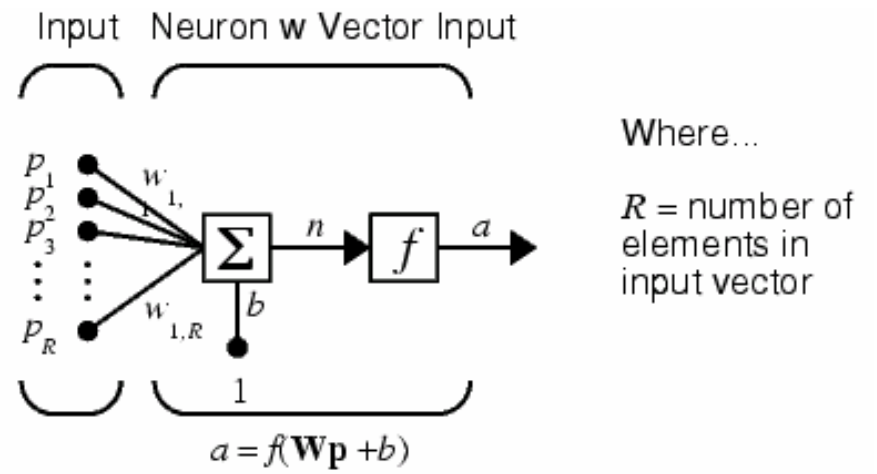
F.T. SIGMOIDAL:

$$a = \frac{1}{1+e^{n}}$$

F.T LINEAL:

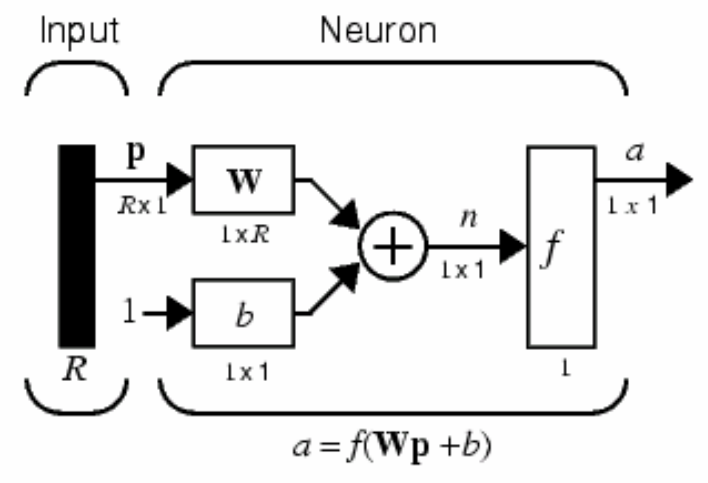
$$a = n$$

The Neuron Model: Triple- Input Neuron



Where...

R = number of elements in input vector



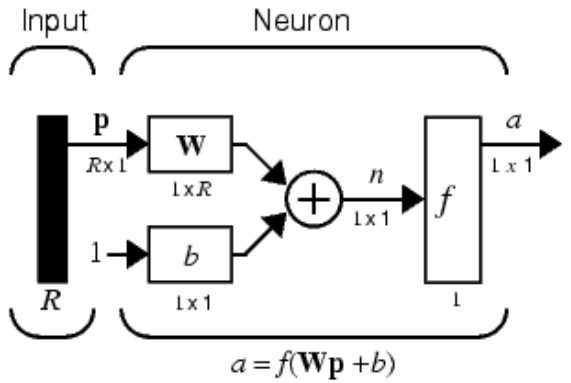
The Neuron Model: Example

Dada una neurona de dos entradas , definida con los siguientes parámetros:

b = 1.2, w = [3 2] y p = [-5 6]^T, calcular su salida para diferentes funciones de transferencia.

