Modelo Backpropagation

Para realizar o trabalho de **classificação/regressão** de dados, modelos de **redes neurais** são úteis para a realização da tarefa. O modelo Backpropagation é utilizado para encontrar **pesos** de uma rede neural que ajustam os dados de entrada e os de saída, **minimizando o erro** entre as saídas desejadas e as saídas calculadas pela rede neural. Considere a próxima base de dados **binária**:

A B C
Features
Características

A	B	C	S
0	0	0	0
0	0	1	1
0	1	0	1
0	1	1	0
1	0	0	1
1	0	1	0
1	1	0	0
1	1	1	1

S
Target
Alvo

As **Características** devem possuir **relação** com o **Alvo**

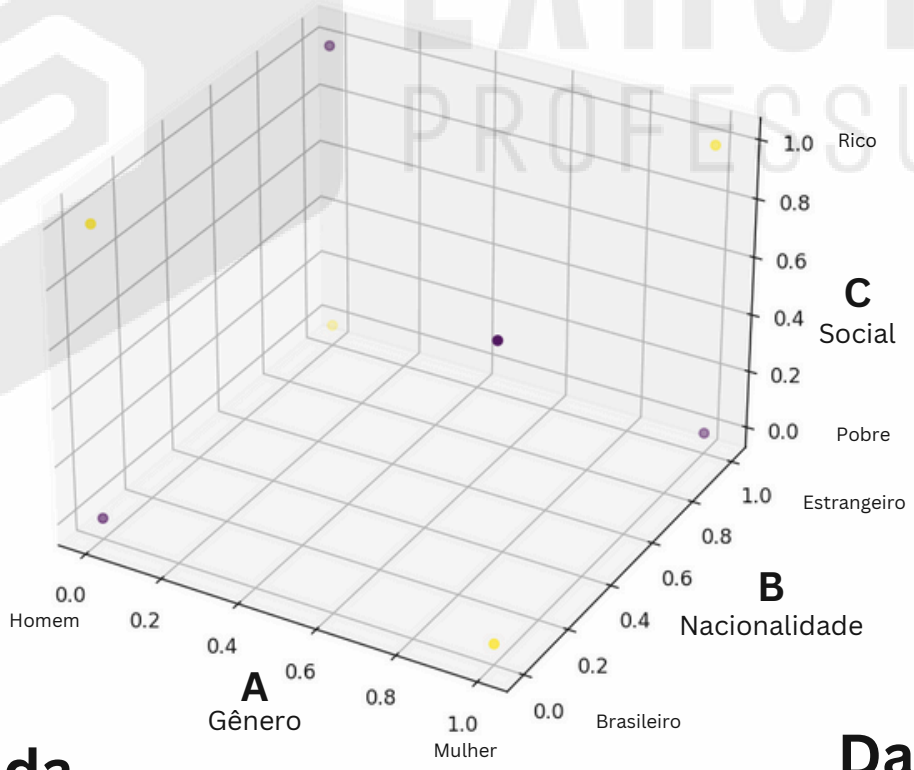
Modelo Backpropagation

Acredita-se que haja uma função ou uma **estrutura de funções** aninhadas que possam gerar a coluna de target utilizando, como entradas, as colunas de **features**. Essa dinâmica é entendida como ajuste dos dados.

O ajuste de dados em classe (adimplência, julgamento, etc.) chama-se **classificação de dados**.

O ajuste de dados do tipo números reais (temperatura, altura, etc.) chama-se **regressão de dados**.

CredituS



Legenda

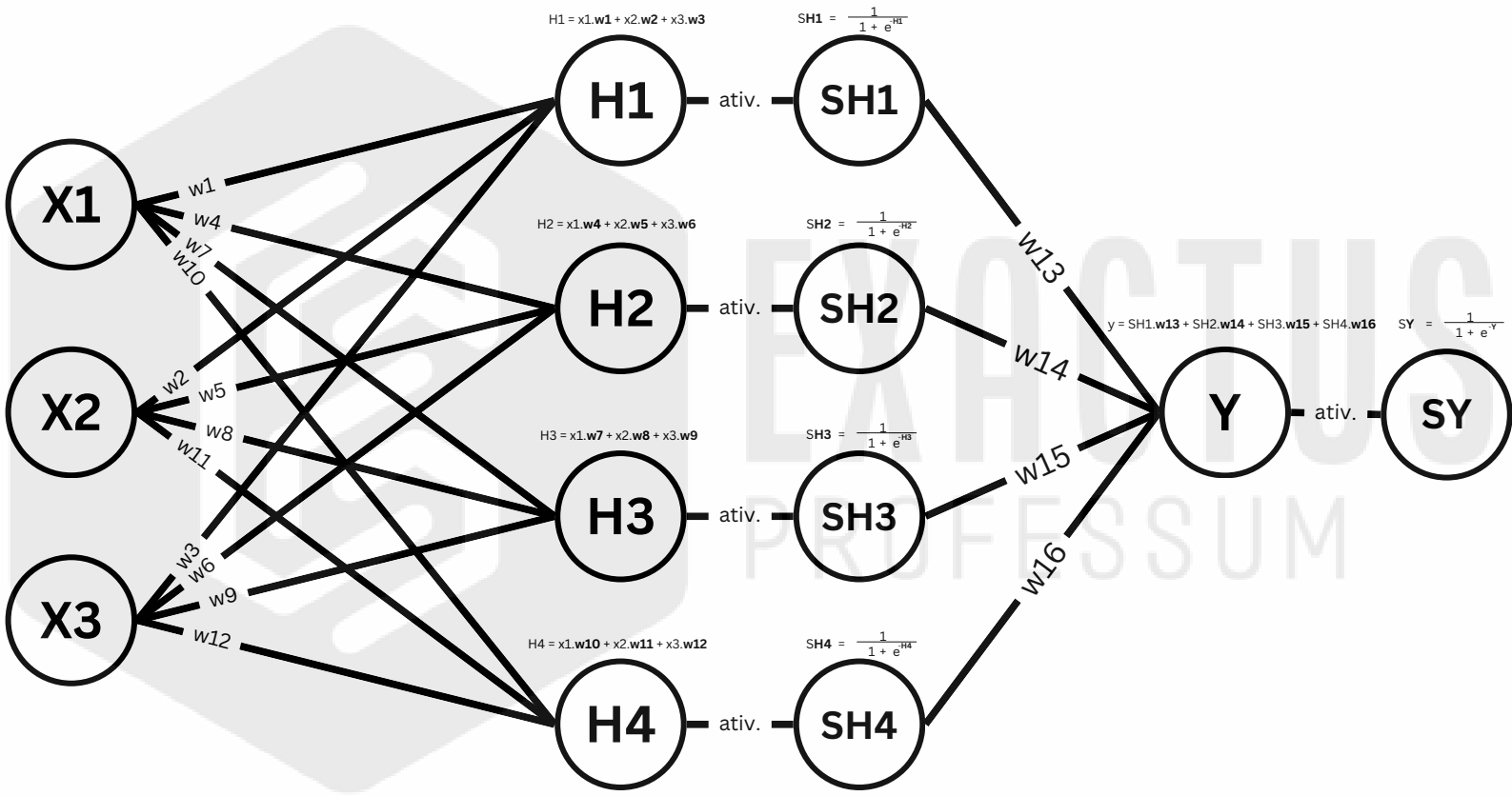
- Adimplente S=0
- Inadimplente S=1

Dados Não Linearmente Separáveis!!!

Modelo Backpropagation

Para dados **não-linearmente** separáveis, o modelo **backpropagation** proporciona uma estrutura funcional capaz de realizar classificação ou regressão não-lineares.

Entradas **Camadas Escondidas** **Saída**



H1 = x1.**w1** + x2.**w2** + x3.**w3**

H2 = x1.**w4** + x2.**w5** + x3.**w6**

H3 = x1.**w7** + x2.**w8** + x3.**w9**

H4 = x1.**w10** + x2.**w11** + x3.**w12**

y = SH1.**w13** + SH2.**w14** + SH3.**w15** + SH4.**w16**

Erro = (S - **SY**)²

$$SH1 = \frac{1}{1 + e^{-H1}}$$

$$SH2 = \frac{1}{1 + e^{-H2}}$$

$$SH3 = \frac{1}{1 + e^{-H3}}$$

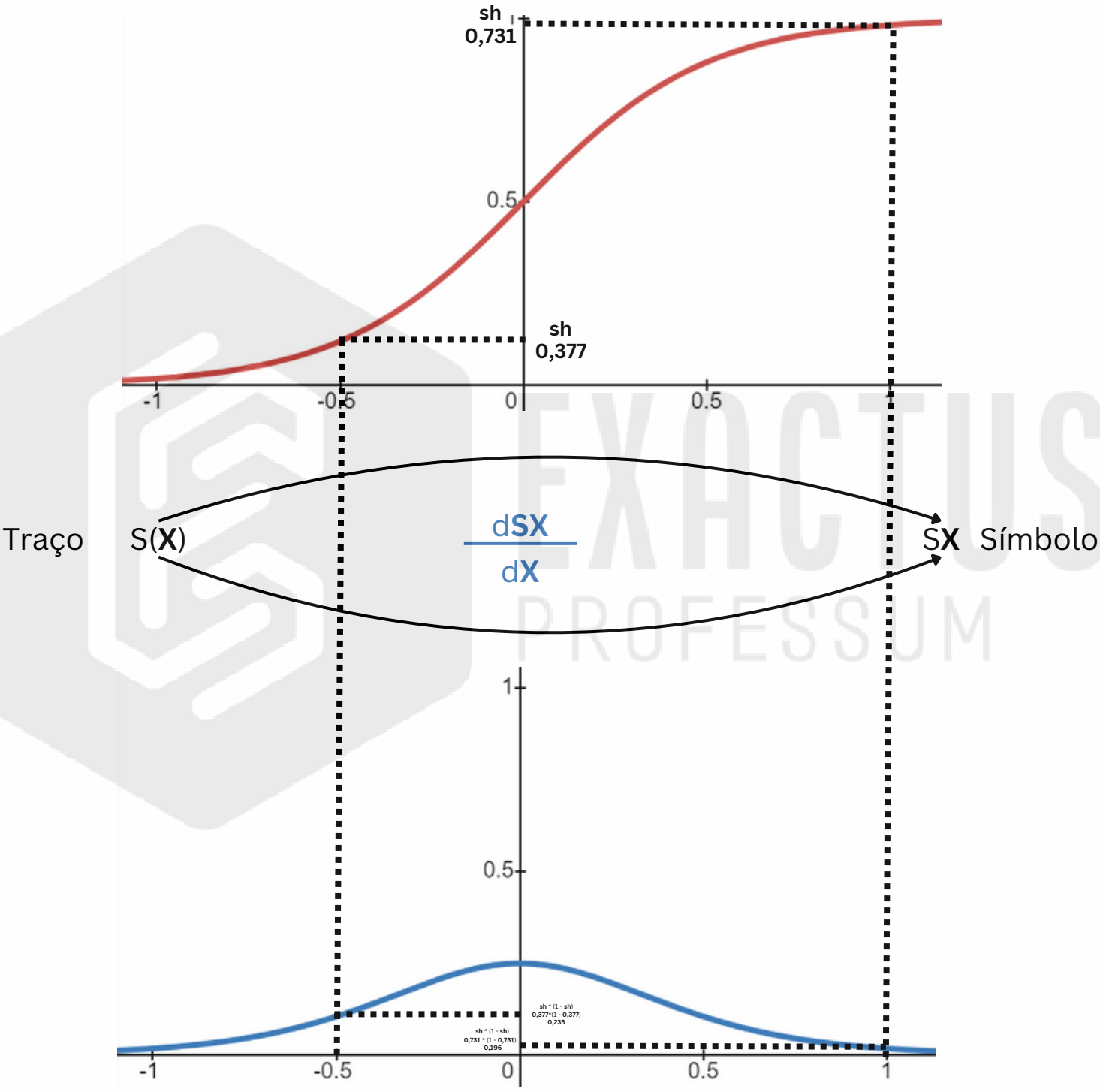
$$SH4 = \frac{1}{1 + e^{-H4}}$$

$$SY = \frac{1}{1 + e^{-Y}}$$

10 Funções Para **ajustar** os dados **Y** + Função **Erro**

Modelo Backpropagation

$$SX = \frac{1}{1 + e^{-X}}$$

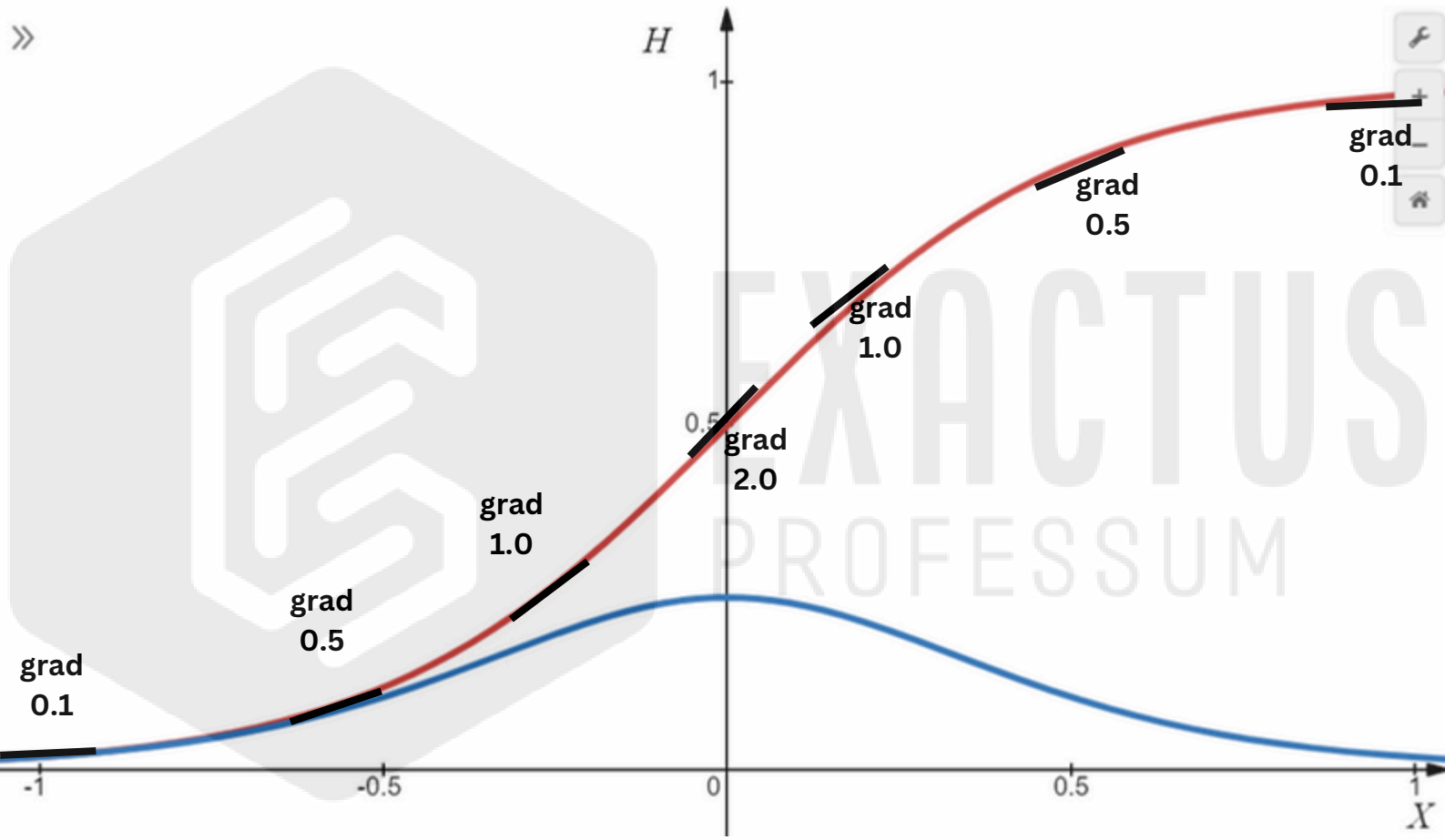


$$\frac{dSX}{dX} = \frac{1}{1+e^{-X}} \left(1 - \frac{1}{1+e^{-X}} \right)$$

$$\frac{dSX}{dX} = SX\,(1 - SX)$$

Modelo Backpropagation

$$SH = \frac{1}{1 + e^{-H}}$$



fonte: desmos.com

$$\frac{dSH}{dH} = SH\,(1 - SH)$$

Ativação Sigmoide

Modelo Backpropagation

Primeira Camada

w1 = -0.150

w2 = 0.608

w3 = 0.252

w4 = 1.572

w5 = 1.791

w6 = 0.507

w7 = 0.222

w8 = -0.382

w9 = -0.991

w10 = -0.127

w11 = -0.077

w12 = 0.364

Pesos Inicialmente **Sorteados**

Segunda Camada

w13 = 0.876

w14 = -0.087

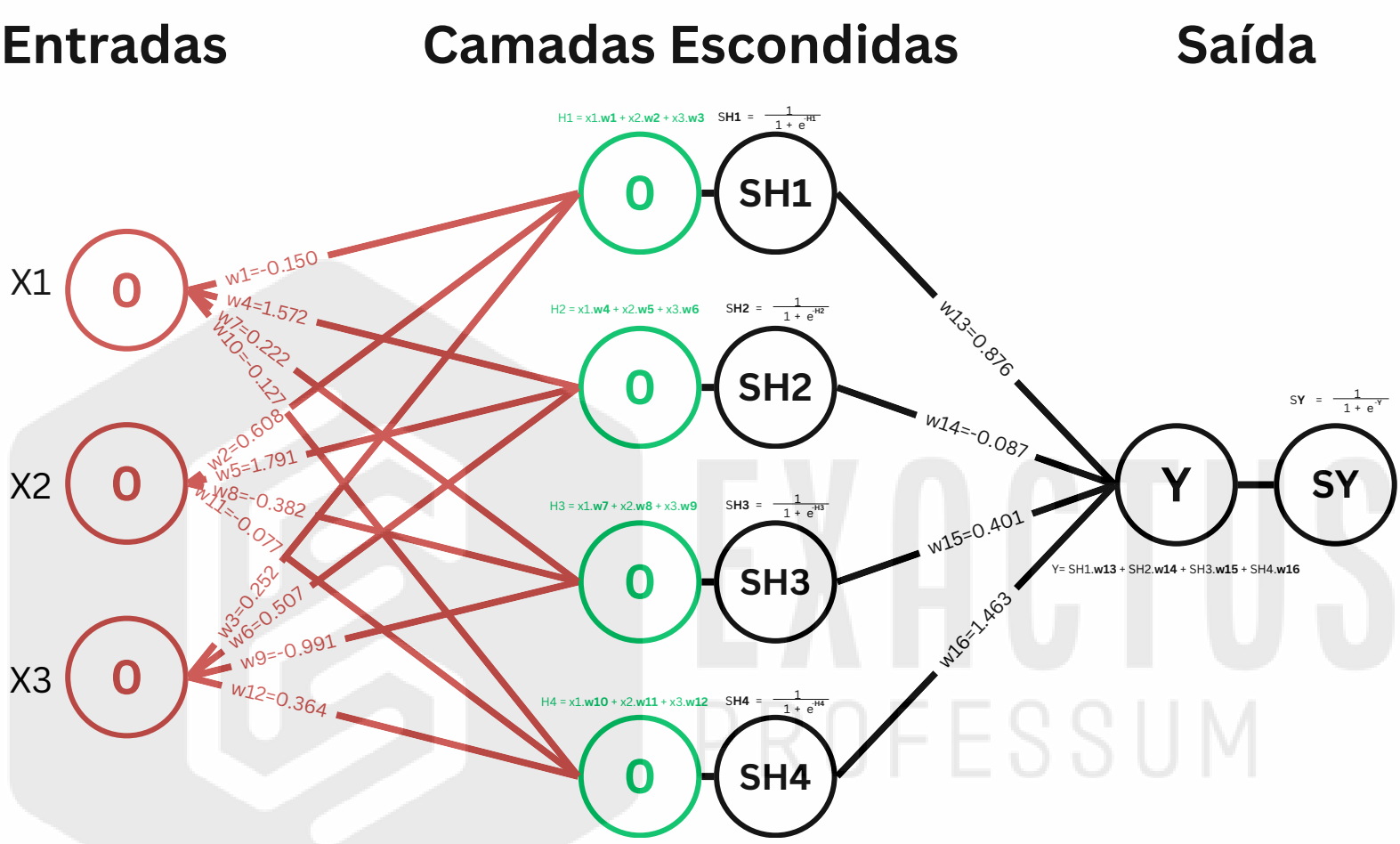
w15 = 0.401

w16 = 1.463

Modelo Backpropagation

Forward Propagation

Iteração 1



$$H1 = -0 \cdot \mathbf{0{,}150} + 0 \cdot \mathbf{0{,}608} + 0 \cdot \mathbf{0{,}252} = \mathbf{0}$$

$$H2 = +0 \cdot \mathbf{1{,}572} + 0 \cdot \mathbf{1{,}791} + 0 \cdot \mathbf{0{,}507} = \mathbf{0}$$

$$H3 = -0 \cdot \mathbf{0{,}222} - 0 \cdot \mathbf{0{,}382} - 0 \cdot \mathbf{0{,}991} = \mathbf{0}$$

$$H4 = -0 \cdot \mathbf{0{,}127} - 0 \cdot \mathbf{0{,}077} + 0 \cdot \mathbf{0{,}364} = \mathbf{0}$$

