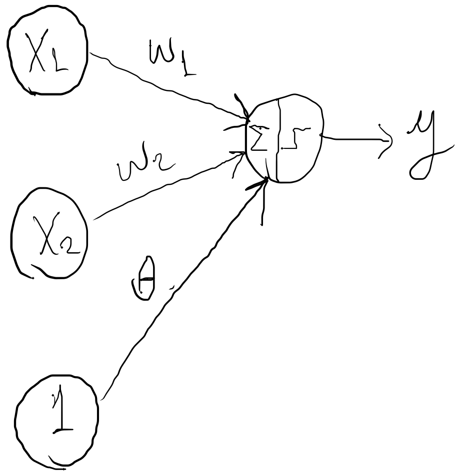
XOR

x_1	x_2	x_1 XOR x_2
1	1	-1
1	-1	1
-1	1	1
-1	-1	-1

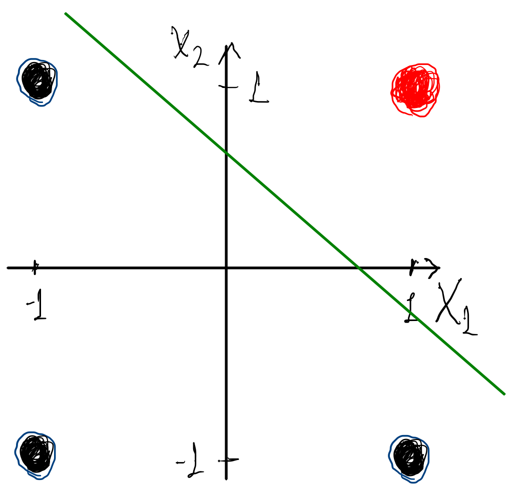
$V \Rightarrow 1$

$F \Rightarrow -1$



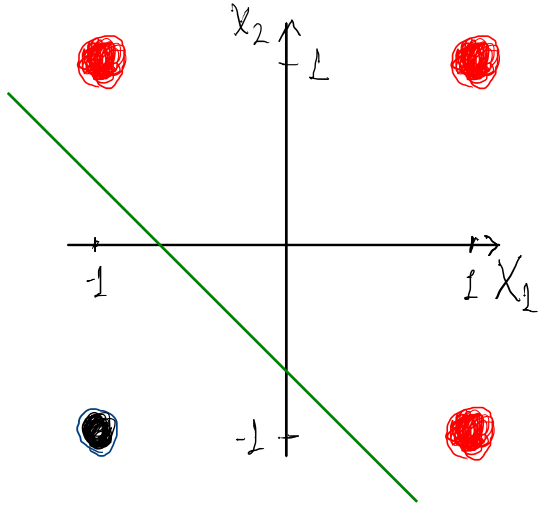
Se usa la función signo

AND



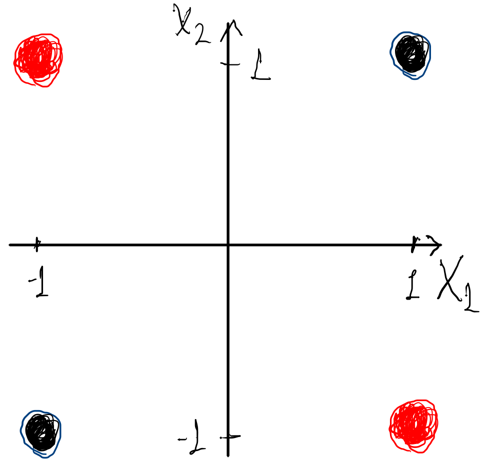
LINEALMENTE SEPARABLE

OR



LINEALMENTE SEPARABLE

XOR



NO ES LINEALMENTE SEPARABLE

Perceptron Simple no puede resolver XOR

Modelo de Red Neuronal "Perceptrón Multicapa"

* Realmente usa Backpropagation (Retropropagación)

