Lec3: Neuron Model

Outline:

1. **Single Input Neuron**
2. **Transfer Functions (Activation Function)**
3. **Activation Function Properties and Conditions**
4. **Tutorial Examples**

1. Single Input Neuron

A single-input neuron is shown in **Figure** 1. The scalar input p is multiplied by the scalar weight w to form $\mathbf{wp}$, one of the terms that is sent to the summer. The summer output n, often referred to as the net input, goes into a transfer function **f**, which produces the scalar neuron output **a**. The actual output depends on the particular transfer function that is chosen

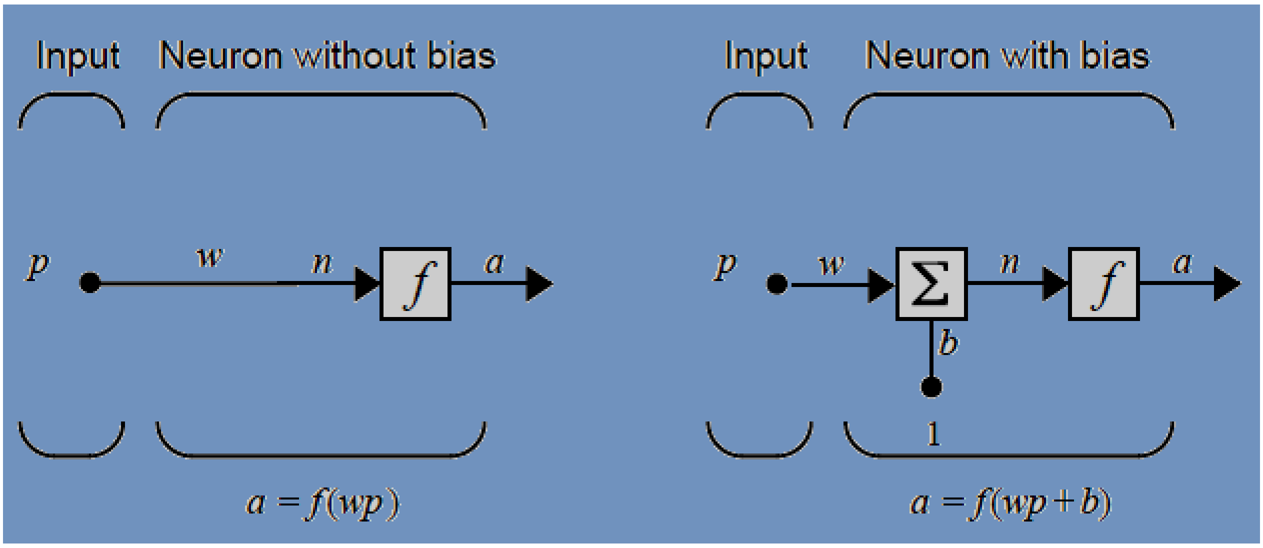


Figure 1: Single-Input Neuron

Notes

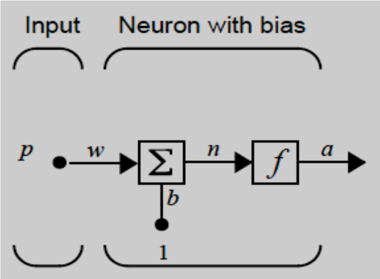
A. Some authors use the term "**Activation Function**" rather than transfer function and "**Offset**" rather than bias.

B. According to the simple model back to the biological neuron that the **weight w** corresponds to the **strength of a synapse**, the **cell body** is represented by the **summation** and the **transfer function** and **the neuron output** a represents the **signal on the axon**

Example: For the Fig below**,** calculated the neuron output, If, for instance, $w = 3, p = 2$ and $b = -1.5$

Solution: The neuron output **is determined as:**

$a = f(wp + b) = a = f(3(2) - 1.5) = f(4.5)$



Note : w and b are both adjustable scalar parameters of the neuron.Typically the transfer function is chosen by the designer and then the parameters w and b will be adjusted by some learning rule so that the neuron input/output relationship meets some specific goal **.**

2. Transfer Functions (Activation Function)

The transfer function may be a linear or a nonlinear function of n. A particular transfer function is chosen to satisfy some specification of the problem that the neuron is attempting to solve. A variety of transfer functions have been included.

3. Activation Function Properties and Conditions

3.1 Hard-limit

The **hard-limit transfer function (as in Fig2**) limits the output of the neuron to either 0, if the net input argument n is less than 0; or 1, if n is greater than or equal to 0. This function used to **create neurons that make classification decisions**. The graph below illustrates the input /output characteristic of **a single-input neuron** that uses a hard limit transfer function. Here we can see the effect of the weight and the bias

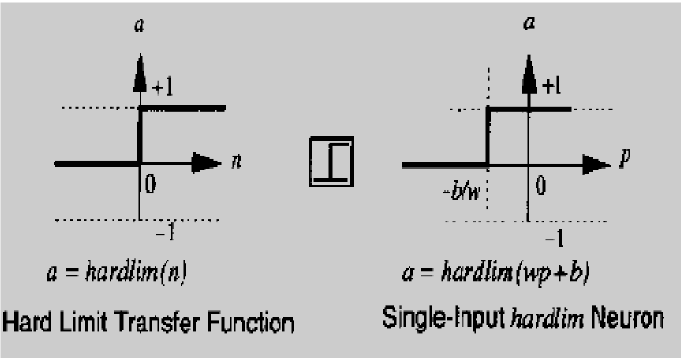


Figure2: Hard-Limit Transfer Function

3.2 Linear

The output of a **linear transfer function (as in Fig3)** is equal to its input, **a = n**,. Neurons with this transfer function are used in the ADALINE networks