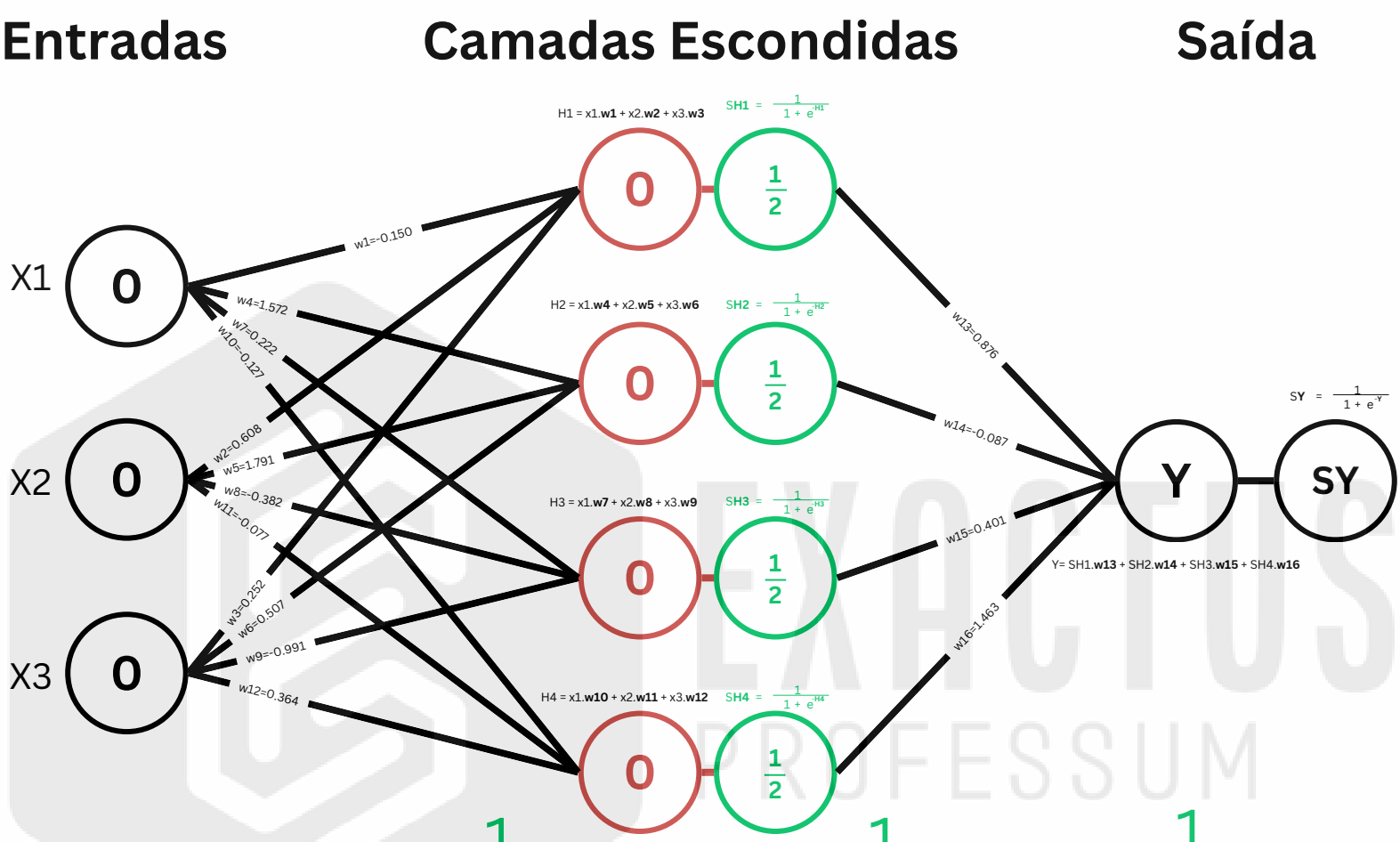
Forward Propagation

Iteração 1

Modelo Backpropagation

→ Forward Propagation →

Iteração 1



$$SH1 = \frac{1}{1 + e^{-H1}} = \frac{1}{1 + e^{0}} = \frac{1}{2}$$

$$SH2 = \frac{1}{1 + e^{-H2}} = \frac{1}{1 + e^{0}} = \frac{1}{2}$$

$$SH3 = \frac{1}{1 + e^{-H3}} = \frac{1}{1 + e^{0}} = \frac{1}{2}$$

$$SH4 = \frac{1}{1 + e^{-H4}} = \frac{1}{1 + e^{0}} = \frac{1}{2}$$

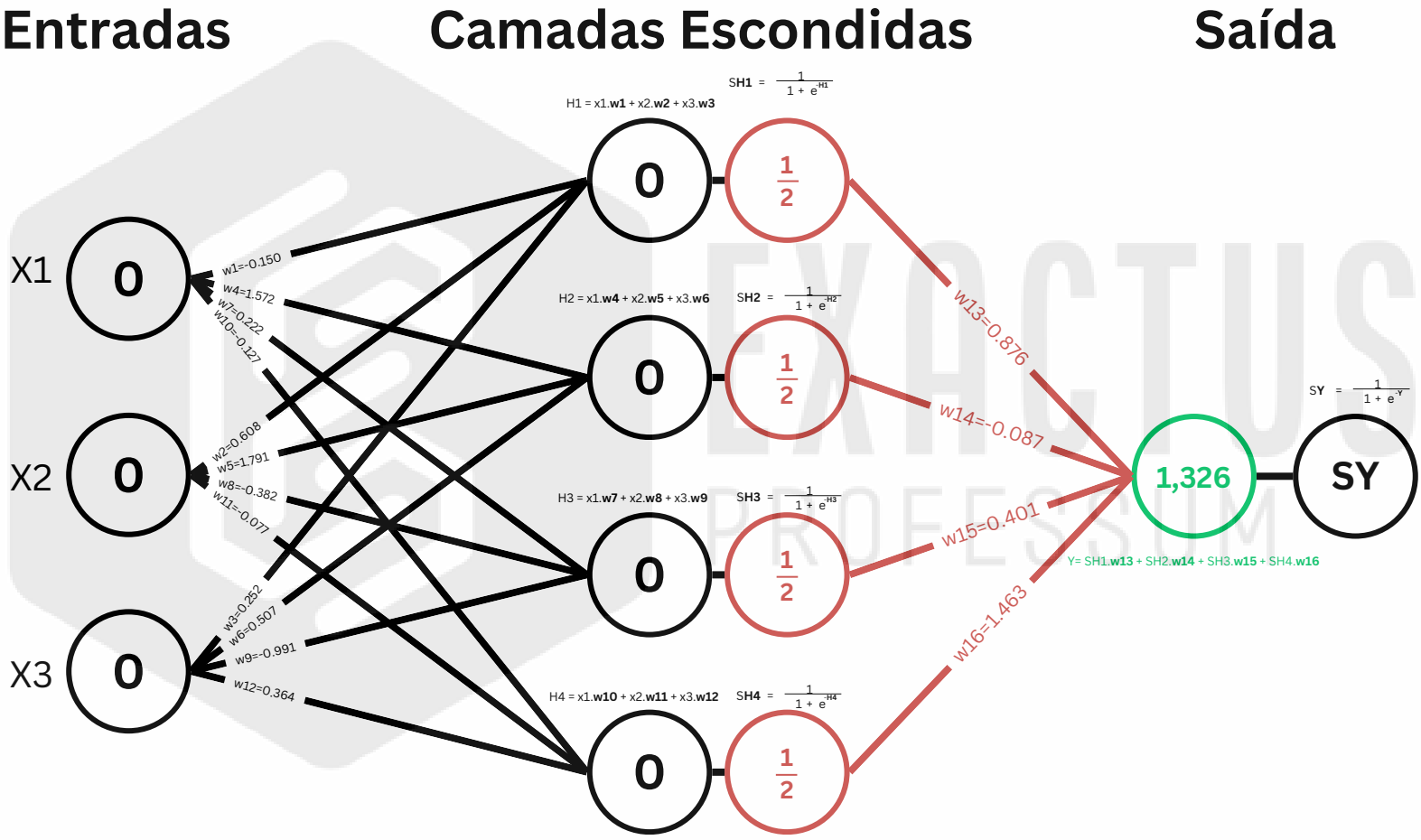
→ Forward Propagation →

Iteração 1

Modelo Backpropagation

→ Forward Propagation →

Iteração 1



$$Y = 0{,}5 \cdot \mathbf{0{,}876} - 0{,}5 \cdot \mathbf{0{,}087} + 0{,}5 \cdot \mathbf{0{,}401} + 0{,}5 \cdot \mathbf{1{,}463} = \mathbf{1{,}326}$$

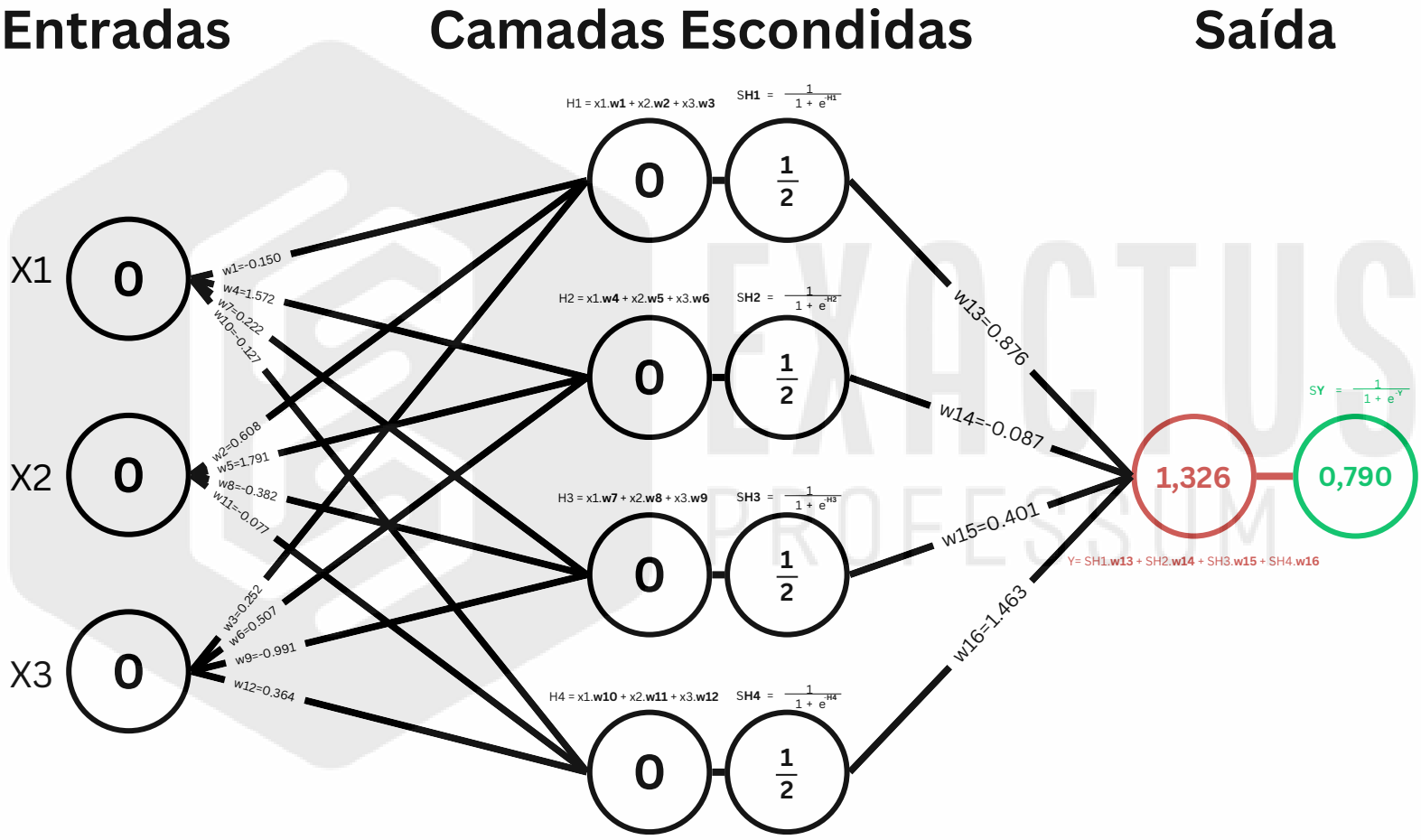
→ Forward Propagation →

Iteração 1

Modelo Backpropagation

→ Forward Propagation →

Iteração 1



$$SY = \frac{1}{1 + e^{-Y}} = \frac{1}{1 + e^{-1,326}} = 0.790$$

→ Forward Propagation →

Iteração 1

Modelo Backpropagation

Cálculo do Erro

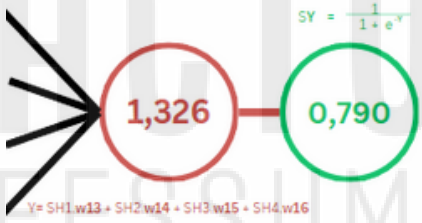
Iteração 1

$$Erro = 0,5 * (S - \mathbf{SY})^2$$

S: Saída Esperada

SY: Saída Calculada

Lição	A	B	C	S
1	0	0	0	0



$$Erro = 0,5 * (0 - 0,790)^2$$

$$Erro = 0,5 * (-0,790)^2$$

$$Erro = 0,5 * 0,043$$

$$Erro = 0,312$$

Cálculo do Erro

Iteração 1

Modelo Backpropagation

← Backward Propagation ←

Iteração 1

E(w1, w2, w3, w4, w5, w6, w7, w8, w9, w10, w11, w12, w13, w14, w15 e w16)

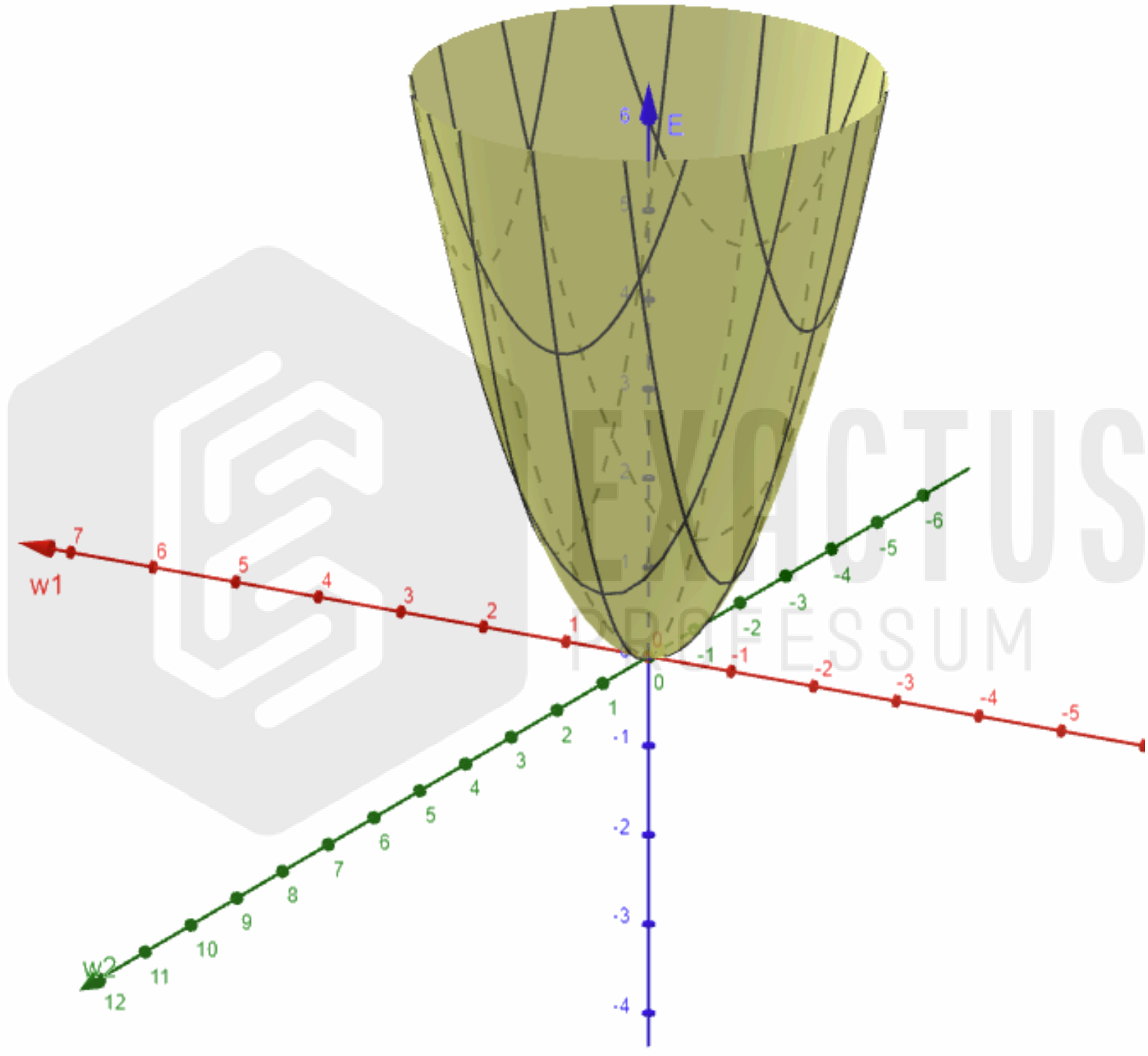
O
Backward Propagation
consiste
em
realizar a **correção** dos
pesos (variáveis)
w1, **w2**, **w3**, **w4**, **w5**, **w6**, **w7**, **w8**, **w9**, **w10**, **w11**, **w12**, **w13**, **w14**, **w15** e **w16**
para
minimizar
o
Erro

$$\text{Erro} = 0{,}5 * (S - \overset{w1\ w2\ w3\ w4}{\underset{w12\ w11\ w10\ w9}{\overset{w16\ \ \ \ w5}{\underset{w15\ \ \ \ w6}{\overset{w14\ \ \ \ w7}{\underset{w13\ \ \ \ w8}{\mathbf{SY}}}}}}})^2$$