XOR

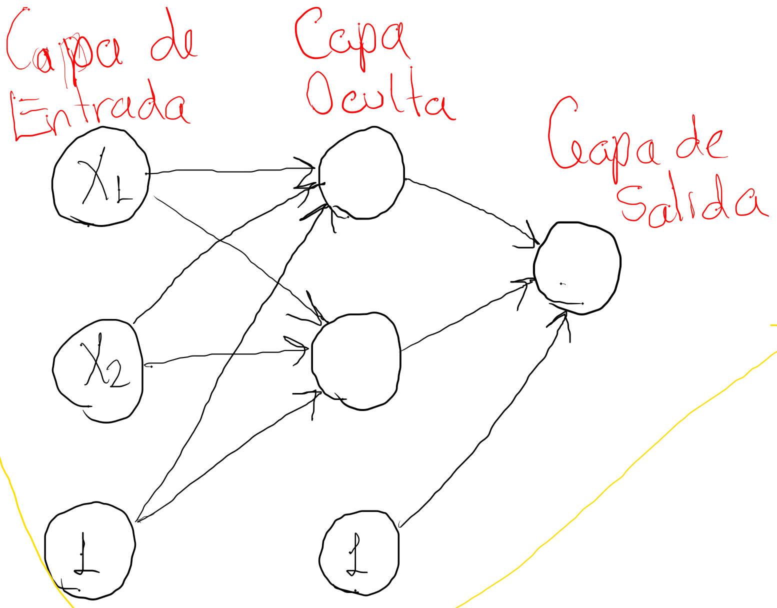
V ⇒ 1 F ⇒ -1

X_1	X_2	X_1 XOR X_2
1	1	-1
1	-1	1
-1	1	1
-1	-1	-1

XOR

V ⇒ 1 F ⇒ 0

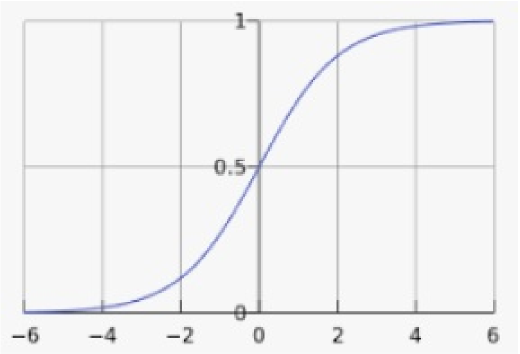
X_1	X_2	X_1 XOR X_2
1	1	0
1	0	1
0	1	1
0	0	0



Función Sigmoide

$$f(x) = \frac{1}{1+e^{-x}}$$

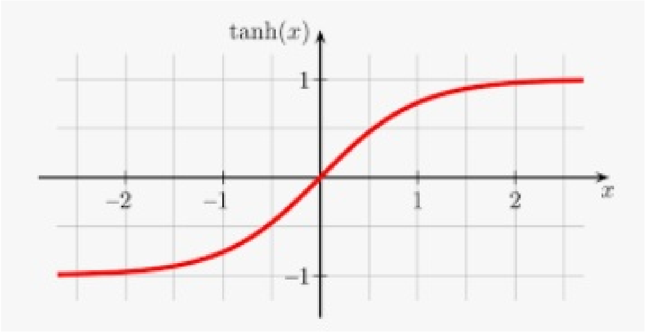
$$f'(x) = f(x)\,(1 - f(x))$$



Función Tangente Hiperbólica

$$f(x) = \frac{e^{x} - e^{-x}}{e^{x} + e^{-x}}$$

$$f'(x) = 1 - f^{2}(x)$$



Modelo de Red Neuronal "Perceptrón Multicapa"

* Realmente usa Backpropagation (Retropropagación)