Entrada neta:

$$Wp + b = [3,2]\begin{bmatrix} -5 \\ 6 \end{bmatrix} + 1.2 = -1.8$$



a) SIMMETRICAL HARD LIMIT Function

a = f (-1.8) = -1

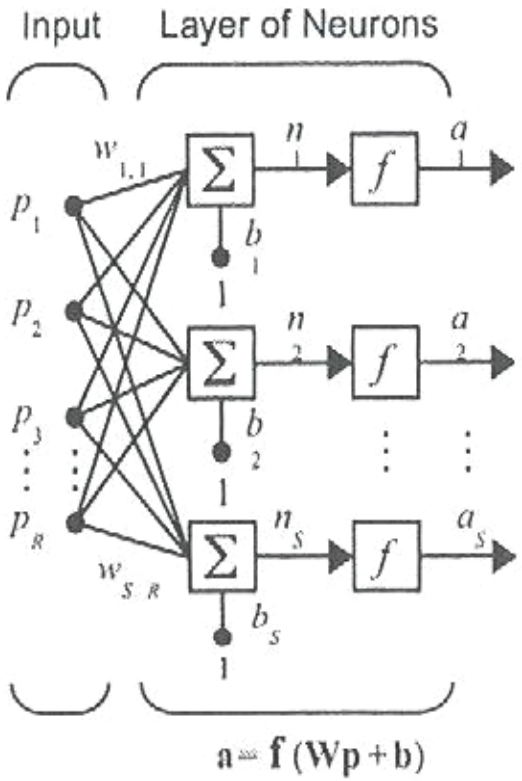
b) SATURATING LINEAR Function

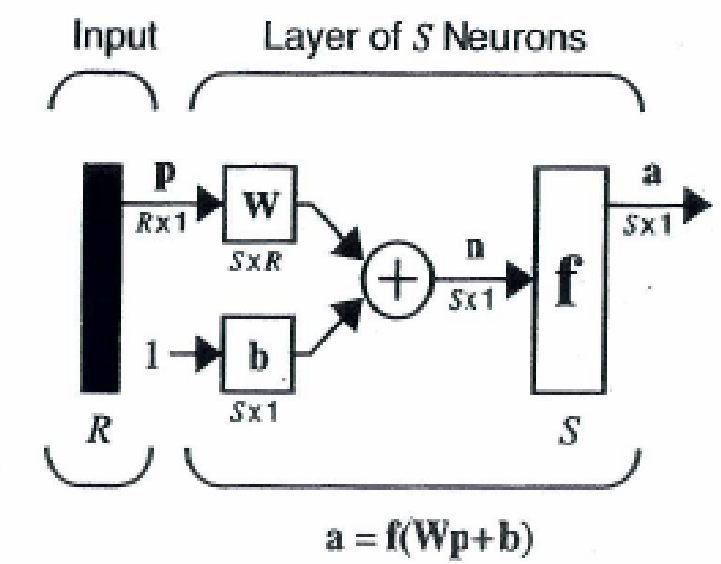
a = f (-1.8) = 0

c) TANG-SIGMOIDEA Function