← Backward Propagation ←

Iteração 1

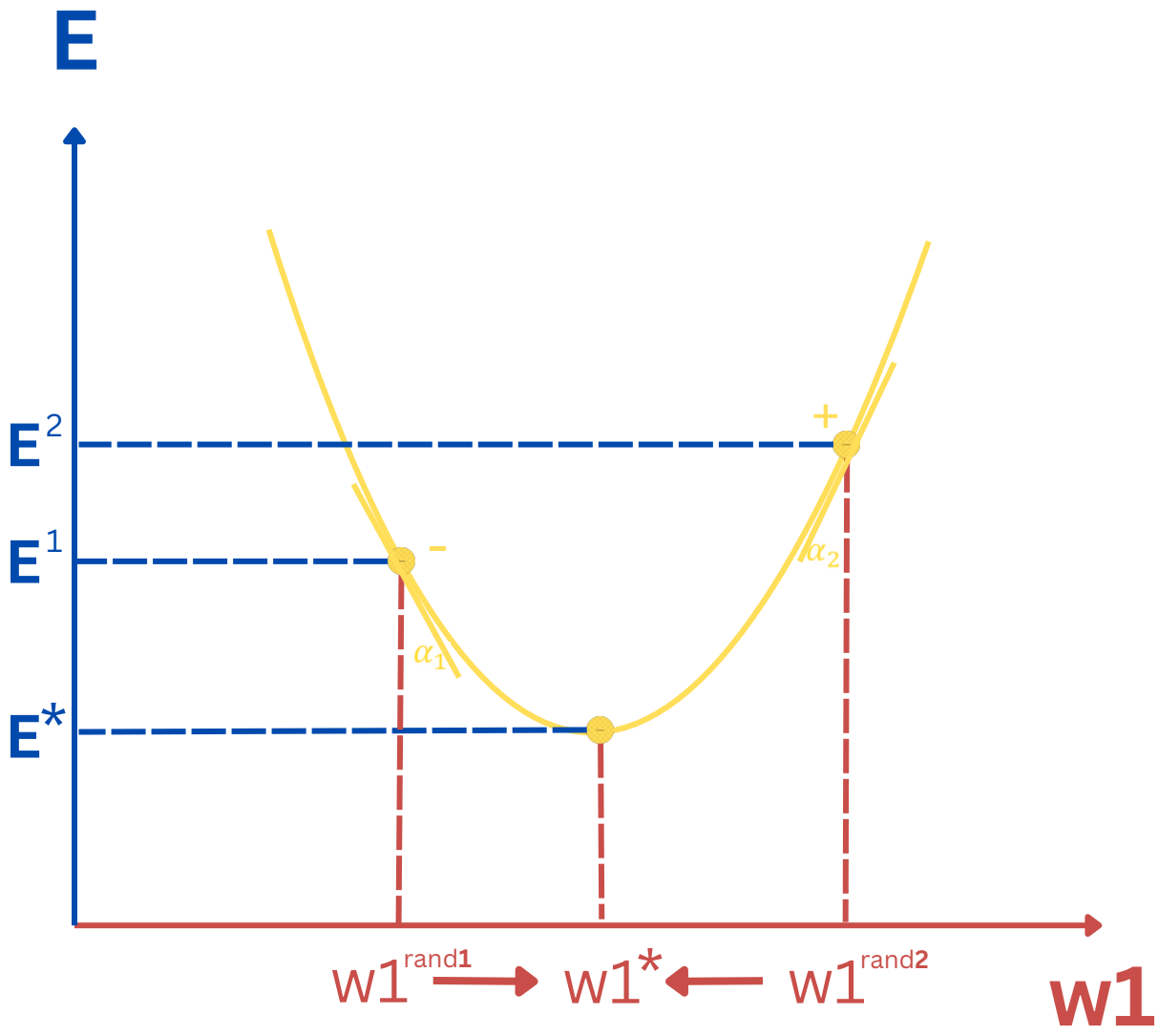
Modelo Backpropagation



fonte: **geogebra**

E(w1, w2)

Modelo Backpropagation



Direcionar W1 para w*:

$$tg(\alpha_1) = \frac{\partial E}{\partial w_1} = k_1\ (-)$$

$$tg(\alpha_2) = \frac{\partial E}{\partial w_2} = k_2\ (+)$$

$$_{new}w_1^{rand1} = {}_{old}w_1^{rand1} - (k1)$$

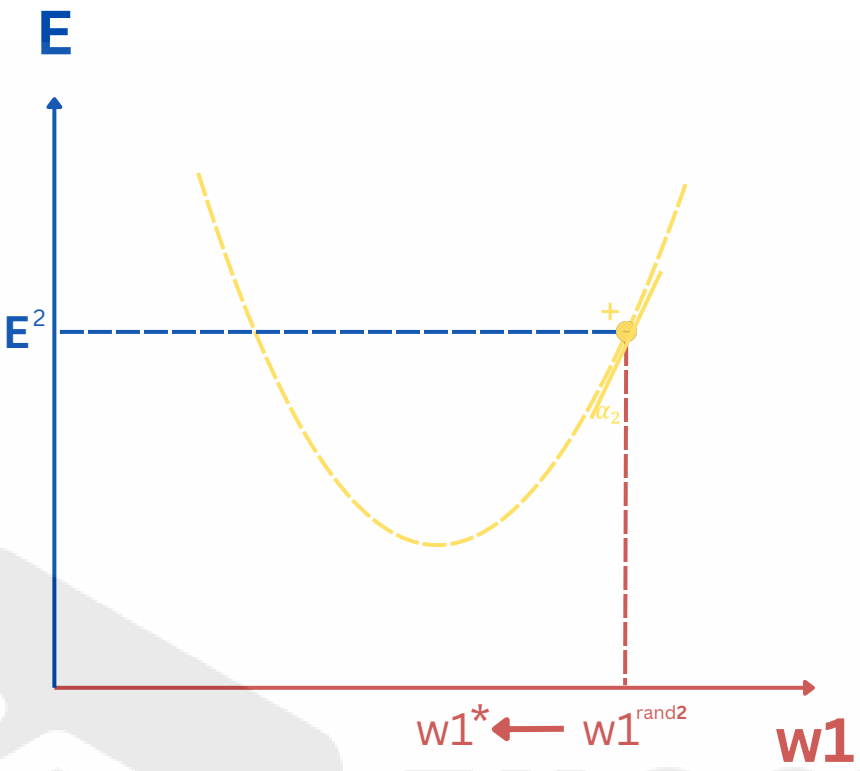
$$_{new}w_1^{rand2} = {}_{old}w_1^{rand2} - (k2)$$

$$_{new}w_1^{rand1} = {}_{old}w_1^{rand1} - \left(\frac{\partial E}{\partial w_1}\right)$$

$$_{new}w_1^{rand2} = {}_{old}w_1^{rand2} - \left(\frac{\partial E}{\partial w_1}\right)$$

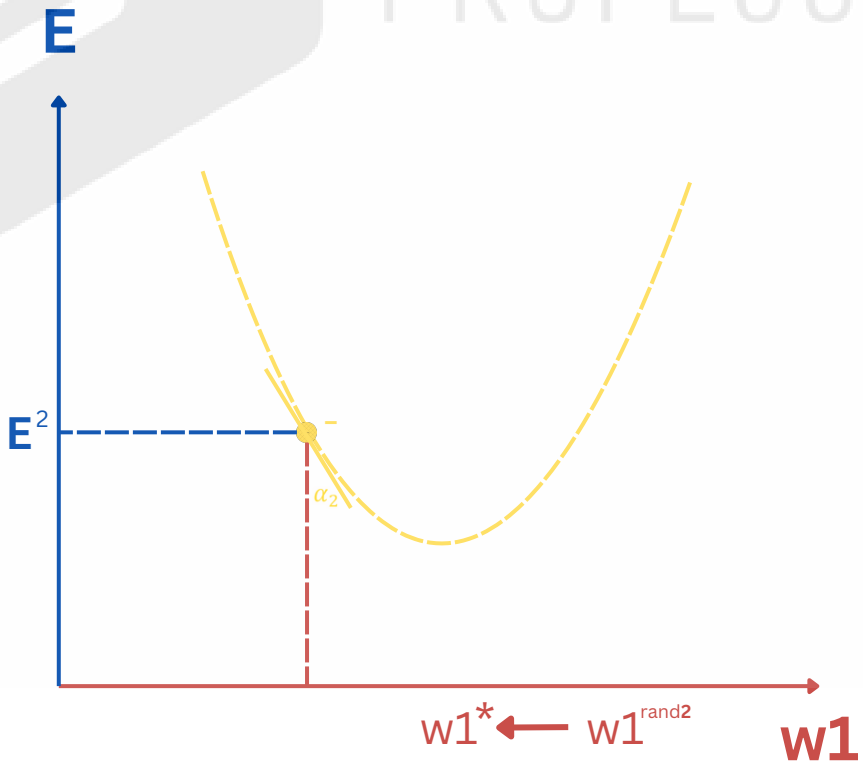
Gradiente Descendente

Modelo Backpropagation



Corrigindo o peso w1 com k **muito grande**:

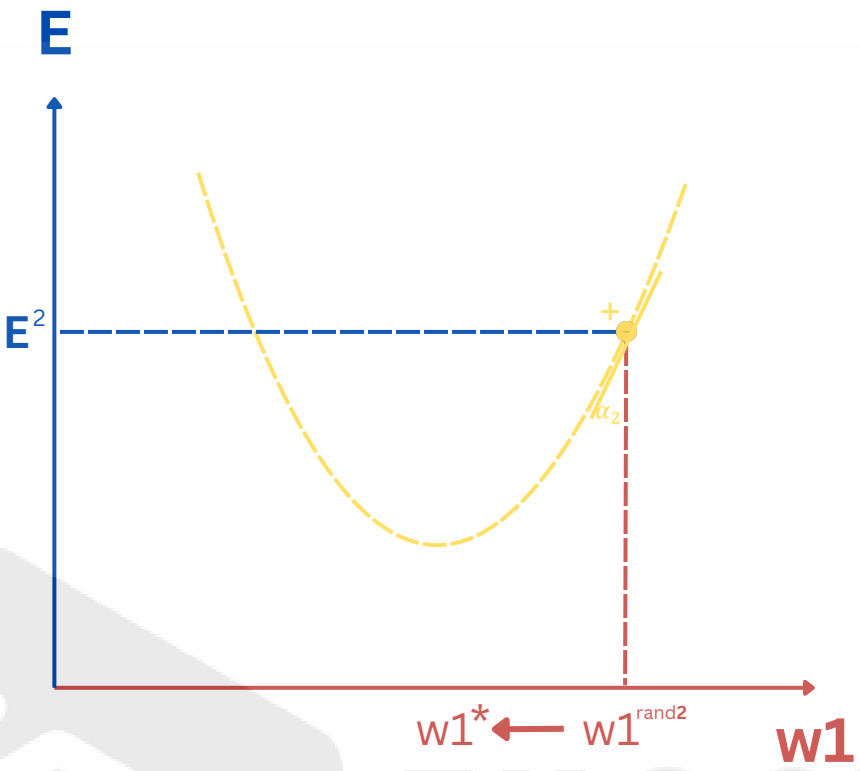
$$W_1^{new} = W_1^{old} - \left(\frac{\partial E}{\partial W_1}\right)$$



Passo **Muito grande**

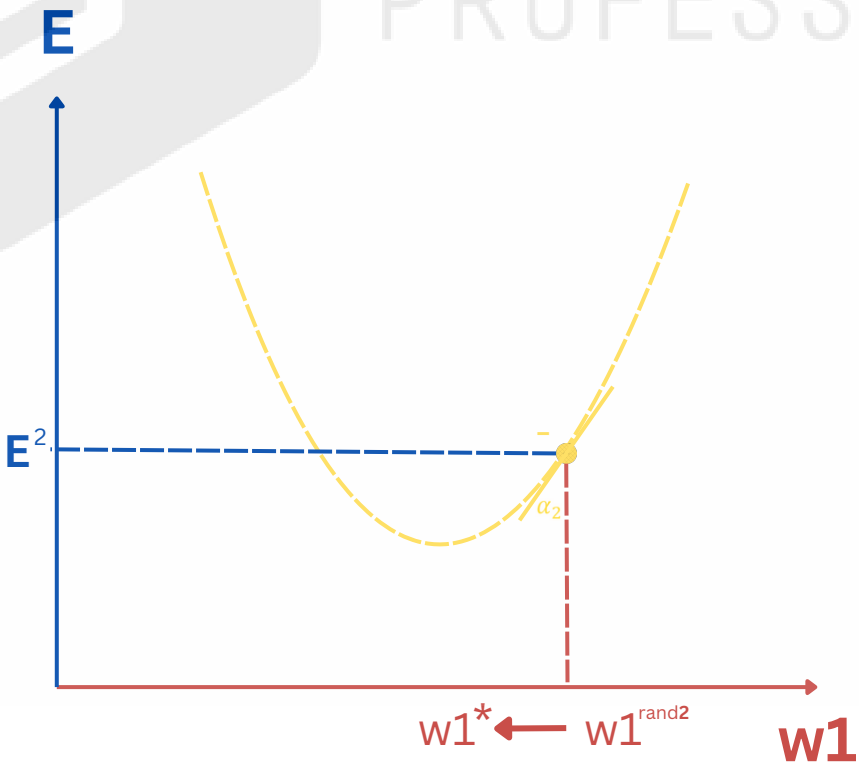
Gradiente Descendente

Modelo Backpropagation



Corrigindo o peso w1 com com k **reajustado (LR)**:

$$W_1^{new} = W_1^{old} - \boldsymbol{LR}.\left(\frac{\partial E}{\partial W_1}\right)$$



Passo mais **adequado** pelo **Learning Rate**

Gradiente Descendente

Modelo Backpropagation

Correções de todos os pesos **Ws**:

$$W_1^{new} = W_1^{old} - \boldsymbol{LR}.\left(\frac{\partial E}{\partial W_1}\right)$$

$$W_2^{new} = W_2^{old} - \boldsymbol{LR}.\left(\frac{\partial E}{\partial W_2}\right)$$

$$W_3^{new} = W_3^{old} - \boldsymbol{LR}.\left(\frac{\partial E}{\partial W_3}\right)$$

$$W_4^{new} = W_4^{old} - \boldsymbol{LR}.\left(\frac{\partial E}{\partial W_4}\right)$$

$$W_5^{new} = W_5^{old} - \boldsymbol{LR}.\left(\frac{\partial E}{\partial W_5}\right)$$

$$W_6^{new} = W_6^{old} - \boldsymbol{LR}.\left(\frac{\partial E}{\partial W_6}\right)$$

$$W_7^{new} = W_7^{old} - \boldsymbol{LR}.\left(\frac{\partial E}{\partial W_7}\right)$$

$$W_8^{new} = W_8^{old} - \boldsymbol{LR}.\left(\frac{\partial E}{\partial W_8}\right)$$

$$W_9^{new} = W_9^{old} - \boldsymbol{LR}.\left(\frac{\partial E}{\partial W_9}\right)$$

$$W_{10}^{new} = W_{10}^{old} - \boldsymbol{LR}.\left(\frac{\partial E}{\partial W_{10}}\right)$$

$$W_{11}^{new} = W_{11}^{old} - \boldsymbol{LR}.\left(\frac{\partial E}{\partial W_{11}}\right)$$

$$W_{12}^{new} = W_{12}^{old} - \boldsymbol{LR}.\left(\frac{\partial E}{\partial W_{12}}\right)$$

$$W_{13}^{new} = W_{13}^{old} - \boldsymbol{LR}.\left(\frac{\partial E}{\partial W_{13}}\right)$$

$$W_{14}^{new} = W_{14}^{old} - \boldsymbol{LR}.\left(\frac{\partial E}{\partial W_{14}}\right)$$

$$W_{15}^{new} = W_{15}^{old} - \boldsymbol{LR}.\left(\frac{\partial E}{\partial W_{15}}\right)$$

$$W_{16}^{new} = W_{16}^{old} - \boldsymbol{LR}.\left(\frac{\partial E}{\partial W_{16}}\right)$$

LR = 0.5

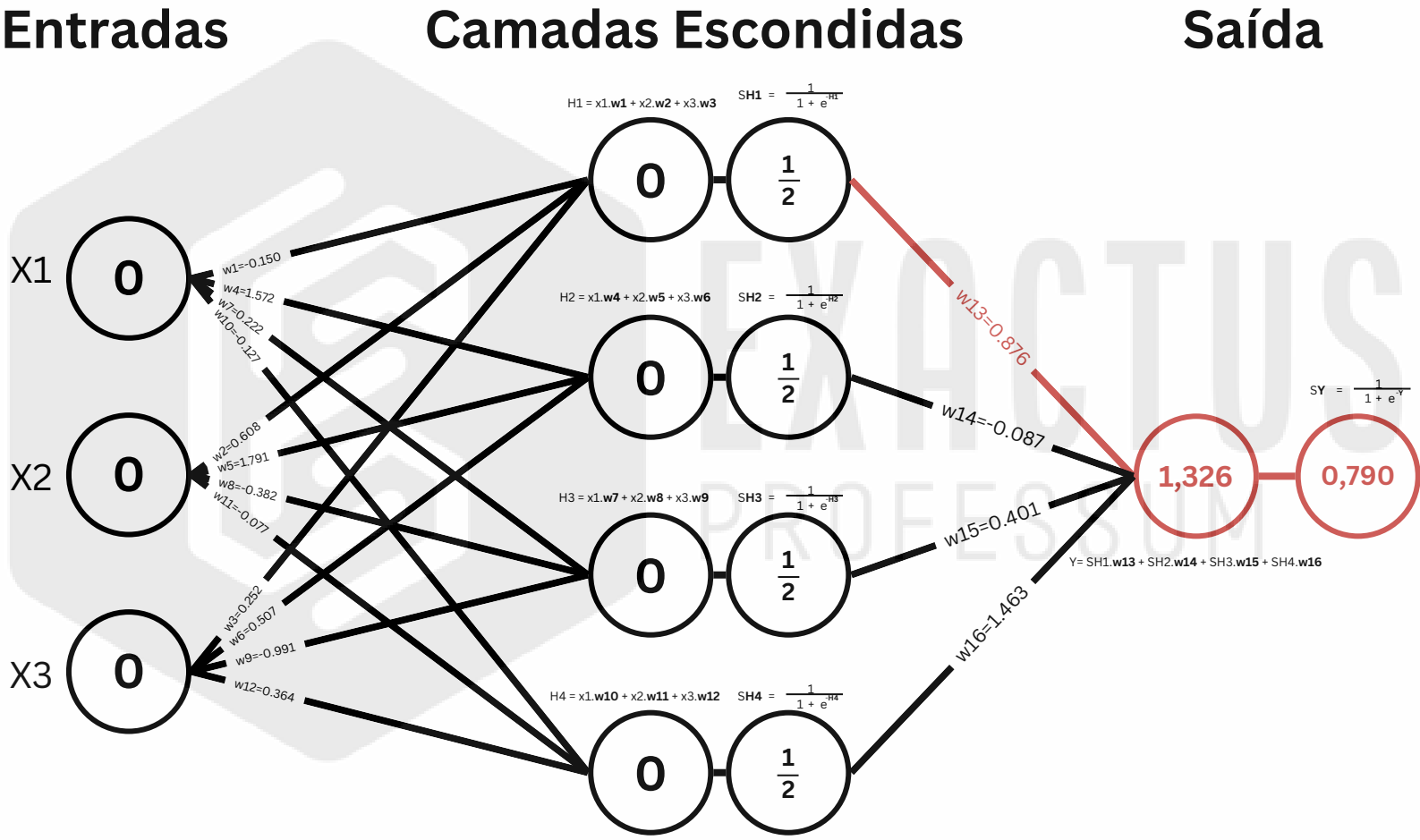
Correção dos Pesos

Modelo Backpropagation

← Backward Propagation ←

Iteração 1

Corrigindo Erro, em função de w13
E(w13)



$$\frac{\partial E}{\partial w_{13}} = \frac{\partial E}{\partial SY} x \frac{\partial SY}{\partial Y} x \frac{\partial Y}{\partial w_{13}}$$

← Backward Propagation ←

Iteração 1

Modelo Backpropagation

← Backward Propagation ←

Iteração 1

A $$\frac{\partial E}{\partial SY} = \frac{2}{2} * (S - SY)^1 * (-1) = (S - SY)^1 * (-1)$$

B $$\frac{\partial SY}{\partial Y} = SY * (1 - SY)$$

C $$\frac{\partial Y}{\partial w_{13}} = SH1.\mathbf{1} + 0 + 0 + 0 = SH1$$

$\frac{\partial E}{\partial SY}$ = (S - SY)¹ * (-1) = (0 - 0,790) * (-1) = 0,790

$\frac{\partial SY}{\partial Y}$ = SY * (1 - SY) = 0,790 * (1 - 0,790) = 0,165

$\frac{\partial Y}{\partial w_{13}}$ = SH1 ========== 0,500

A B C

Gradiente $\frac{\partial E}{\partial w_{13}} = 0{,}790\ x\ 0{,}165\ x\ 0{,}500 = 0{,}065$ **W13**