XOR

V ⇒ 1   F ⇒ 0

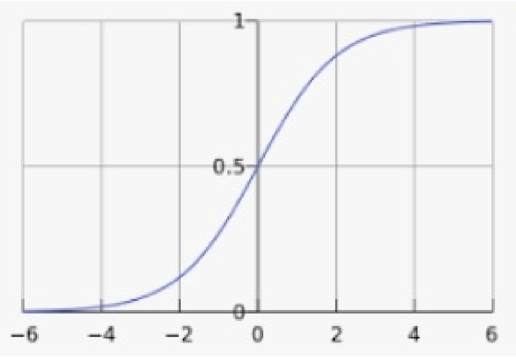
x_1	x_2	x_1 XOR x_2
1	1	0
1	0	1
0	1	1
0	0	0

```
x1 = [1,1,0,0]
x2 = [1,0,1,0]
z  = [0,1,1,0]
```

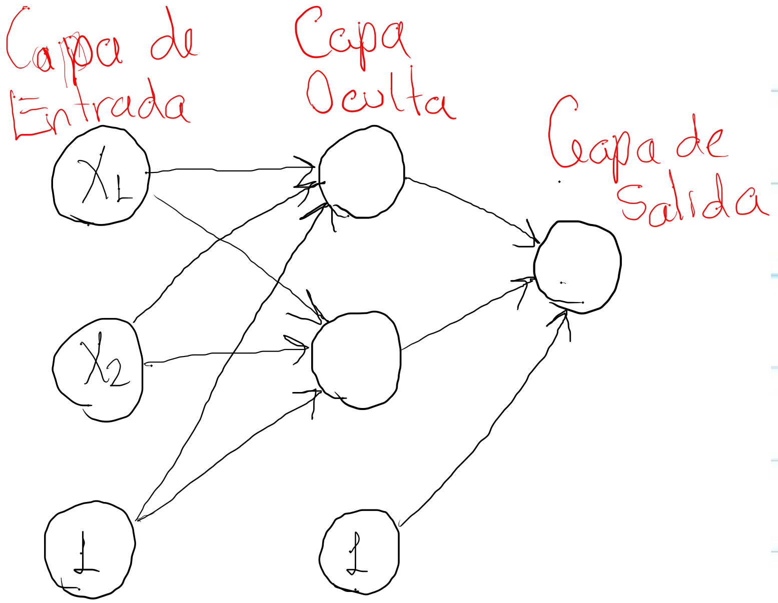
Función Sigmoide

$$f(x) = \frac{1}{1+e^{-x}}$$

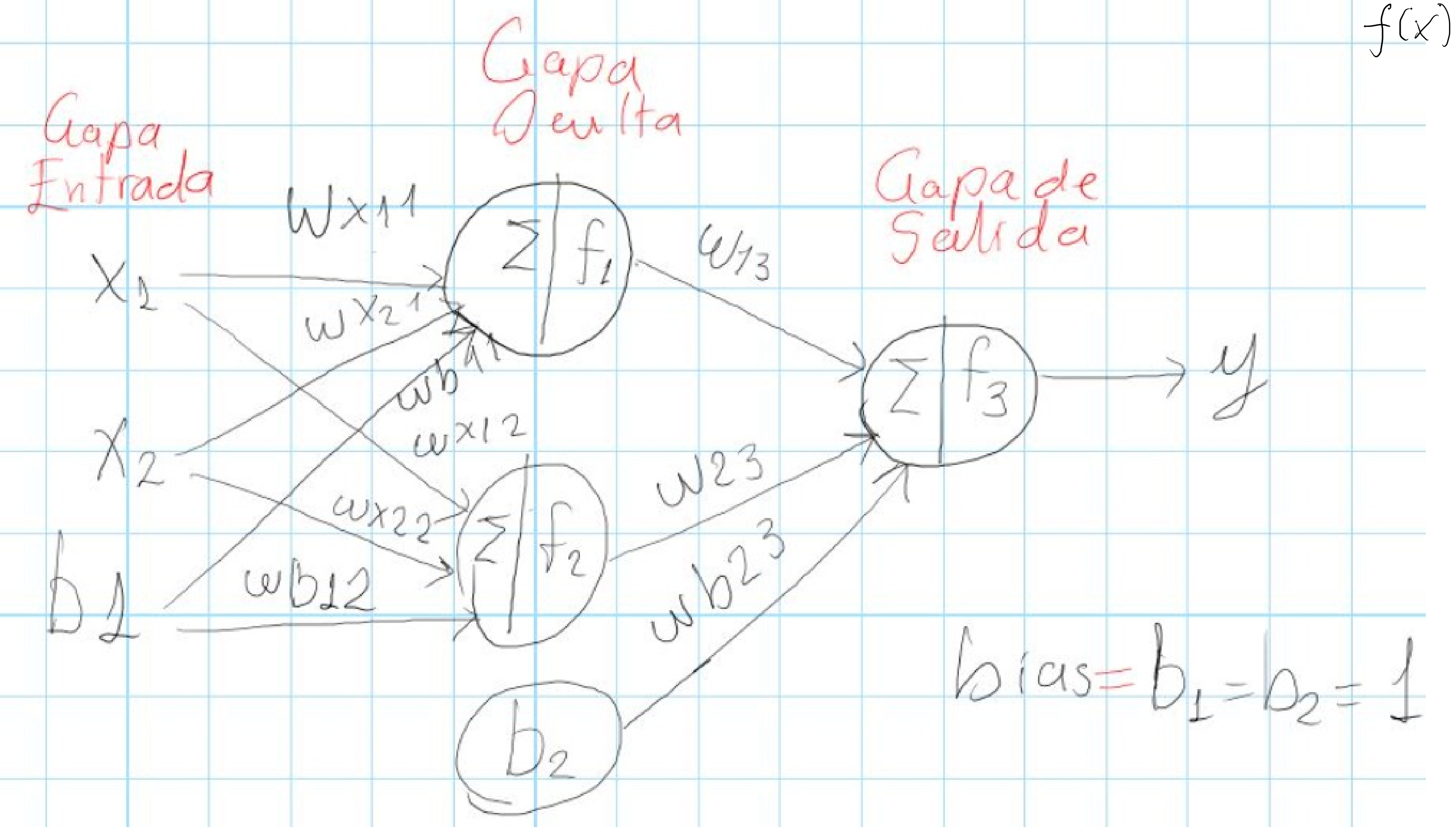
$$f'(x) = f(x)\,(1 - f(x))$$