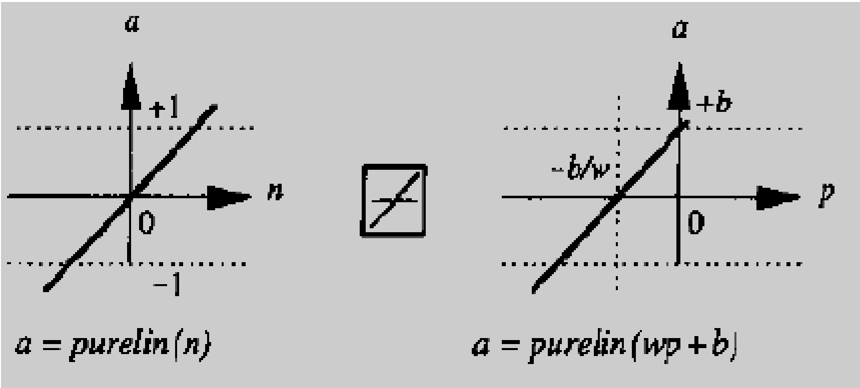


Figure3: Linear Transfer Function

3.3 log-sigmoid

The log-sigmoid transfer function is shown in Figure 4, this transfer function takes the input (which may have any value between plus and minus infinity) and squashes the output into the range 0 to 1, according to the expression

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

The log-sigmoid transfer function **is commonly used in multilayer networks that are trained using the back propagation algorithm**, in part because this function is differentiable

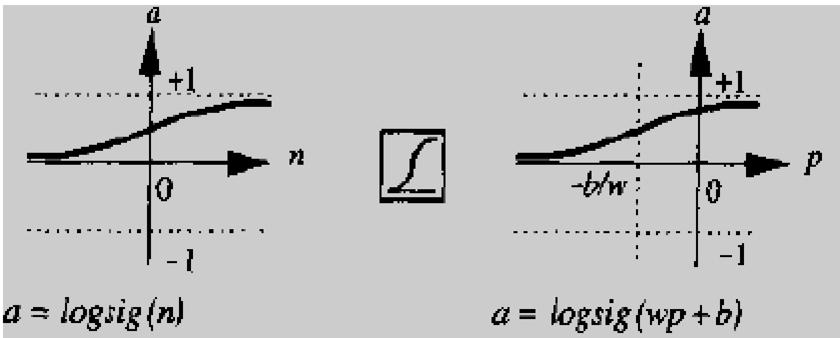
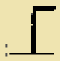
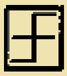
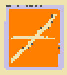
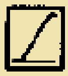
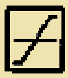
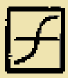
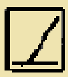


Figure4:: Log-Sigmoid Transfer Function

Most of the transfer functions used are summarized in **Table 2.1**

Name	Input/Output Relation	Icon	MATLAB 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
Symmetric Saturating Linear	$a = -1 \quad n < -1$ $a = n \quad -1 \leq n \leq 1$ $a = 1 \quad n > 1$		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	$a = 0 \quad n < 0$ $a = n \quad 0 \leq n$		poslin
Competitive	$a = 1$ neuron with max n $a = 0$ all other neurons	C	compet

4. Tutorial Examples

Ex1: the input to a single-input neuron is 2.0, its weight is 2.3 and its bias is -3.

i. What is the net input to the transfer function?
ii. What is the neuron output?

Solution:

i. The net input is given by:

$$n = wp + b = (2.3)(2) + (-3) = 1.6$$

ii. The output cannot be determined because the transfer function is not specified.

Ex2: The input to a single-input neuron is 2.5, its weight is 2 and its bias is -3.5, what is the **output of the neuron** if the output has the following transfer functions?

i. Hard Limit
ii. Linear
iii. Log-Sigmoid

Solution:

The net input is given by:

$$n = wp + b = (2.5)(2) + (-3.5) = 1.5$$

i. For the hard limit transfer function: $a = hardlim(1.5) = 1.0$
ii. For the linear transfer function: a = pure/in (1.5) = 1.5
iii. For the log-sigmoid transfer function:

a = Logsig (1.5) , $a = \frac{1}{1+e^{-n}} =$, $a = \frac{1}{1+e^{-1.5}}$

a= 0.817

Ex3: Given a two-input neuron with the following parameters: $b = 1.2$, $W = [3\ 2]$ and $p = [-5\ 6]^r$, calculate the neuron output for the following transfer functions:

i. A symmetrical hard limit transfer function

ii. A saturating linear transfer function

iii. A hyperbolic tangent sigmoid (tansig) transfer function

Solution:

First calculate the net input n :

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

Now find the outputs for each of the transfer function

i. a= hardlims(-1.8)= -1

ii. a =satlin (-1.8) = 0

iii. a= tansig(-1.8) = -0.9468