← Backward Propagation ←

Iteração 1

Modelo Backpropagation

← Backward Propagation ←

Iteração 1

$$w_{13}^{new} = w_{13}^{old} - 0{,}50\ x\ \left(\frac{\partial E}{\partial w_{13}}\right)$$

$$w_{13}^{new} = 0{,}876 - 0{,}50 * (0{,}065)$$

$$w_{13}^{new} = 0{,}843$$

← Backward Propagation ←

Iteração 1

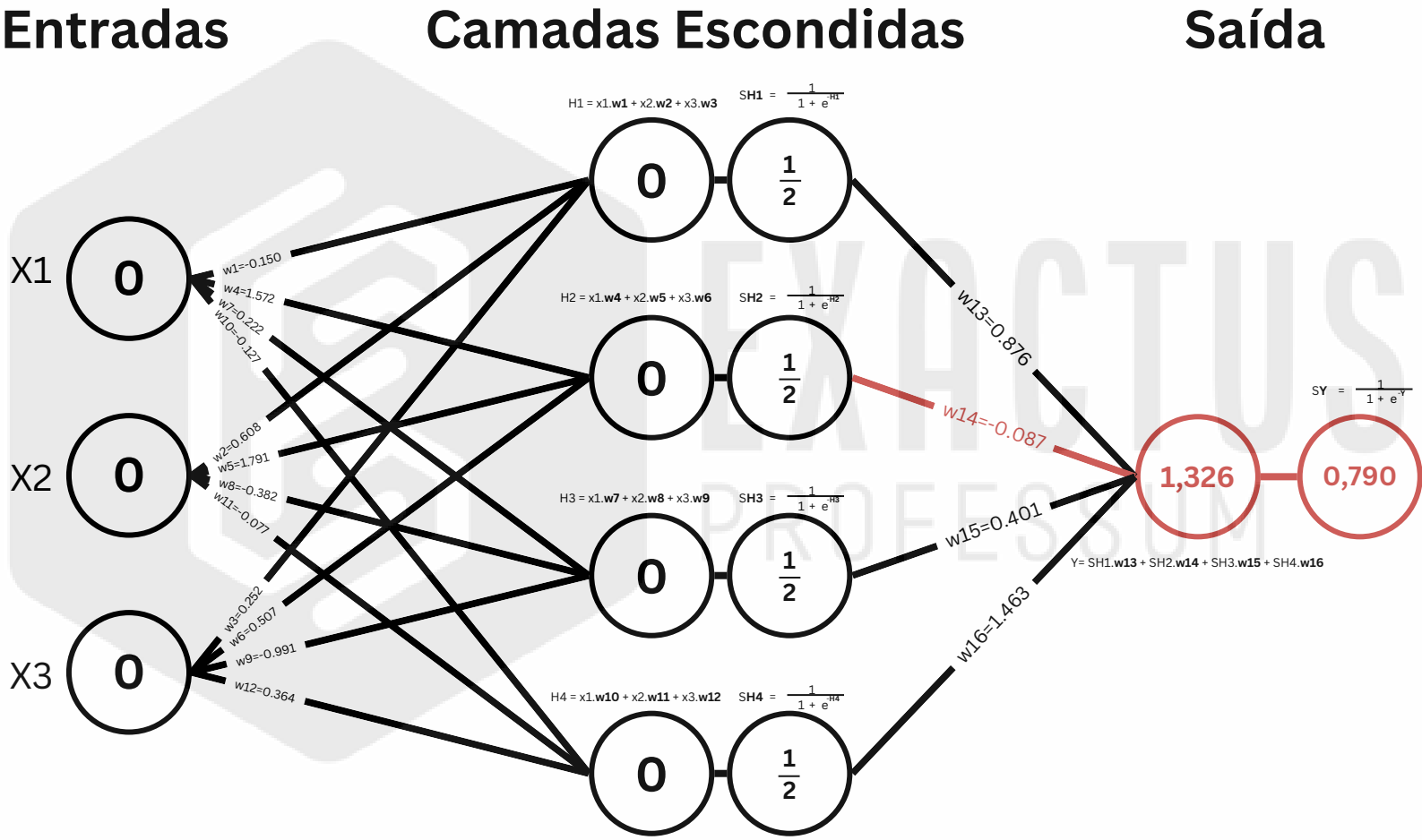
Modelo Backpropagation

← Backward Propagation ←

Iteração 1

Corrigindo Erro, em função de w14

E(w14)



$$\frac{\partial E}{\partial w_{14}} = \frac{\partial E}{\partial SY} x \frac{\partial SY}{\partial Y} x \frac{\partial Y}{\partial w_{14}}$$

← Backward Propagation ←

Iteração 1

Modelo Backpropagation

← Backward Propagation ←

Iteração 1

A $$\frac{\partial E}{\partial SY} = \frac{2}{2} * (S - SY)^1 * (-1) = (S - SY)^1 * (-1)$$

B $$\frac{\partial SY}{\partial Y} = SY * (1 - SY)$$

C $$\frac{\partial Y}{\partial w_{14}} = 0 + SH2 \,.\, 1 + 0 + 0 = SH2$$

$\frac{\partial E}{\partial SY}$ = (S - SY)¹ * (-1) = (0 - 0,790) * (-1) = 0,790

$\frac{\partial SY}{\partial Y}$ = SY * (1 - SY) = 0,790 * (1 - 0,790) = 0,165

$\frac{\partial Y}{\partial w_{14}}$ = SH2 ========== 0,500

A B C

Gradiente $\frac{\partial E}{\partial w_{14}} = 0{,}790\ x\ 0{,}165\ x\ 0{,}500 = 0{,}065$ **W14**

← Backward Propagation ←

Iteração 1

Modelo Backpropagation

← Backward Propagation ←

Iteração 1

$$w_{14}^{new} = w_{14}^{old} - 0{,}50\ x\ \left(\frac{\partial E}{\partial w_{14}}\right)$$

$$w_{14}^{new} = -0{,}087 - 0{,}50 * (0{,}065)$$

$$w_{14}^{new} = -0{,}119$$

← Backward Propagation ←

Iteração 1

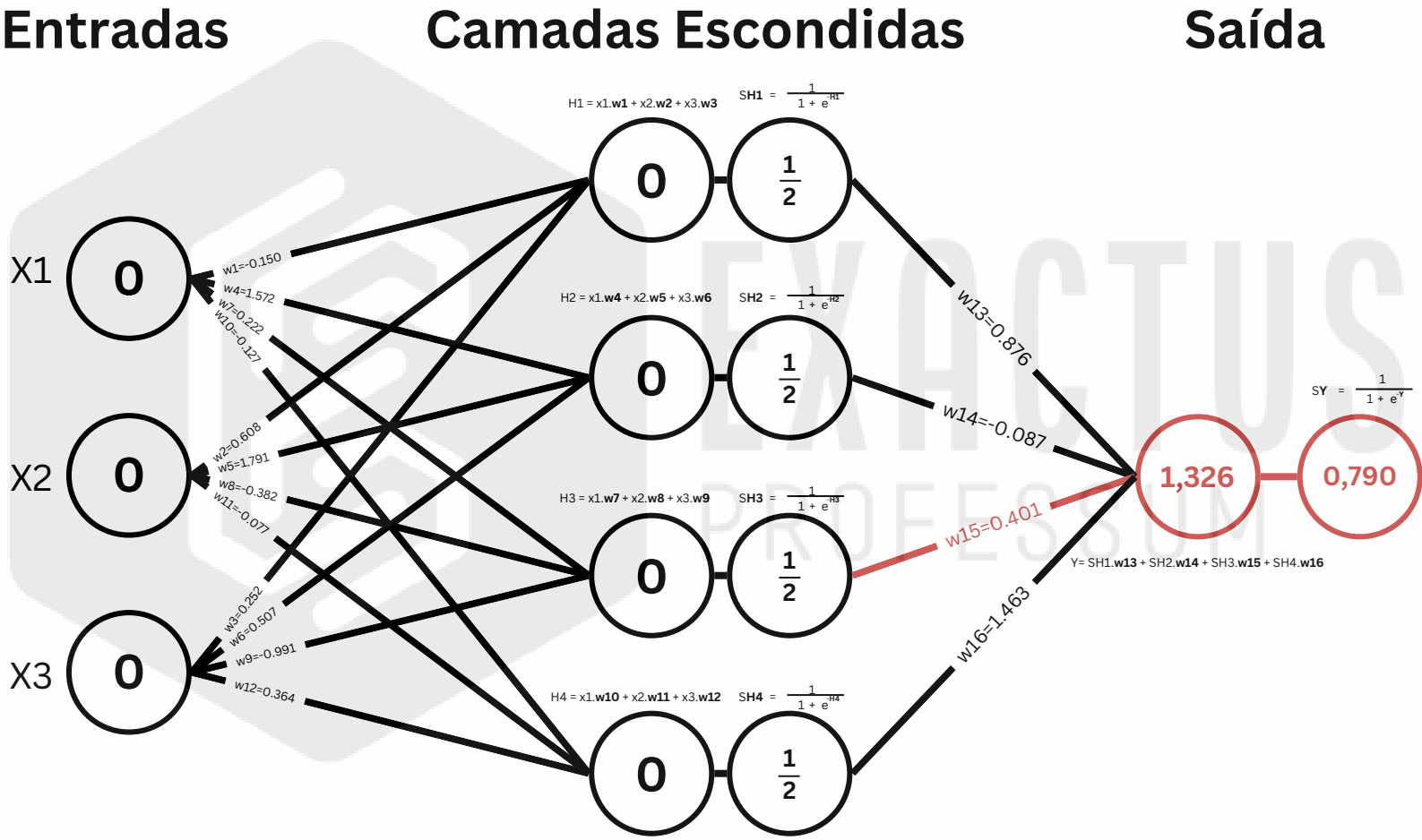
Modelo Backpropagation

← Backward Propagation ←

Iteração 1

Corrigindo Erro, em função de w15

E(w15)



$$\frac{\partial E}{\partial w_{15}} = \frac{\partial E}{\partial SY} x \frac{\partial SY}{\partial Y} x \frac{\partial Y}{\partial w_{15}}$$

← Backward Propagation ←

Iteração 1

Modelo Backpropagation

← Backward Propagation ←

Iteração 1

A $$\frac{\partial E}{\partial SY} = \frac{2}{2} * (S - SY)^1 * (-1) = (S - SY)^1 * (-1)$$

B $$\frac{\partial SY}{\partial Y} = SY * (1 - SY)$$

C $$\frac{\partial Y}{\partial w_{15}} = 0 + 0 + SH3 \,.\, 1 + 0 = SH3$$

$$\frac{\partial E}{\partial SY} = (S - SY)^1 * (-1) = (0 - 0{,}790) * (-1) = 0{,}790$$

$$\frac{\partial SY}{\partial Y} = SY * (1 - SY) = 0{,}790 * (1 - 0{,}790) = 0{,}165$$

$$\frac{\partial Y}{\partial w_{15}} = SH3 \text{ ========== } 0{,}500$$

A B C

Gradiente $$\frac{\partial E}{\partial w_{15}} = 0{,}790 \; x \; 0{,}165 \; x \; 0{,}500 = 0{,}065$$ **W15**

← Backward Propagation ←

Iteração 1

Modelo Backpropagation

← Backward Propagation ←

Iteração 1

$$w_{15}^{new} = w_{15}^{old} - 0{,}50\ x\ \left(\frac{\partial E}{\partial w_{15}}\right)$$

$$w_{15}^{new} = 0{,}401 - 0{,}50 * (0{,}065)$$

$$w_{15}^{new} = 0{,}368$$

← Backward Propagation ←

Iteração 1

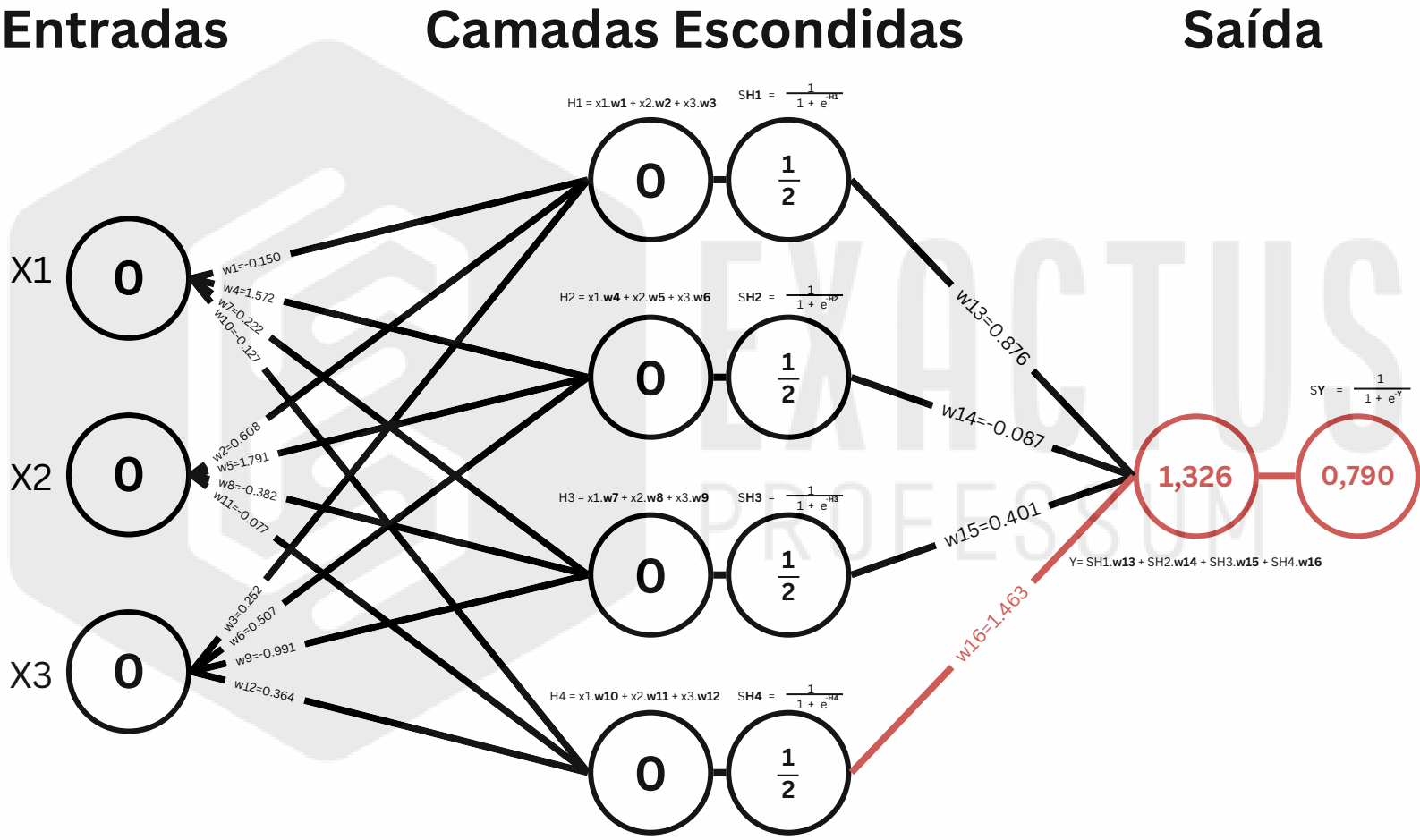
Modelo Backpropagation

← Backward Propagation ←

Iteração 1

Corrigindo Erro, em função de w16

E(w16)



$$\frac{\partial E}{\partial w_{16}} = \frac{\partial E}{\partial SY} x \frac{\partial SY}{\partial Y} x \frac{\partial Y}{\partial w_{16}}$$

← Backward Propagation ←

Iteração 1

Modelo Backpropagation

← Backward Propagation ←

Iteração 1

A $$\frac{\partial E}{\partial SY} = \frac{2}{2} * (S - SY)^1 * (-1) = (S - SY)^1 * (-1)$$

B $$\frac{\partial SY}{\partial Y} = SY * (1 - SY)$$

C $$\frac{\partial Y}{\partial w_{16}} = 0 + 0 + 0 + SH4 \,.\, \mathbf{1} = SH4$$

$\frac{\partial E}{\partial SY}$ = (S - SY)¹ * (-1) = (0 - 0,790) * (-1) = 0,790

$\frac{\partial SY}{\partial Y}$ = SY * (1 - SY) = 0,790 * (1 - 0,790) = 0,165

$\frac{\partial Y}{\partial w_{16}}$ = SH4 ========== 0,500

A B C

Gradiente $\frac{\partial E}{\partial w_{16}} = 0{,}790\ x\ 0{,}165\ x\ 0{,}500 = 0{,}065$ **W16**

← Backward Propagation ←

Iteração 1

Modelo Backpropagation

← Backward Propagation ←

Iteração 1

$$w_{16}^{new} = w_{16}^{old} - 0{,}50\ x\ \left(\frac{\partial E}{\partial w_{16}}\right)$$

$$w_{16}^{new} = 1{,}463 - 0{,}50 * (0{,}065)$$

$$w_{16}^{new} = 1{,}430$$

← Backward Propagation ←

Iteração 1

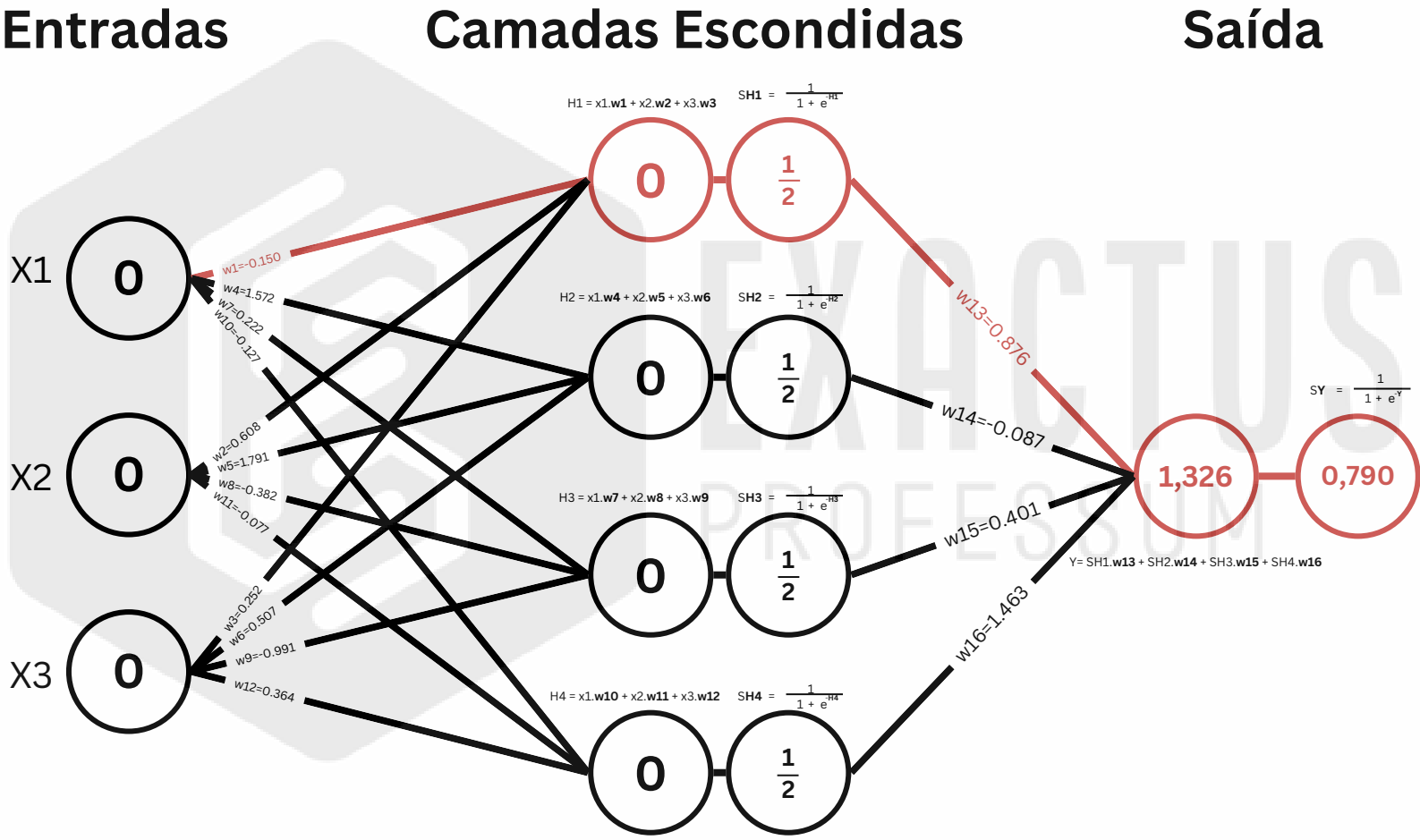
Modelo Backpropagation

← Backward Propagation ←

Iteração 1

Corrigindo Erro, em função de w1

E(w1)



$$\frac{\partial E}{\partial w_1} = \frac{\partial E}{\partial SY} x \frac{\partial SY}{\partial Y} x \frac{\partial Y}{\partial SH1} x \frac{\partial SH1}{\partial H1} x \frac{\partial H1}{\partial w_1}$$