$$f(x) = f_1(x) = f_2(x) = f_3(x)$$



$\eta = 0.5$

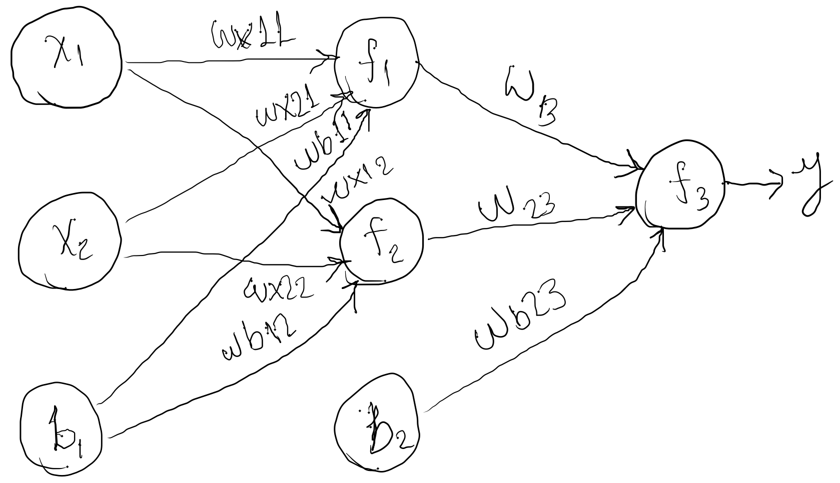


Neurona 1
wx11 = 0.909769237923872
wx21 = 0.2940790407586785
wb11 = 0.4594338793312195
Neurona 2
wx12 = 0.1363587105435612
wx22 = 0.9950607203462696
wb12 = 0.15464399620754732
Neurona 3
w13 = 0.6739395534640641
w23 = 0.5980255545416808
wb23 = 0.7146237169889224