a = f (-1.8) = ($e^{-1.8}$ – $e^{1.8}$) / ($e^{-1.8}$ + $e^{1.8}$) = -0.9468

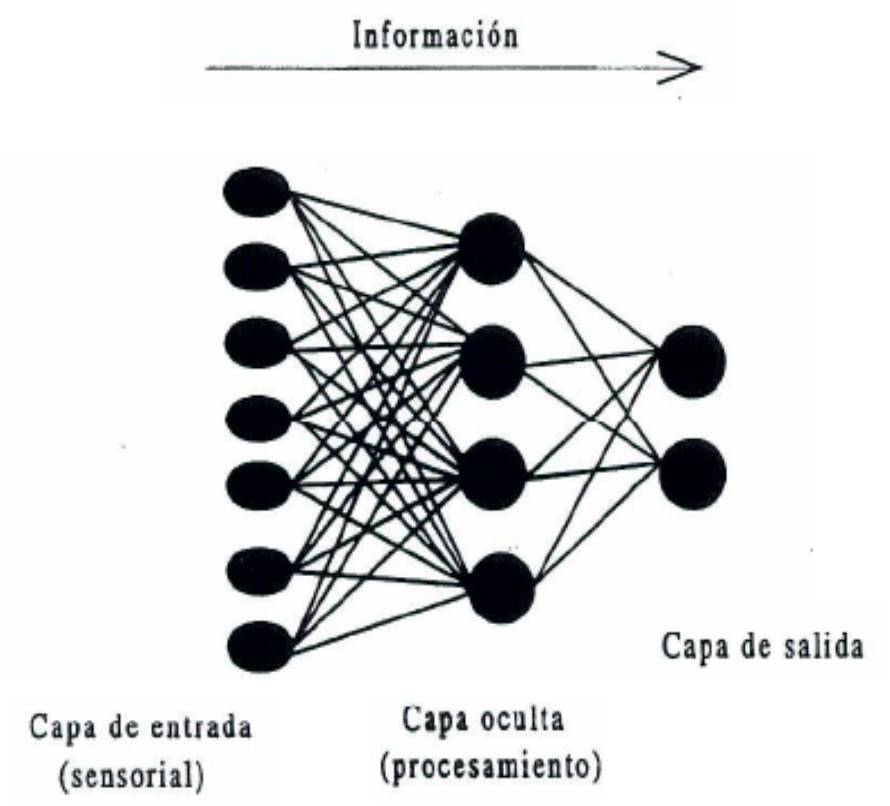
The Neuron Model: One Layer of Neurons





R+1 unknowns : $w^1_{1,1}$;…;$w^1_{1,R}$; b^1

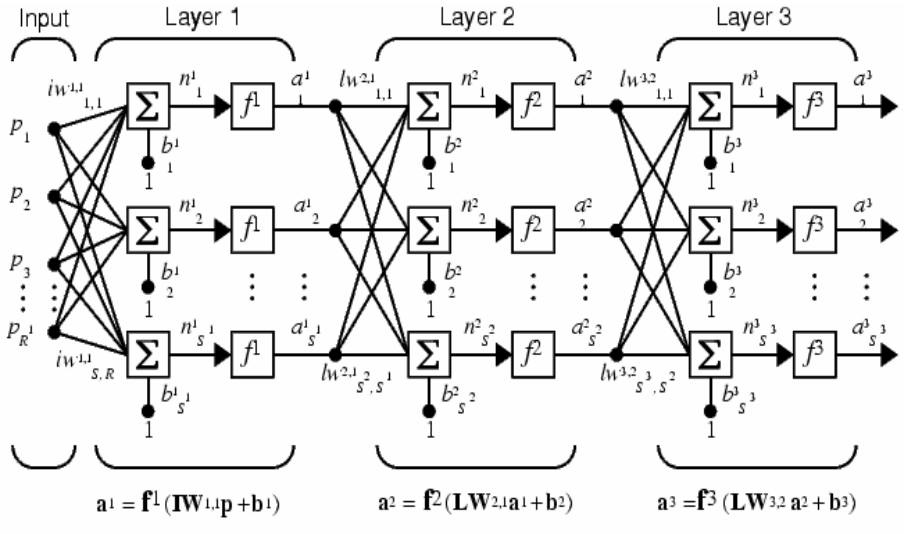
The Neuron Model: Multy- Layer of Neurons



Unidirectional structure in three layers:

- Input
- Hidden
- Output

The Neuron Model: Three-Layers of Neurons



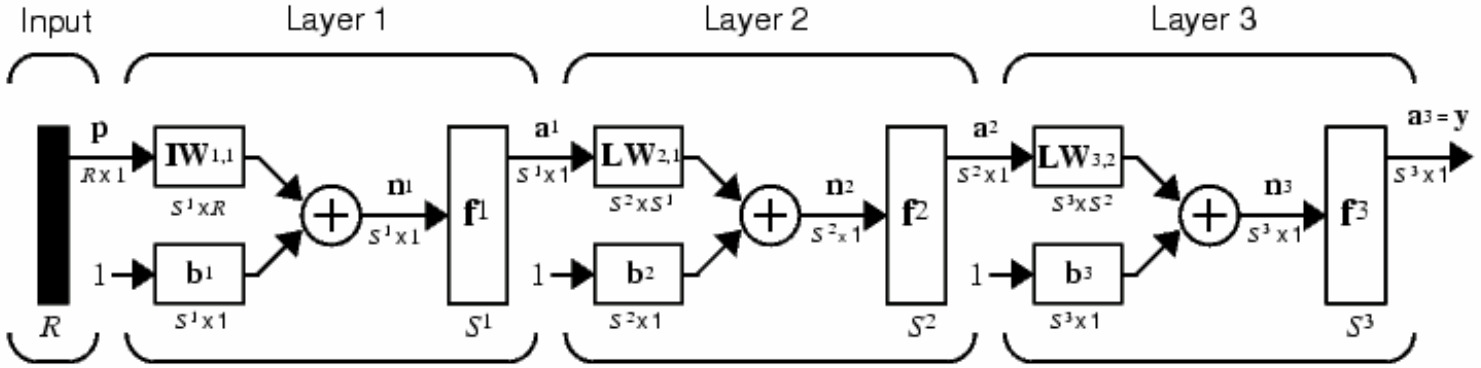
$R\text{-}S^1\text{-}S^2\text{-}S^3$

R inputs

S^3 outputs

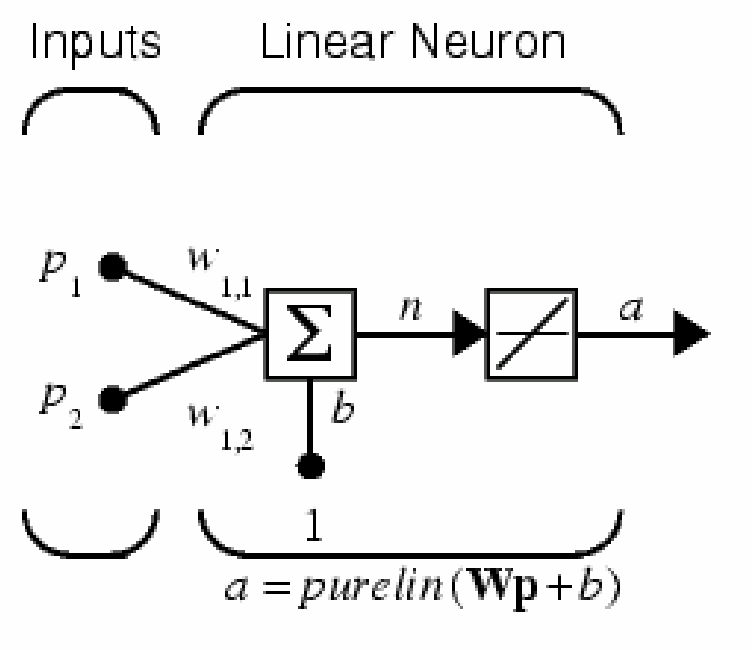
3 layers

- 2 hidden layer
  - S^1- neurons in the 1st
  - S^2- neurons in the 2nd
- 1 output layer with S^3 neurons in it

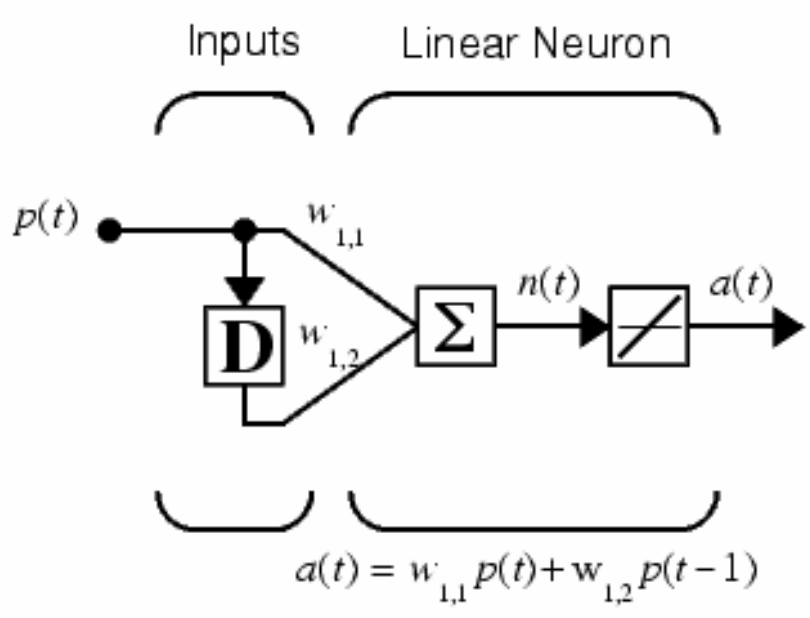


$$a^3 = f^3(LW^{3,2}f^2(LW^{2,1}f^1(IW^{1,1}p + b^1) + b^2) + b^3 = y$$

The Neuron Model: Data Structures



Linear Neuron With
Two-Element Vector Input



Dynamic Network With
One Delay