← Backward Propagation ←

Iteração 1

Modelo Backpropagation

← Backward Propagation ←

Iteração 1

A $$\frac{\partial E}{\partial SY} = \frac{2}{2} * (S - SY)^1 * (-1) = (S - SY)^1 * (-1)$$

B $$\frac{\partial SY}{\partial Y} = SY * (1 - SY)$$

C1 $$\frac{\partial Y}{\partial SH1} = 1.w13 + 0 + 0 + 0$$

C2 $$\frac{\partial SH1}{\partial H1} = SH1 * (1 - SH1)$$

C3 $$\frac{\partial H1}{\partial w_1} = X1.1 + 0 + 0$$

$\frac{\partial E}{\partial SY}$ = (S - SY)¹ * (-1) = (0 - 0,790) * (-1) = 0,790

$\frac{\partial SY}{\partial Y}$ = SY * (1 - SY) = 0,790 * (1 - 0,790) = 0,165

$\frac{\partial Y}{\partial SH1}$ = w13 ========== 0,876

$\frac{\partial SH1}{\partial H1}$ = SH1 * (1 - SH1) = 0,5 * (1 - 0,5) === 0,250

$\frac{\partial H1}{\partial w_1}$ = X1 ========== 0,000

Gradiente $\frac{\partial E}{\partial w_1} = 0,790\ x\ 0,165\ x\ 0,876\ x\ 0,250\ x\ 0,000 = 0,000$ **W1**

← Backward Propagation ←

Modelo Backpropagation

← Backward Propagation ←

Iteração 1

$$W_1^{new} = W_1^{old} - 0.50\left(\frac{\partial E}{\partial W_1}\right)$$

$$W_1^{new} = -0{,}150 - 0.50 * (0{,}000)$$

$$W_1^{new} = -0{,}150$$

← Backward Propagation ←

Iteração 1

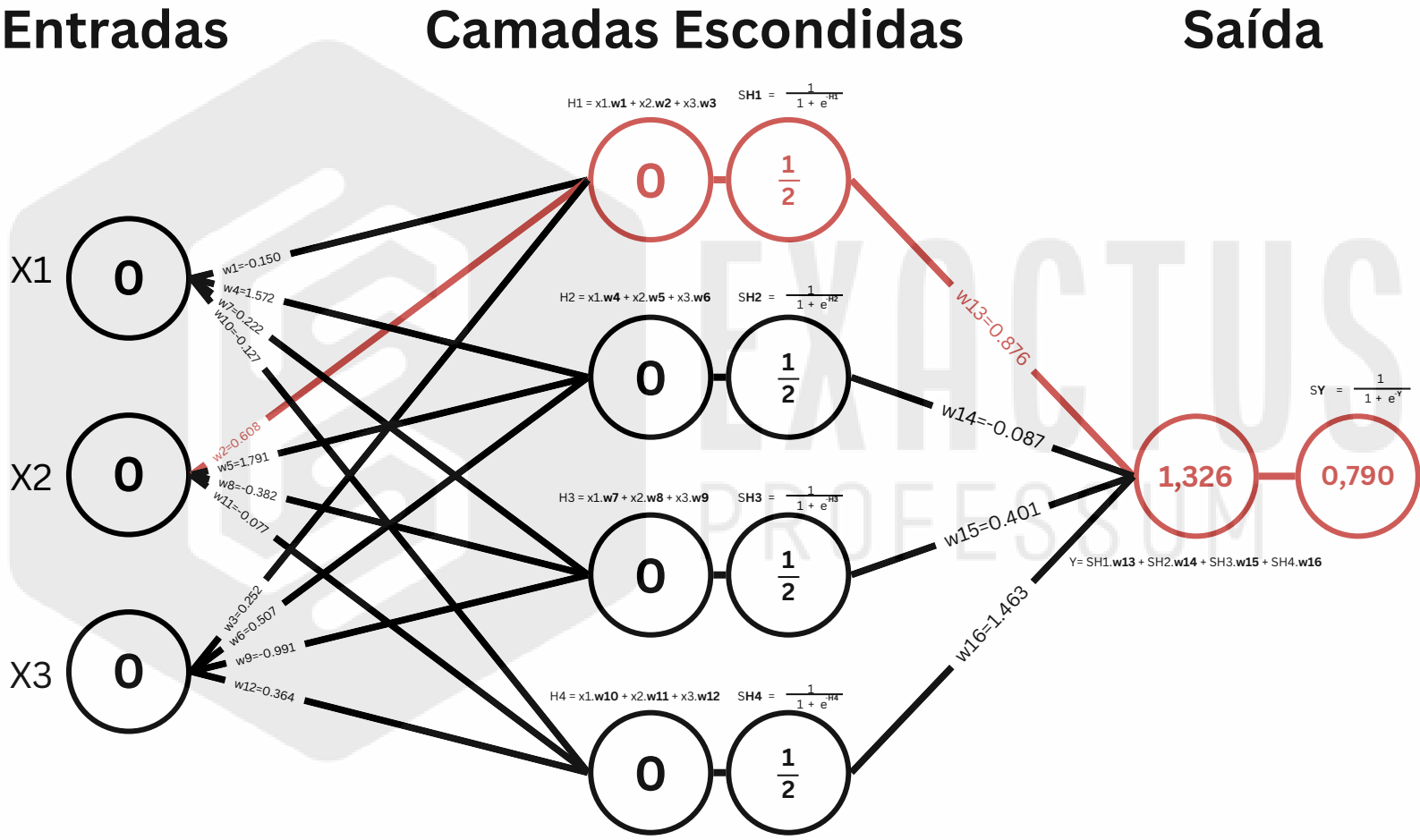
Modelo Backpropagation

← Backward Propagation ←

Iteração 1

Corrigindo Erro, em função de w2

E(w2)



$$\frac{\partial E}{\partial w_2} = \frac{\partial E}{\partial SY} x \frac{\partial SY}{\partial Y} x \frac{\partial Y}{\partial SH1} x \frac{\partial SH1}{\partial H1} x \frac{\partial H1}{\partial w_2}$$

← Backward Propagation ←

Iteração 1

Modelo Backpropagation

← Backward Propagation ←

Iteração 1

A $$\frac{\partial E}{\partial SY} = \frac{2}{2} * (S - SY)^1 * (-1) = (S - SY)^1 * (-1)$$

B $$\frac{\partial SY}{\partial Y} = SY * (1 - SY)$$

C1 $$\frac{\partial Y}{\partial SH1} = 1.w13 + 0 + 0 + 0$$

C2 $$\frac{\partial SH1}{\partial H1} = SH1 * (1 - SH1)$$

C3 $$\frac{\partial H1}{\partial w_2} = 0 + X2.1 + 0$$

$\frac{\partial E}{\partial SY}$ = (S - SY)¹ * (-1) = (0 - 0,790) * (-1) = 0,790

$\frac{\partial SY}{\partial Y}$ = SY * (1 - SY) = 0,790 * (1 - 0,790) = 0,165

$\frac{\partial Y}{\partial SH1}$ = w13 ========== 0,876

$\frac{\partial SH1}{\partial H1}$ = SH1 * (1 - SH1) = 0,5 * (1 - 0,5) === 0,250

$\frac{\partial H1}{\partial w_2}$ = X2 ========== 0,000

Gradiente $\frac{\partial E}{\partial w_2} = 0{,}790\ x\ 0{,}165\ x\ 0{,}876\ x\ 0{,}250\ x\ 0{,}000 = 0{,}000$ **W2**

← Backward Propagation ←

Modelo Backpropagation

← Backward Propagation ←

Iteração 1

$$W_2^{new} = W_2^{old} - 0.50\left(\frac{\partial E}{\partial W_2}\right)$$

$$W_2^{new} = 0{,}608 - 0.50 * (0{,}000)$$

$$W_2^{new} = 0{,}608$$

← Backward Propagation ←

Iteração 1

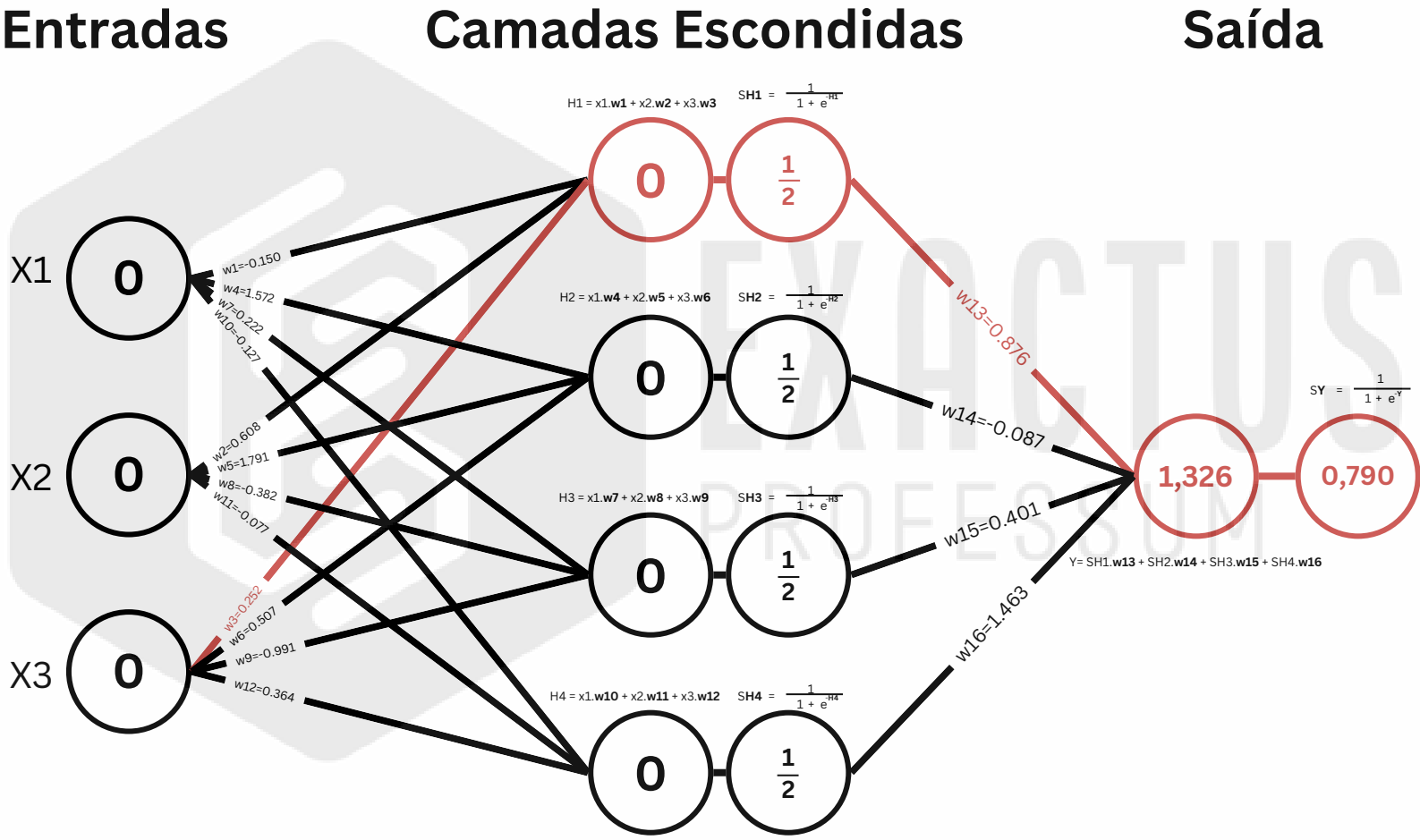
Modelo Backpropagation

← Backward Propagation ←

Iteração 1

Corrigindo Erro, em função de w3

E(w3)



$$\frac{\partial E}{\partial w_3} = \frac{\partial E}{\partial SY} x \frac{\partial SY}{\partial Y} x \frac{\partial Y}{\partial SH1} x \frac{\partial SH1}{\partial H1} x \frac{\partial H1}{\partial w_3}$$

← Backward Propagation ←

Iteração 1

Modelo Backpropagation

Backward Propagation

Iteração 1

A $$\frac{\partial E}{\partial SY} = \frac{2}{2} * (S - SY)^1 * (-1) = (S - SY)^1 * (-1)$$

B $$\frac{\partial SY}{\partial Y} = SY * (1 - SY)$$

C1 $$\frac{\partial Y}{\partial SH1} = 1.w13 + 0 + 0 + 0$$

C2 $$\frac{\partial SH1}{\partial H1} = SH1 * (1 - SH1)$$

C3 $$\frac{\partial H1}{\partial w_3} = 0 + 0 + X3 \,.\, 1$$

$\frac{\partial E}{\partial SY}$ = (S - SY)¹ * (-1) = (0 - 0,790) * (-1) = 0,790

$\frac{\partial SY}{\partial Y}$ = SY * (1 - SY) = 0,790 * (1 - 0,790) = 0,165

$\frac{\partial Y}{\partial SH1}$ = w13 ========== 0,876

$\frac{\partial SH1}{\partial H1}$ = SH1 * (1 - SH1) = 0,5 * (1 - 0,5) === 0,250

$\frac{\partial H1}{\partial w_3}$ = X3 ========== 0,000

Gradiente $\frac{\partial E}{\partial w_3} = 0{,}790\ x\ 0{,}165\ x\ 0{,}876\ x\ 0{,}250\ x\ 0{,}000 = 0{,}000$ **W3**

Backward Propagation

Modelo Backpropagation

← Backward Propagation ←

Iteração 1

$$W_3^{new} = W_3^{old} - 0.50\left(\frac{\partial E}{\partial W_3}\right)$$

$$W_3^{new} = 0{,}252 - 0.50 * (0{,}000)$$

$$W_3^{new} = 0{,}252$$

← Backward Propagation ←

Iteração 1

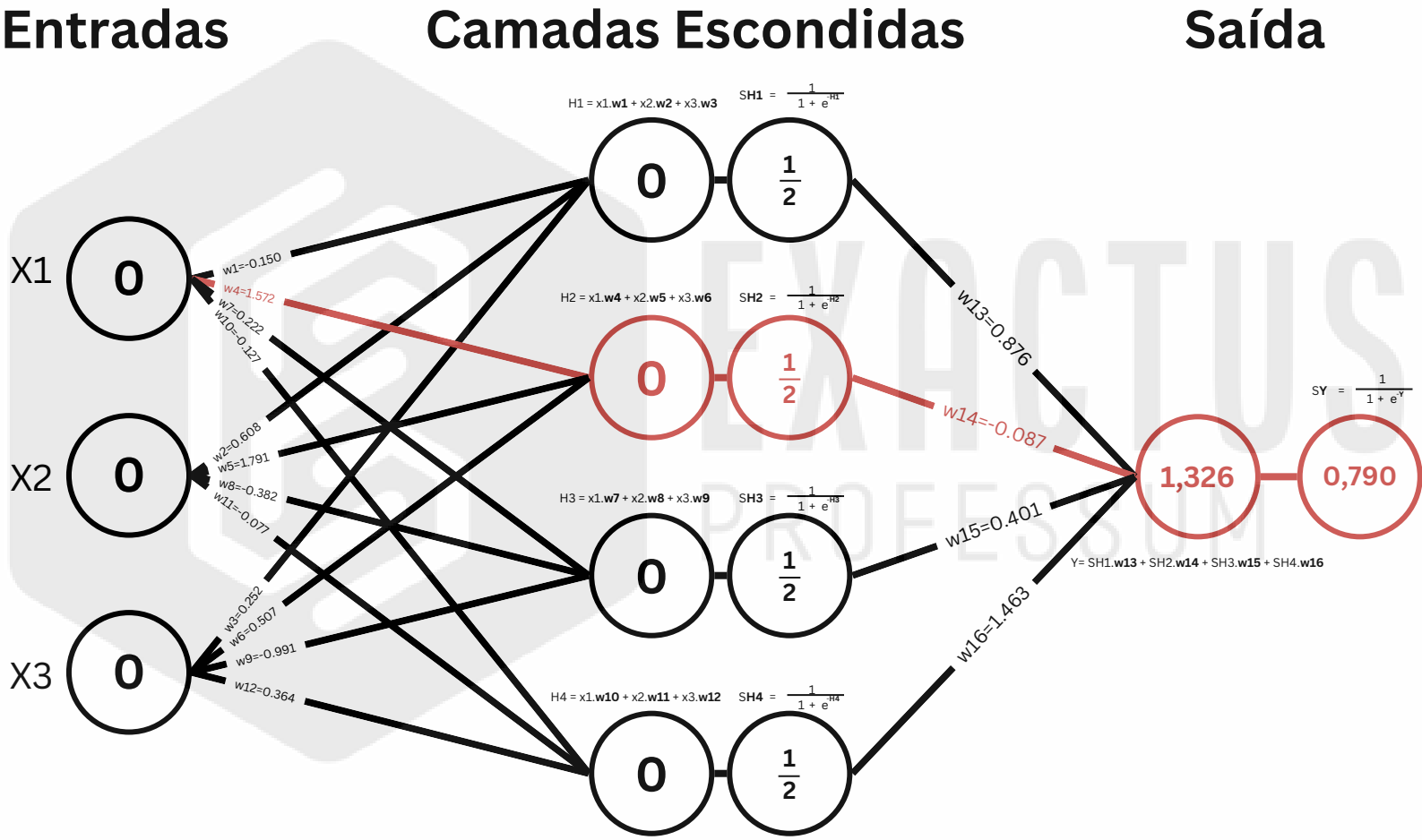
Modelo Backpropagation

← Backward Propagation ←

Iteração 1

Corrigindo Erro, em função de w4

E(w4)



$$\frac{\partial E}{\partial w_4} = \frac{\partial E}{\partial SY} x \frac{\partial SY}{\partial Y} x \frac{\partial Y}{\partial SH2} x \frac{\partial SH2}{\partial H2} x \frac{\partial H2}{\partial w_4}$$

← Backward Propagation ←

Iteração 1

Modelo Backpropagation

Backward Propagation

Iteração 1

A $$\frac{\partial E}{\partial SY} = \frac{2}{2} * (S - SY)^1 * (-1) = (S - SY)^1 * (-1)$$

B $$\frac{\partial SY}{\partial Y} = SY * (1 - SY)$$

C1 $$\frac{\partial Y}{\partial SH2} = 0 + w14 \,.\, \mathbf{1} + 0 + 0$$

C2 $$\frac{\partial SH2}{\partial H2} = SH2 * (1 - SH2)$$

C3 $$\frac{\partial H2}{\partial w_4} = X1 \,.\, \mathbf{1} + 0 + 0$$

$\frac{\partial E}{\partial SY}$ = (S - SY)¹ * (-1) = (0 - 0,790) * (-1) = 0,790

$\frac{\partial SY}{\partial Y}$ = SY * (1 - SY) = 0,790 * (1 - 0,790) = 0,165

$\frac{\partial Y}{\partial SH2}$ = w14 ========== -0,087

$\frac{\partial SH2}{\partial H2}$ = SH2 * (1 - SH2) = 0,5 * (1 - 0,5) === 0,250

$\frac{\partial H2}{\partial w_4}$ = X1 ========== 0,000

Gradiente $$\frac{\partial E}{\partial w_4} = 0{,}790 \; x \; 0{,}165 \; x \; (-0{,}087) \; x \; 0{,}250 \; x \; 0{,}000 = 0{,}000$$ **W4**