$$f_1 = f\left((x_1)(wx_{11}) + x_2(wx_{21}) + b_1(wb_{11})\right) = y_1$$

$$f_2 = f\left(x_1(wx_{12}) + x_2(wx_{22}) + b_1(wb_{12})\right) = y_2$$

$$f_3 = f\left(f_1 W_{13} + f_2 W_{23} + b_2 W_{b23}\right) = y$$



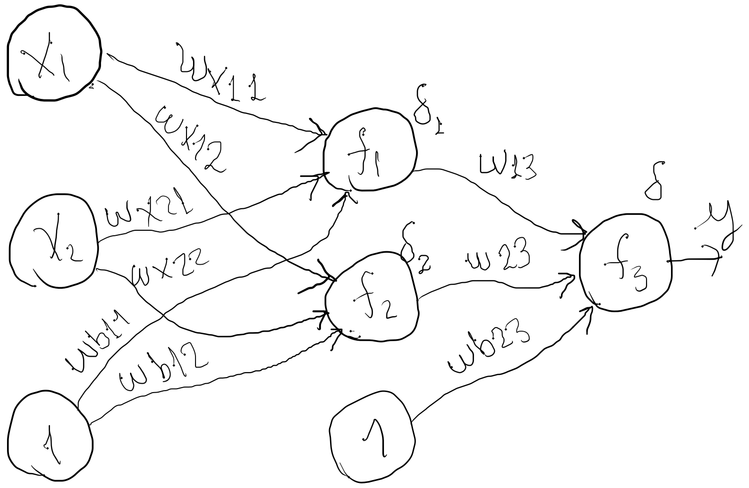
$$f = \frac{1}{1+e^{-x}}$$

$$b_1 = b_2 = 1$$

X_1	X_2	XOR
1	1	0
1	0	1
0	1	1
0	0	0

```
def rmse(lisX1,lisX2,lisZ):
  sum = 0
  e.clear()
  for i in range(0,len(lisX1)):
    y[i] = calcular_y(x1[i],x2[i])
    e.append(y[i] - z[i])
    print(e[i])
    sum = sum + e[i]*e[i]
  return math.sqrt(sum/len(lisX1))
```

rmse = 0.599430972279072
[0.8519188807951853, -0.16880249864585717, -0.16423634749611138, 0.8099606911859769]



$$y_1 = f_1$$
$$y_2 = f_2$$
$$y = f_3$$

$$\delta = e = z - y$$

$$\delta_1 = \delta\, w_{13}$$
$$\delta_2 = \delta\, w23$$

$$w'_{(x1)2} = w_{(x1)2} + \eta\,\delta_2 \frac{df_2(e)}{de} x_1$$

η = tasa de aprendizaje

$$\begin{cases} wx11 = wx11 + \eta\,\delta_1\, f'(x_1)\, x_1 \\ wx12 = wx12 + \eta\,\delta_2\, f'(x_1)\, x_1 \\ wx21 = wx21 + \eta\,\delta_1\, f'(x_2)\, x_2 \\ wx22 = wx22 + \eta\,\delta_2\, f'(x_2)\, x_2 \\ wb11 = wb11 + \eta\,\delta_1\, f'(1)(1) \\ wb12 = wb12 + \eta\,\delta_2\, f'(1)(1) \end{cases}$$

$$f(x) = \frac{1}{1+e^{-x}}$$

$$f'(x) = f(x) - f^2(x)$$

$$\begin{cases} w13 = w13 + \eta\,\delta\, f'(y_1)\, y_1 \\ w23 = w23 + \eta\,\delta\, f'(y_2)\, y_2 \\ wb23 = wb23 + \eta\,\delta\, f'(1)(1) \end{cases}$$