Backward Propagation

Modelo Backpropagation

← Backward Propagation ←

Iteração 1

$$W_4^{new} = W_4^{old} - 0.50\left(\frac{\partial E}{\partial W_4}\right)$$

$$W_4^{new} = 1{,}572 - 0.50 * (0{,}000)$$

$$W_4^{new} = 1{,}572$$

← Backward Propagation ←

Iteração 1

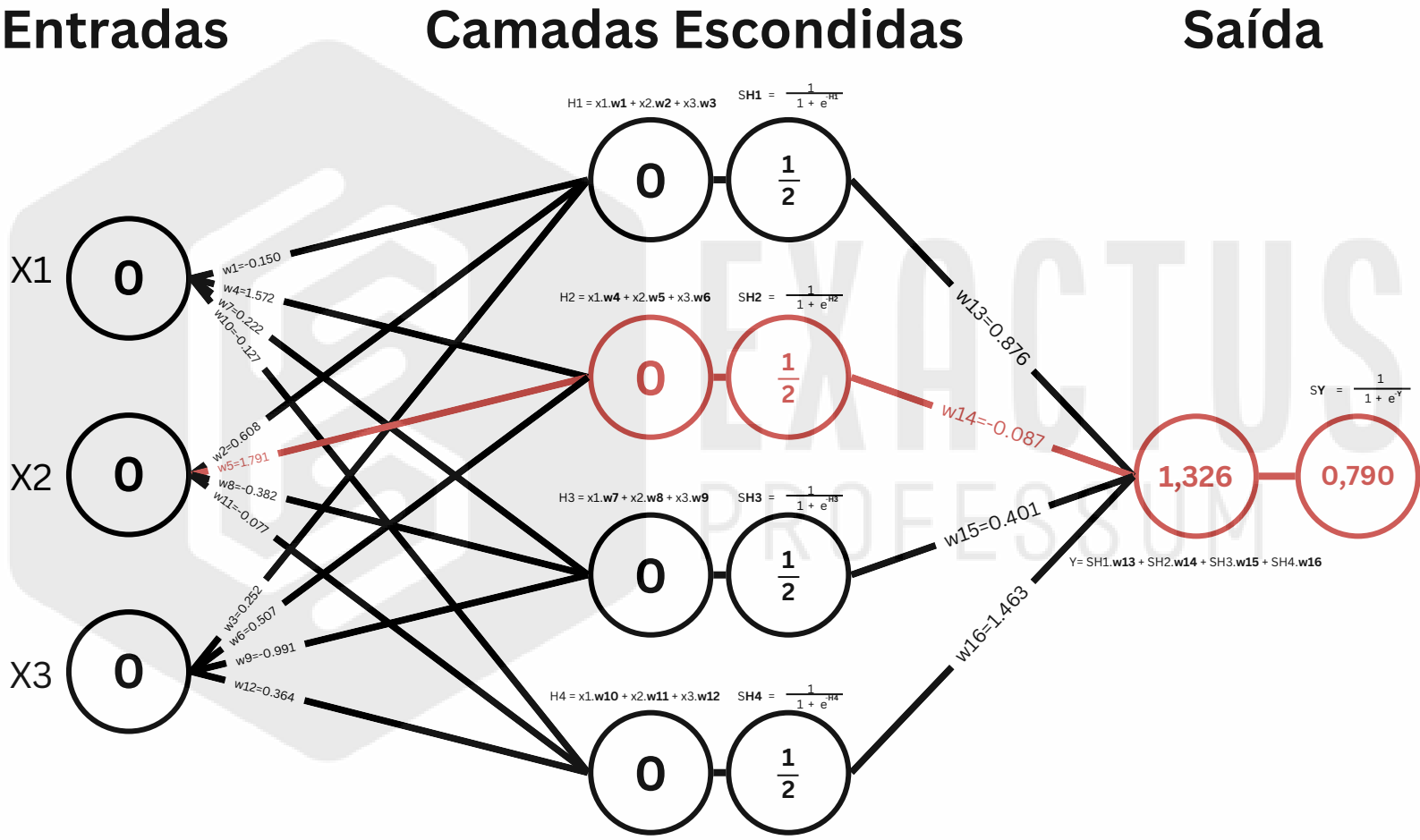
Modelo Backpropagation

← Backward Propagation ←

Iteração 1

Corrigindo Erro, em função de w5

E(w5)



$$\frac{\partial E}{\partial w_5} = \frac{\partial E}{\partial SY} x \frac{\partial SY}{\partial Y} x \frac{\partial Y}{\partial SH2} x \frac{\partial SH2}{\partial H2} x \frac{\partial H2}{\partial w_5}$$

← Backward Propagation ←

Iteração 1

Modelo Backpropagation

← Backward Propagation ←

Iteração 1

A $$\frac{\partial E}{\partial SY} = \frac{2}{2} * (S - SY)^1 * (-1) = (S - SY)^1 * (-1)$$

B $$\frac{\partial SY}{\partial Y} = SY * (1 - SY)$$

C1 $$\frac{\partial Y}{\partial SH2} = 0 + w14 \,.\, \mathbf{1} + 0 + 0$$

C2 $$\frac{\partial SH2}{\partial H2} = SH2 * (1 - SH2)$$

C3 $$\frac{\partial H2}{\partial w_5} = 0 + X2 \,.\, \mathbf{1} + 0$$

$\frac{\partial E}{\partial SY}$ = (S - SY)¹ * (-1) = (0 - 0,790) * (-1) = 0,790

$\frac{\partial SY}{\partial Y}$ = SY * (1 - SY) = 0,790 * (1 - 0,790) = 0,165

$\frac{\partial Y}{\partial SH2}$ = w14 ========== 0,087

$\frac{\partial SH2}{\partial H2}$ = SH2 * (1 - SH2) = 0,5 * (1 - 0,5) === 0,250

$\frac{\partial H2}{\partial w_5}$ = X2 ========== 0,000

Gradiente $$\frac{\partial E}{\partial w_5} = 0{,}790 \; x \; 0{,}165 \; x \; 0{,}087 \; x \; 0{,}250 \; x \; 0{,}000 = 0{,}000$$ **W5**

← Backward Propagation ←

Modelo Backpropagation

← Backward Propagation ←

Iteração 1

$$W_5^{new} = W_5^{old} - 0.50\left(\frac{\partial E}{\partial W_5}\right)$$

$$W_5^{new} = 1{,}791 - 0.50 * (0{,}000)$$

$$W_5^{new} = 1{,}791$$

← Backward Propagation ←

Iteração 1

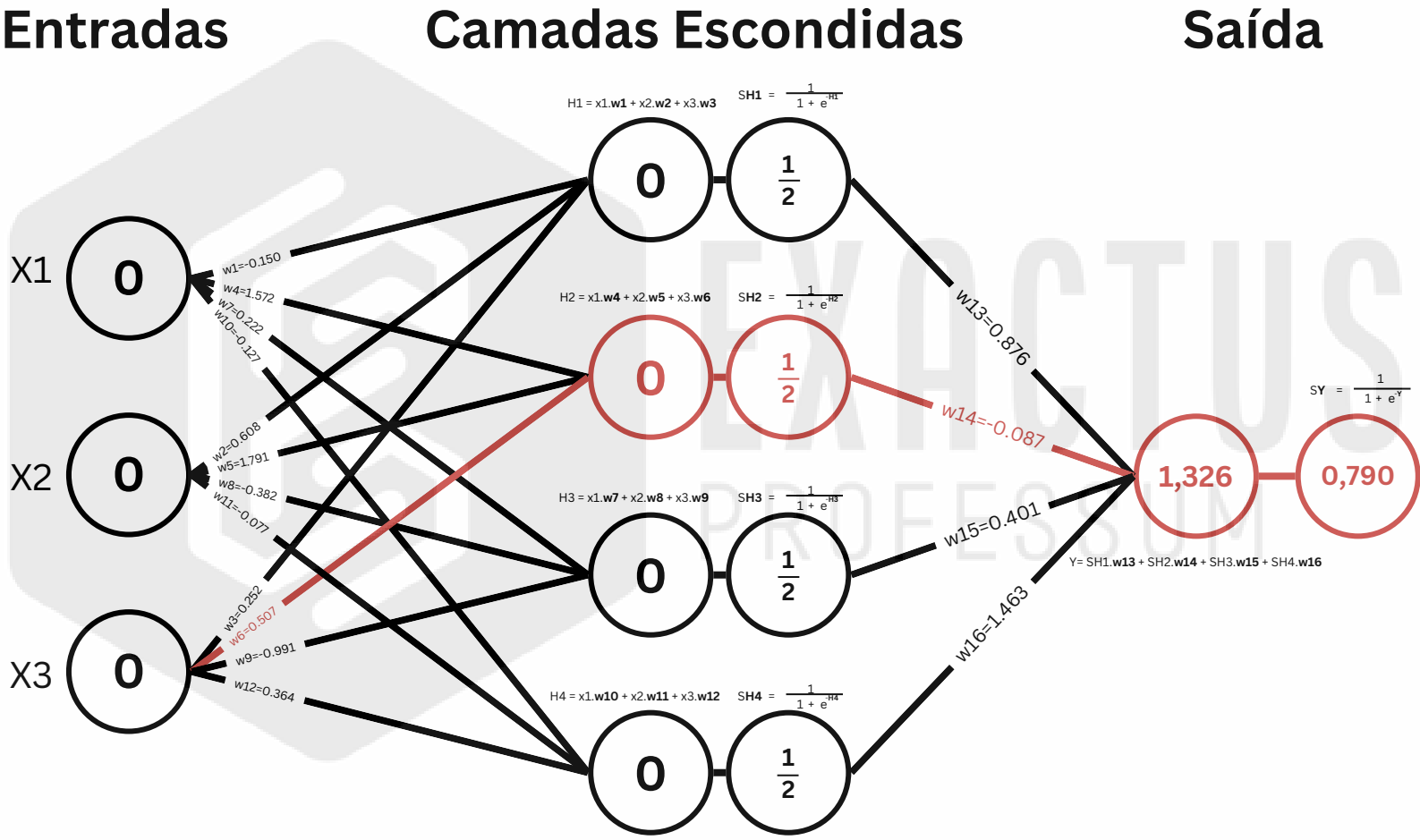
Modelo Backpropagation

← Backward Propagation ←

Iteração 1

Corrigindo Erro, em função de w6

E(w6)



$$\frac{\partial E}{\partial w_6} = \frac{\partial E}{\partial SY} x \frac{\partial SY}{\partial Y} x \frac{\partial Y}{\partial SH2} x \frac{\partial SH2}{\partial H2} x \frac{\partial H2}{\partial w_6}$$

← Backward Propagation ←

Iteração 1

Modelo Backpropagation

← Backward Propagation ←

Iteração 1

A $$\frac{\partial E}{\partial SY} = \frac{2}{2} * (S - SY)^1 * (-1) = (S - SY)^1 * (-1)$$

B $$\frac{\partial SY}{\partial Y} = SY * (1 - SY)$$

C1 $$\frac{\partial Y}{\partial SH2} = 0 + w14 \,.\, \mathbf{1} + 0 + 0$$

C2 $$\frac{\partial SH2}{\partial H2} = SH2 * (1 - SH2)$$

C3 $$\frac{\partial H2}{\partial w_6} = 0 + 0 + X3 \,.\, \mathbf{1}$$

$\frac{\partial E}{\partial SY}$ = (S - SY)¹ * (-1) = (0 - 0,790) * (-1) = 0,790

$\frac{\partial SY}{\partial Y}$ = SY * (1 - SY) = 0,790 * (1 - 0,790) = 0,165

$\frac{\partial Y}{\partial SH2}$ = w14 ========== 0,087

$\frac{\partial SH2}{\partial H2}$ = SH2 * (1 - SH2) = 0,5 * (1 - 0,5) === 0,250

$\frac{\partial H2}{\partial w_6}$ = X3 ========== 0,000

Gradiente $$\frac{\partial E}{\partial w_6} = 0{,}790 \; x \; 0{,}165 \; x \; 0{,}087 \; x \; 0{,}250 \; x \; 0{,}000 = 0{,}000$$ **W6**

← Backward Propagation ←

Modelo Backpropagation

← Backward Propagation ←

Iteração 1

$$W_6^{new} = W_6^{old} - 0.50\left(\frac{\partial E}{\partial W_6}\right)$$

$$W_6^{new} = 0{,}507 - 0.50 * (0{,}000)$$

$$W_6^{new} = 0{,}507$$

← Backward Propagation ←

Iteração 1

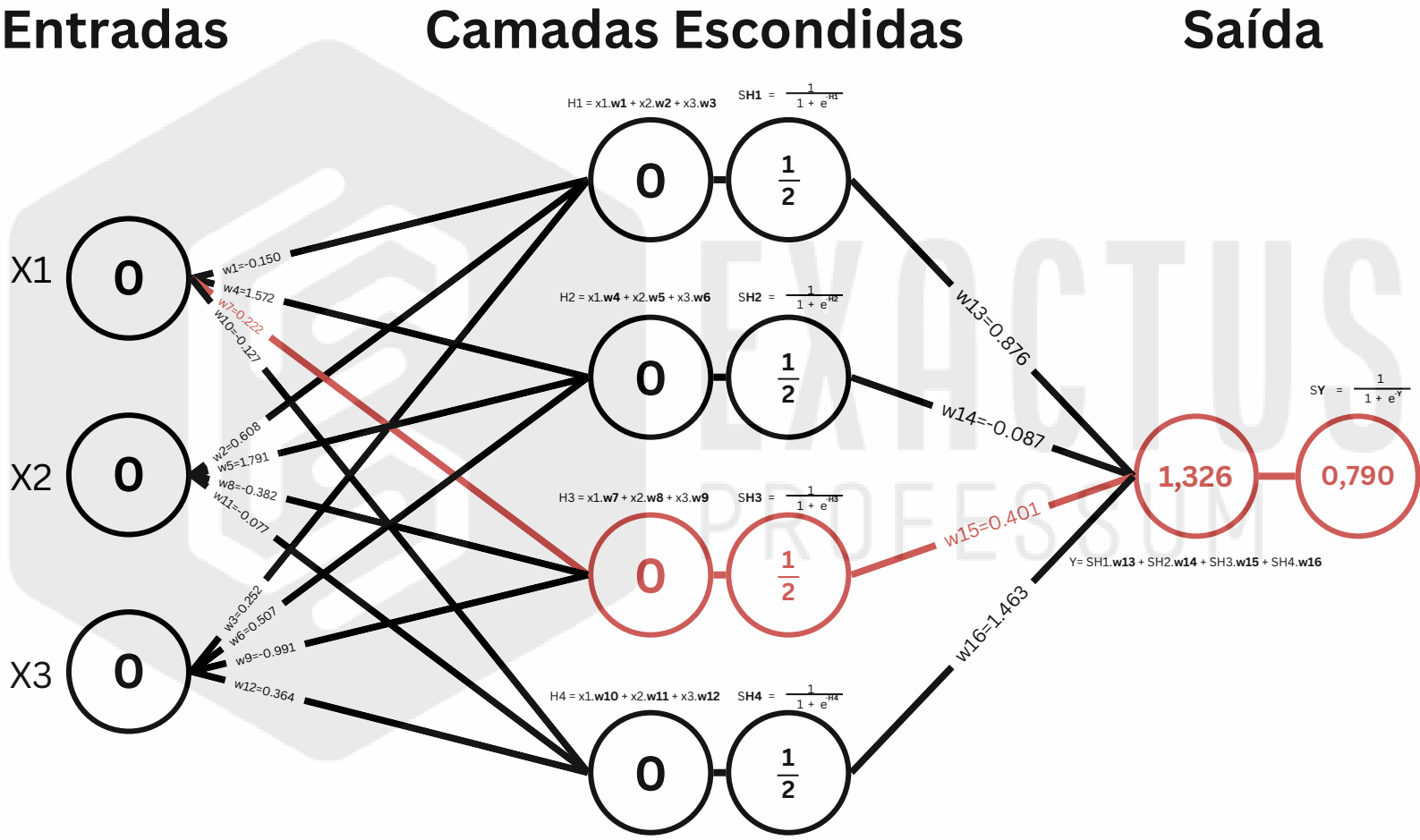
Modelo Backpropagation

← Backward Propagation ←

Iteração 1

Corrigindo Erro, em função de w7

E(w7)



$$\frac{\partial E}{\partial w_7} = \frac{\partial E}{\partial SY} x \frac{\partial SY}{\partial Y} x \frac{\partial Y}{\partial SH3} x \frac{\partial SH3}{\partial H3} x \frac{\partial H3}{\partial w_7}$$

← Backward Propagation ←

Iteração 1

Modelo Backpropagation

← Backward Propagation ←

Iteração 1

A $$\frac{\partial E}{\partial SY} = \frac{2}{2} * (S - SY)^1 * (-1) = (S - SY)^1 * (-1)$$

B $$\frac{\partial SY}{\partial Y} = SY * (1 - SY)$$

C1 $$\frac{\partial Y}{\partial SH3} = 0 + 0 + w15 \,.\, \mathbf{1} + 0$$

C2 $$\frac{\partial SH3}{\partial H3} = SH3 * (1 - SH3)$$

C3 $$\frac{\partial H3}{\partial w_7} = X1 \,.\, \mathbf{1} + 0 + 0$$

$\frac{\partial E}{\partial SY}$ = (S - SY)¹ * (-1) = (0 - 0,790) * (-1) = 0,790

$\frac{\partial SY}{\partial Y}$ = SY * (1 - SY) = 0,790 * (1 - 0,790) = 0,165

$\frac{\partial Y}{\partial SH3}$ = w15 ========== 0,401

$\frac{\partial SH3}{\partial H3}$ = SH3 * (1 - SH3) = 0,5 * (1 - 0,5) === 0,250

$\frac{\partial H3}{\partial w_7}$ = X1 ========== 0,000

Gradiente $$\frac{\partial E}{\partial w_7} = 0{,}790 \; x \; 0{,}165 \; x \; 0{,}401 \; x \; 0{,}250 \; x \; 0{,}000 = 0{,}000$$ **W7**

← Backward Propagation ←

Modelo Backpropagation

← Backward Propagation ←

Iteração 1

$$W_7^{new} = W_7^{old} - 0.50\left(\frac{\partial E}{\partial W_7}\right)$$

$$W_7^{new} = 0{,}222 - 0.50 * (0{,}000)$$

$$W_7^{new} = 0{,}222$$

← Backward Propagation ←

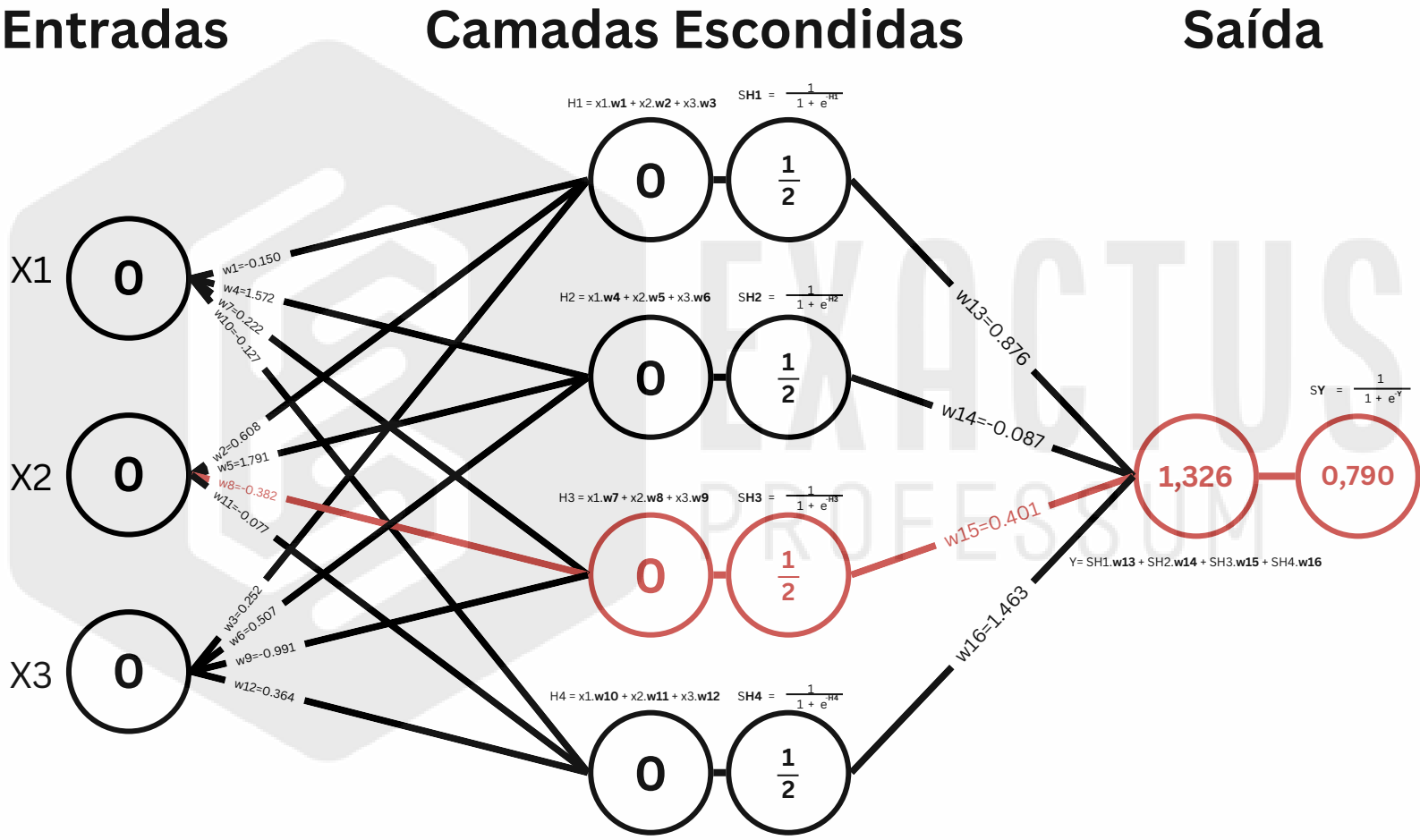
Iteração 1

Modelo Backpropagation

← Backward Propagation ←

Iteração 1

Corrigindo Erro, em função de w8
E(w8)



$$\frac{\partial E}{\partial w_8} = \frac{\partial E}{\partial SY} x \frac{\partial SY}{\partial Y} x \frac{\partial Y}{\partial SH3} x \frac{\partial SH3}{\partial H3} x \frac{\partial H3}{\partial w_8}$$

← Backward Propagation ←

Iteração 1

Modelo Backpropagation

← Backward Propagation ←

Iteração 1

A $$\frac{\partial E}{\partial SY} = \frac{2}{2} * (S - SY)^1 * (-1) = (S - SY)^1 * (-1)$$

B $$\frac{\partial SY}{\partial Y} = SY * (1 - SY)$$

C1 $$\frac{\partial Y}{\partial SH3} = 0 + 0 + w15 \,.\, \mathbf{1} + 0$$

C2 $$\frac{\partial SH3}{\partial H3} = SH3 * (1 - SH3)$$

C3 $$\frac{\partial H3}{\partial w_8} = 0 + X2 \,.\, \mathbf{1} + 0$$

$\frac{\partial E}{\partial SY}$ = (S - SY)¹ * (-1) = (0 - 0,790) * (-1) = 0,790

$\frac{\partial SY}{\partial Y}$ = SY * (1 - SY) = 0,790 * (1 - 0,790) = 0,165

$\frac{\partial Y}{\partial SH3}$ = w15 ========== 0,401

$\frac{\partial SH3}{\partial H3}$ = SH3 * (1 - SH3) = 0,5 * (1 - 0,5) === 0,250

$\frac{\partial H3}{\partial w_8}$ = X2 ========== 0,000

Gradiente $\frac{\partial E}{\partial w_8} = 0{,}790 \; x \; 0{,}165 \; x \; 0{,}401 \; x \; 0{,}250 \; x \; 0{,}000 = 0{,}000$ **W8**

← Backward Propagation ←

Modelo Backpropagation

← Backward Propagation ←

Iteração 1

$$W_8^{new} = W_8^{old} - 0.50\left(\frac{\partial E}{\partial W_8}\right)$$

$$W_8^{new} = -0{,}382 - 0.50 * (0{,}000)$$

$$W_8^{new} = -0{,}382$$

← Backward Propagation ←

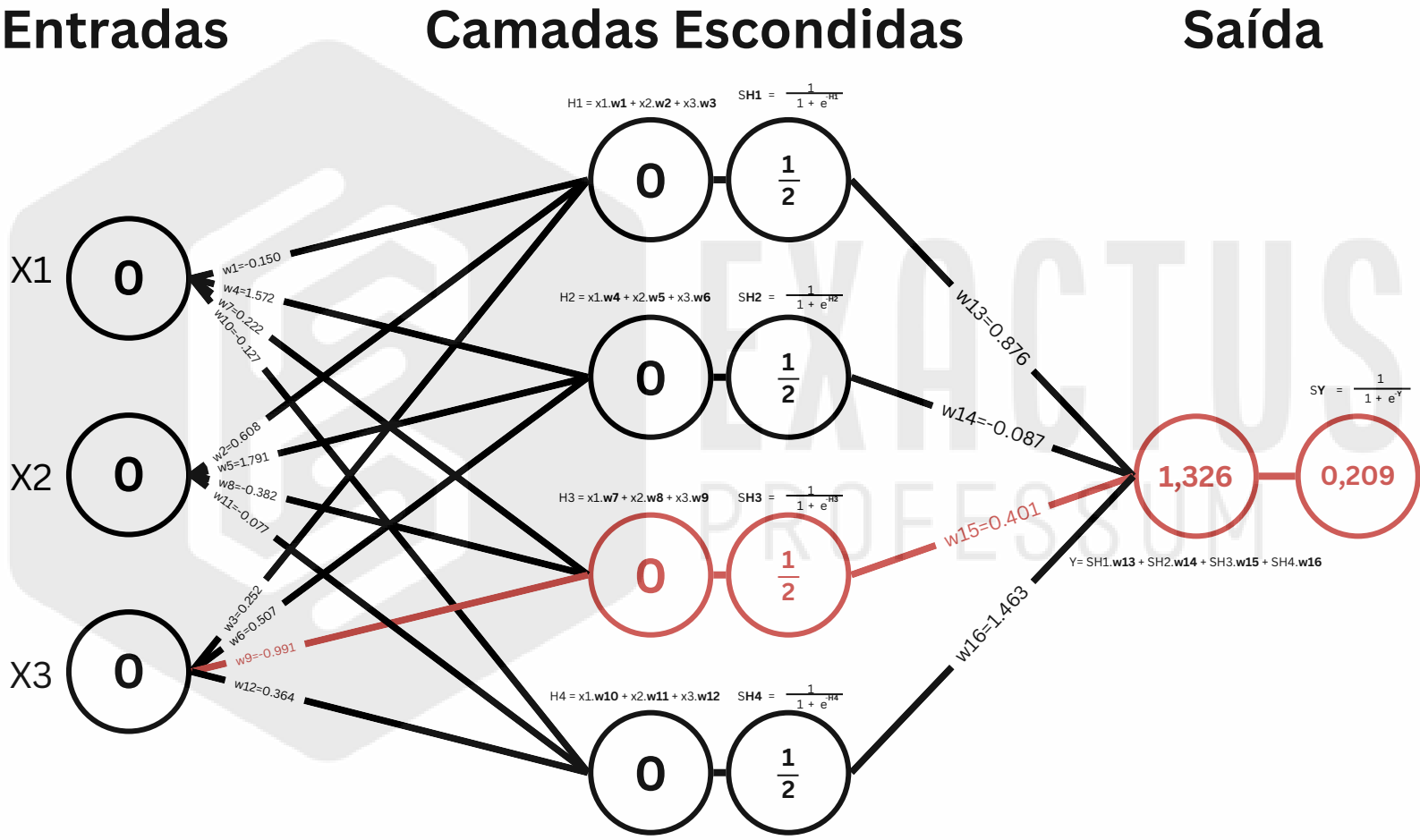
Iteração 1

Modelo Backpropagation

← Backward Propagation ←

Iteração 1

Corrigindo Erro, em função de w9
E(w9)



$$\frac{\partial E}{\partial w_9} = \frac{\partial E}{\partial SY} x \frac{\partial SY}{\partial Y} x \frac{\partial Y}{\partial SH3} x \frac{\partial SH3}{\partial H3} x \frac{\partial H3}{\partial w_9}$$

← Backward Propagation ←

Iteração 1

Modelo Backpropagation

Backward Propagation

Iteração 1

A $$\frac{\partial E}{\partial SY} = \frac{2}{2} * (S - SY)^1 * (-1) = (S - SY)^1 * (-1)$$

B $$\frac{\partial SY}{\partial Y} = SY * (1 - SY)$$

C1 $$\frac{\partial Y}{\partial SH3} = 0 + 0 + w15 \,.\, \mathbf{1} + 0$$

C2 $$\frac{\partial SH3}{\partial H3} = SH3 * (1 - SH3)$$

C3 $$\frac{\partial H3}{\partial w_9} = 0 + 0 + X3 \,.\, \mathbf{1}$$

$\frac{\partial E}{\partial SY}$ = (S - SY)¹ * (-1) = (0 - 0,790) * (-1) = 0,790

$\frac{\partial SY}{\partial Y}$ = SY * (1 - SY) = 0,790 * (1 - 0,790) = 0,165

$\frac{\partial Y}{\partial SH3}$ = w15 ========== 0,401

$\frac{\partial SH3}{\partial H3}$ = SH3 * (1 - SH3) = 0,5 * (1 - 0,5) === 0,250

$\frac{\partial H3}{\partial w_9}$ = X3 ========== 0,000

Gradiente $$\frac{\partial E}{\partial w_9} = 0{,}790 \; x \; 0{,}165 \; x \; 0{,}401 \; x \; 0{,}250 \; x \; 0{,}000 = 0{,}000$$ **W9**

Backward Propagation

Modelo Backpropagation

← Backward Propagation ←

Iteração 1

$$W_9^{new} = W_9^{old} - 0.50\left(\frac{\partial E}{\partial W_9}\right)$$

$$W_9^{new} = -0{,}991 - 0.50 * (0{,}000)$$

$$W_9^{new} = -0{,}991$$

← Backward Propagation ←

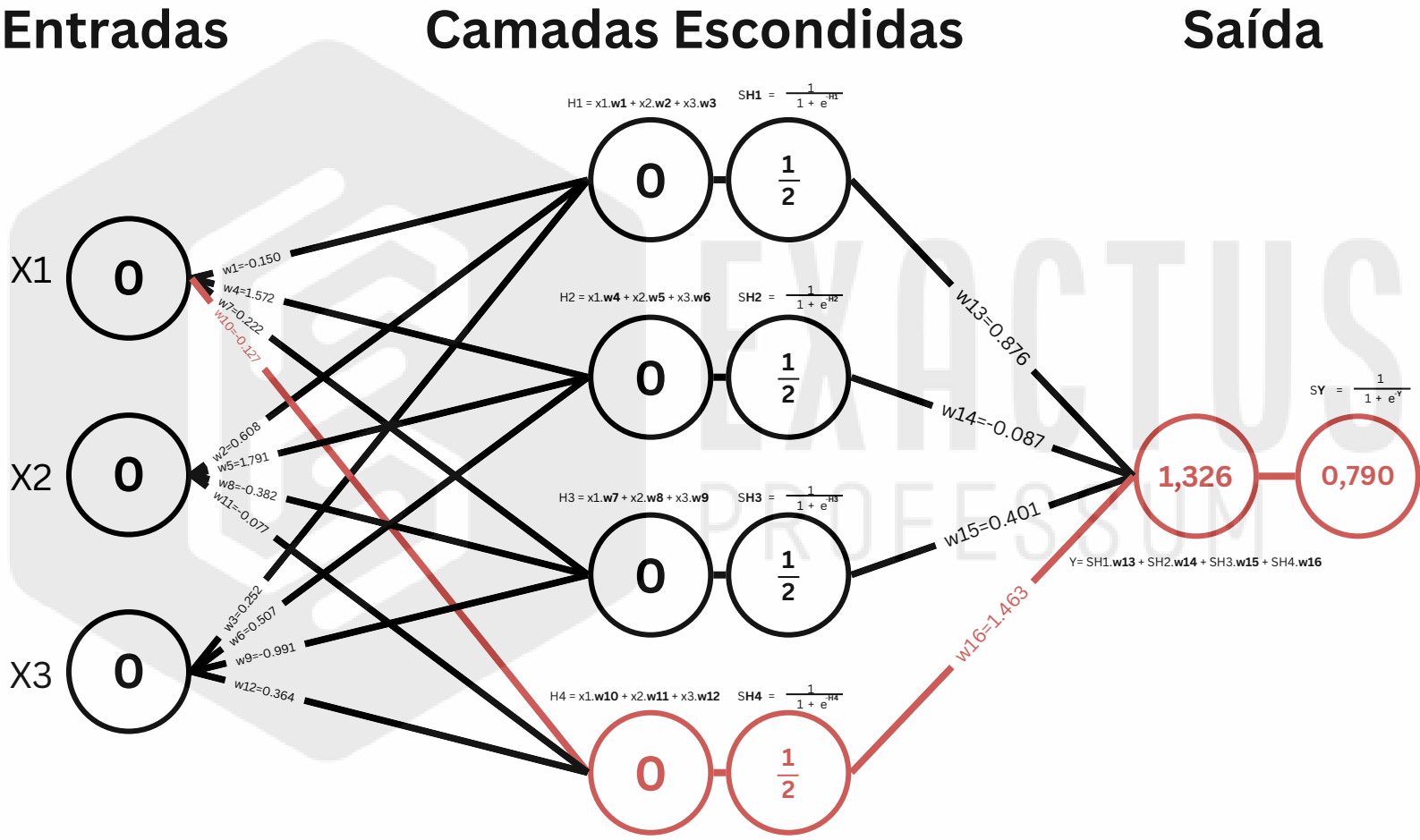
Iteração 1

Modelo Backpropagation

← Backward Propagation ←

Iteração 1

Corrigindo Erro, em função de w10
E(w10)



$$\frac{\partial E}{\partial w_{10}} = \frac{\partial E}{\partial SY} x \frac{\partial SY}{\partial Y} x \frac{\partial Y}{\partial SH4} x \frac{\partial SH4}{\partial H4} x \frac{\partial H4}{\partial w_{10}}$$

← Backward Propagation ←

Iteração 1

Modelo Backpropagation

← Backward Propagation ←

Iteração 1

A $$\frac{\partial E}{\partial SY} = \frac{2}{2} * (S - SY)^1 * (-1) = (S - SY)^1 * (-1)$$

B $$\frac{\partial SY}{\partial Y} = SY * (1 - SY)$$

C1 $$\frac{\partial Y}{\partial SH4} = 0 + 0 + 0 + w16 \,.\, \mathbf{1}$$

C2 $$\frac{\partial SH4}{\partial H4} = SH4 * (1 - SH4)$$

C3 $$\frac{\partial H4}{\partial w_{10}} = X1 \,.\, \mathbf{1} + 0 + 0$$

$\frac{\partial E}{\partial SY}$ = (S - SY)¹ * (-1) = (0 - 0,790) * (-1) = 0,790

$\frac{\partial SY}{\partial Y}$ = SY * (1 - SY) = 0,790 * (1 - 0,790) = 0,165

$\frac{\partial Y}{\partial SH4}$ = w16 ========== 1,463

$\frac{\partial SH4}{\partial H4}$ = SH4 * (1 - SH4) = 0,5 * (1 - 0,5) === 0,250

$\frac{\partial H4}{\partial w_{10}}$ = X1 ========== 0,000

Gradiente $$\frac{\partial E}{\partial w_{10}} = 0{,}790 \; x \; 0{,}165 \; x \; 1{,}463 \; x \; 0{,}250 \; x \; 0{,}000 = 0{,}000$$ **W10**

← Backward Propagation ←

Modelo Backpropagation

← Backward Propagation ←

Iteração 1

$$W_{10}^{new} = W_{10}^{old} - 0.50\left(\frac{\partial E}{\partial W_{10}}\right)$$

$$W_{10}^{new} = -0{,}127 - 0.50 * (0{,}000)$$

$$W_{10}^{new} = -0{,}127$$

← Backward Propagation ←

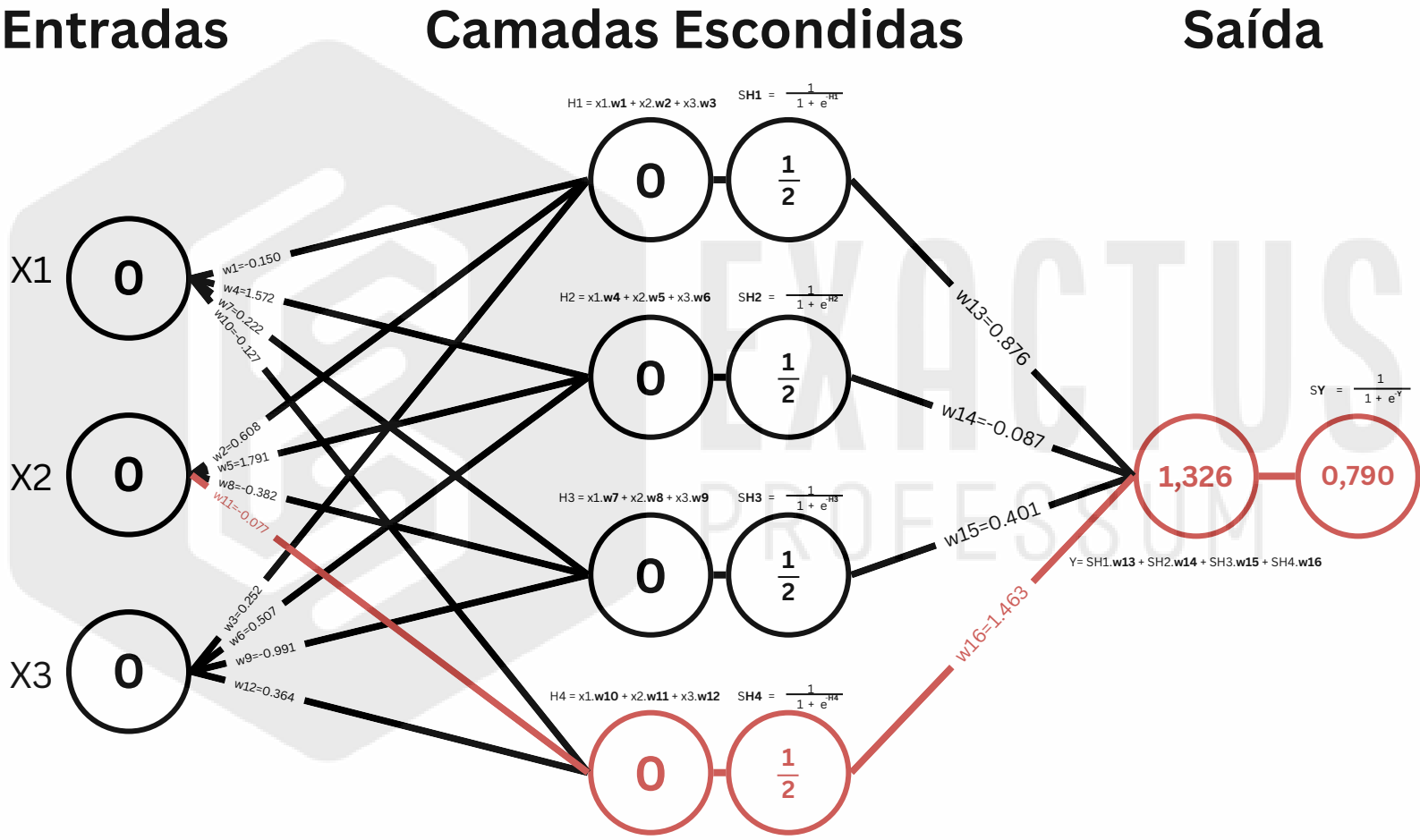
Iteração 1

Modelo Backpropagation

← Backward Propagation ←

Iteração 1

Corrigindo Erro, em função de w11
E(w11)



$$\frac{\partial E}{\partial w_{11}} = \frac{\partial E}{\partial SY} x \frac{\partial SY}{\partial Y} x \frac{\partial Y}{\partial SH4} x \frac{\partial SH4}{\partial H4} x \frac{\partial H4}{\partial w_{11}}$$

← Backward Propagation ←

Iteração 1

Modelo Backpropagation

← Backward Propagation ←

Iteração 1

A $$\frac{\partial E}{\partial SY} = \frac{2}{2} * (S - SY)^1 * (-1) = (S - SY)^1 * (-1)$$

B $$\frac{\partial SY}{\partial Y} = SY * (1 - SY)$$

C1 $$\frac{\partial Y}{\partial SH4} = 0 + 0 + 0 + w16 \,.\, \mathbf{1}$$

C2 $$\frac{\partial SH4}{\partial H4} = SH4 * (1 - SH4)$$

C3 $$\frac{\partial H4}{\partial w_{11}} = 0 + X2 \,.\, \mathbf{1} + 0$$

$\frac{\partial E}{\partial SY}$ = (S - SY)¹ * (-1) = (0 - 0,790) * (-1) = 0,790

$\frac{\partial SY}{\partial Y}$ = SY * (1 - SY) = 0,790 * (1 - 0,790) = 0,165

$\frac{\partial Y}{\partial SH4}$ = w16 ========== 1,463

$\frac{\partial SH4}{\partial H4}$ = SH4 * (1 - SH4) = 0,5 * (1 - 0,5) === 0,250

$\frac{\partial H4}{\partial w_{11}}$ = X2 ========== 0,000

Gradiente $$\frac{\partial E}{\partial w_{11}} = 0{,}790 \; x \; 0{,}165 \; x \; 1{,}463 \; x \; 0{,}250 \; x \; 0{,}000 = 0{,}000$$ **W11**

← Backward Propagation ←

Modelo Backpropagation

← Backward Propagation ←

Iteração 1

$$W_{11}^{new} = W_{11}^{old} - 0.50\left(\frac{\partial E}{\partial W_{11}}\right)$$

$$W_{11}^{new} = -0{,}077 - 0.50 * (0{,}000)$$

$$W_{11}^{new} = -0{,}077$$

← Backward Propagation ←

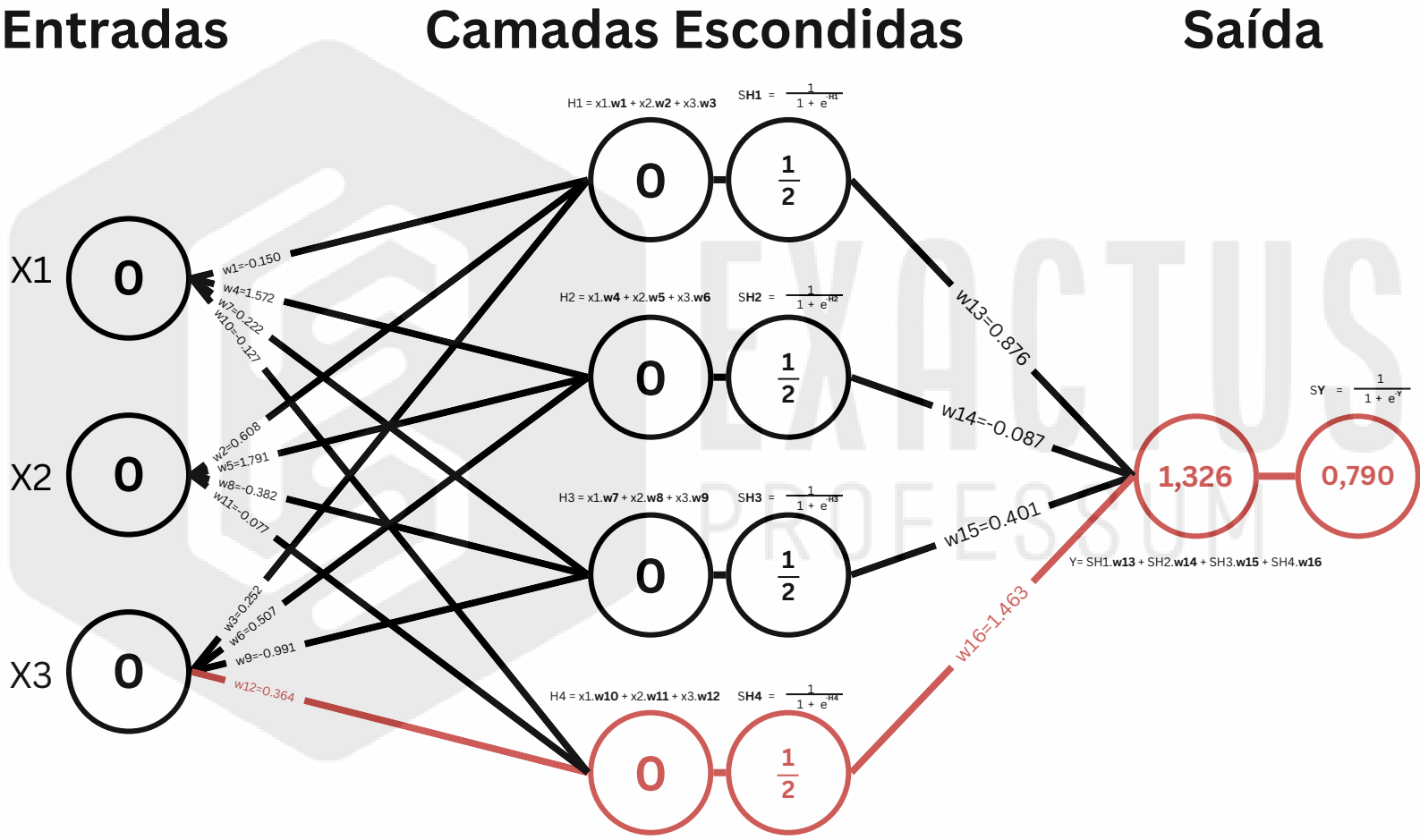
Iteração 1

Modelo Backpropagation

← Backward Propagation ←

Iteração 1

Corrigindo Erro, em função de w12
E(w12)



$$\frac{\partial E}{\partial w_{12}} = \frac{\partial E}{\partial SY} x \frac{\partial SY}{\partial Y} x \frac{\partial Y}{\partial SH4} x \frac{\partial SH4}{\partial H4} x \frac{\partial H4}{\partial w_{12}}$$

← Backward Propagation ←

Iteração 1

Modelo Backpropagation

← Backward Propagation ←

Iteração 1

A $$\frac{\partial E}{\partial SY} = \frac{2}{2} * (S - SY)^1 * (-1) = (S - SY)^1 * (-1)$$

B $$\frac{\partial SY}{\partial Y} = SY * (1 - SY)$$

C1 $$\frac{\partial Y}{\partial SH4} = 0 + 0 + 0 + w16 \,.\, \mathbf{1}$$

C2 $$\frac{\partial SH4}{\partial H4} = SH4 * (1 - SH4)$$

C3 $$\frac{\partial H4}{\partial w_{12}} = 0 + 0 + X3 \,.\, \mathbf{1}$$

$\frac{\partial E}{\partial SY}$ = (S - SY)¹ * (-1) = (0 - 0,790) * (-1) = 0,790

$\frac{\partial SY}{\partial Y}$ = SY * (1 - SY) = 0,790 * (1 - 0,790) = 0,165

$\frac{\partial Y}{\partial SH4}$ = w16 ========== 1,463

$\frac{\partial SH4}{\partial H4}$ = SH4 * (1 - SH4) = 0,5 * (1 - 0,5) === 0,250

$\frac{\partial H4}{\partial w_{12}}$ = X3 ========== 0,000

Gradiente $\frac{\partial E}{\partial w_{12}} = 0{,}790 \; x \; 0{,}165 \; x \; 1{,}463 \; x \; 0{,}250 \; x \; 0{,}000 = 0{,}000$ **W12**

← Backward Propagation ←

Modelo Backpropagation

← Backward Propagation ←

Iteração 1

$$W_{12}^{new} = W_{12}^{old} - 0.50\left(\frac{\partial E}{\partial W_{12}}\right)$$

$$W_{12}^{new} = 0{,}364 - 0.50 * (0{,}000)$$

$$W_{12}^{new} = 0{,}364$$

← Backward Propagation ←

Iteração 1

Modelo Backpropagation

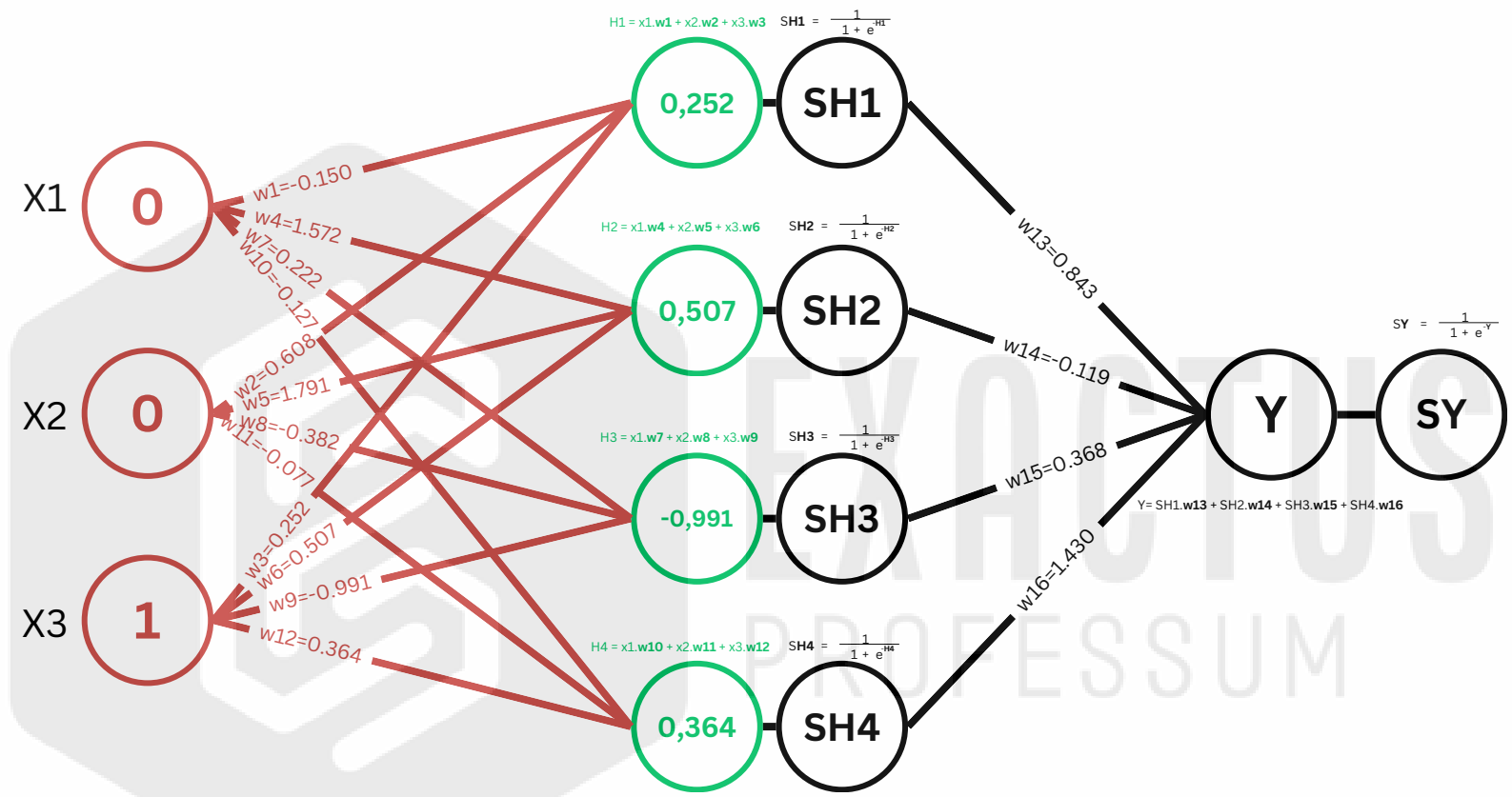
$w_1 = -0{,}150$	→	$w_1 = -0{,}150$
$w_2 = 0{,}608$	→	$w_2 = 0{,}608$
$w_3 = 0{,}252$	→	$w_3 = 0{,}252$
$w_4 = 1{,}572$	→	$w_4 = 1{,}572$
$w_5 = 1{,}791$	→	$w_5 = 1{,}791$
$w_6 = 0{,}507$	→	$w_6 = 0{,}507$
$w_7 = 0{,}222$	→	$w_7 = 0{,}222$
$w_8 = -0{,}382$	→	$w_8 = -0{,}382$
$w_9 = -0{,}991$	→	$w_9 = -0{,}991$
$w_{10} = -0{,}127$	→	$w_{10} = -0{,}127$
$w_{11} = -0{,}077$	→	$w_{11} = -0{,}077$
$w_{12} = 0{,}364$	→	$w_{12} = -0{,}150$
$w_{13} = 0{,}876$	→	$w_{13} = 0{,}843$
$w_{14} = -0{,}087$	→	$w_{14} = -0{,}119$
$w_{15} = 0{,}401$	→	$w_{15} = 0{,}368$
$w_{16} = 1{,}463$	→	$w_{16} = 1{,}430$

Pesos Anteriores → Pesos Atualizados

Modelo Backpropagation

Forward Propagation

Iteração 2



H1 = - 0 . **0,150** + 0 . **0,608** + 1 . **0,252** = **0,252**

H2 = + 0 . **1,572** + 0 . **1,791** + 1 . **0,507** = **0,507**

H3 = - 0 . **0,222** - 0 . **0,382** - 1 . **0,991** = **-0,991**

H4 = - 0 . **0,127** - 0 . **0,077** + 1 . **0,364** = **0,364**

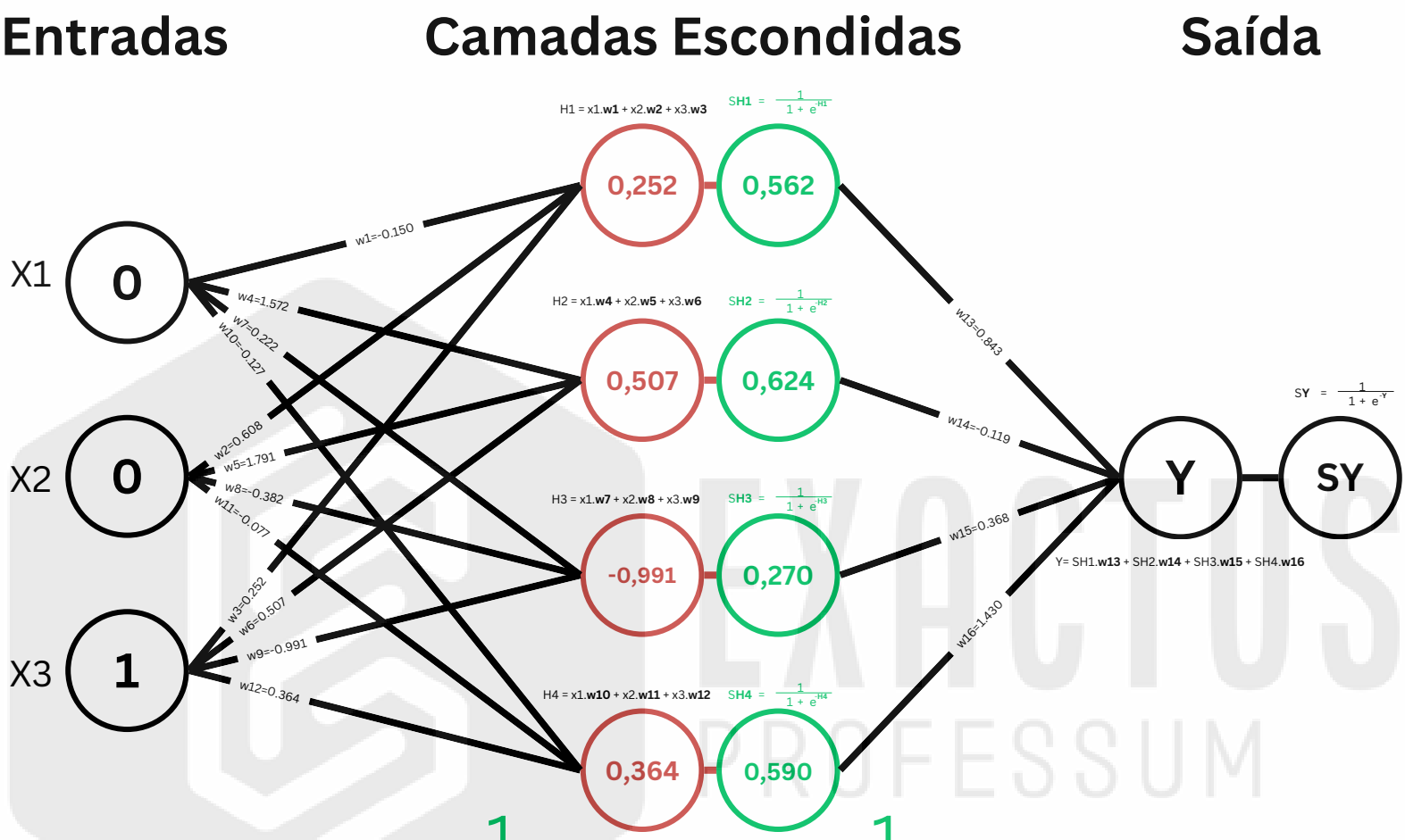
Forward Propagation

Iteração 2

Modelo Backpropagation

→ Forward Propagation →

Iteração 2



$$SH1 = \frac{1}{1 + e^{-H1}} = \frac{1}{1 + e^{-0,252}} = 0,562$$

$$SH2 = \frac{1}{1 + e^{-H2}} = \frac{1}{1 + e^{-0,507}} = 0,624$$

$$SH3 = \frac{1}{1 + e^{-H3}} = \frac{1}{1 + e^{0,991}} = 0,270$$

$$SH4 = \frac{1}{1 + e^{-H4}} = \frac{1}{1 + e^{-0,364}} = 0,590$$

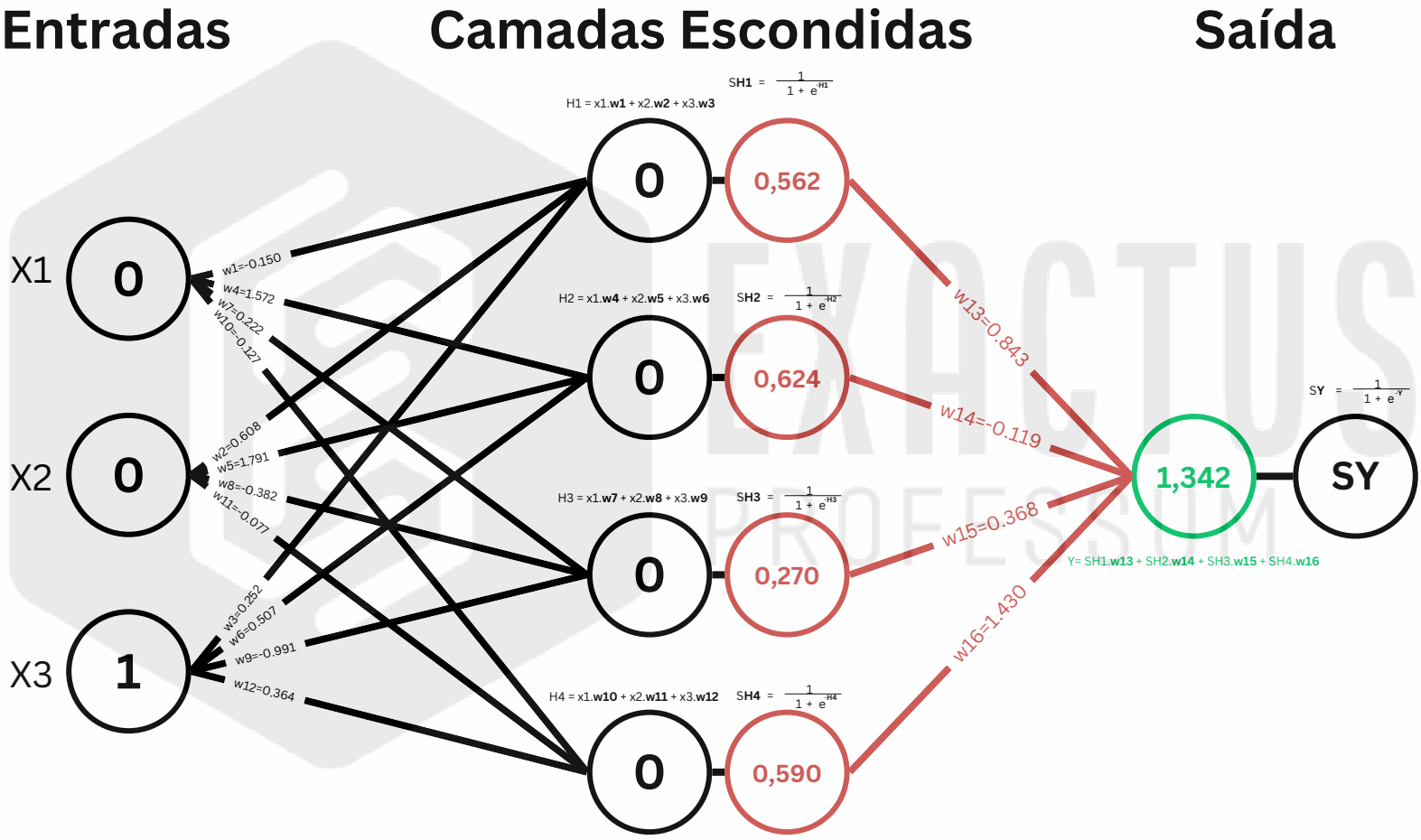
→ Forward Propagation →

Iteração 2

Modelo Backpropagation

→ Forward Propagation →

Iteração 2



Y = 0,562 . **0,843** - 0,624 . **0, 119** + 0,270 . **0,368** + 0,590 . **1,430** = **1,342**

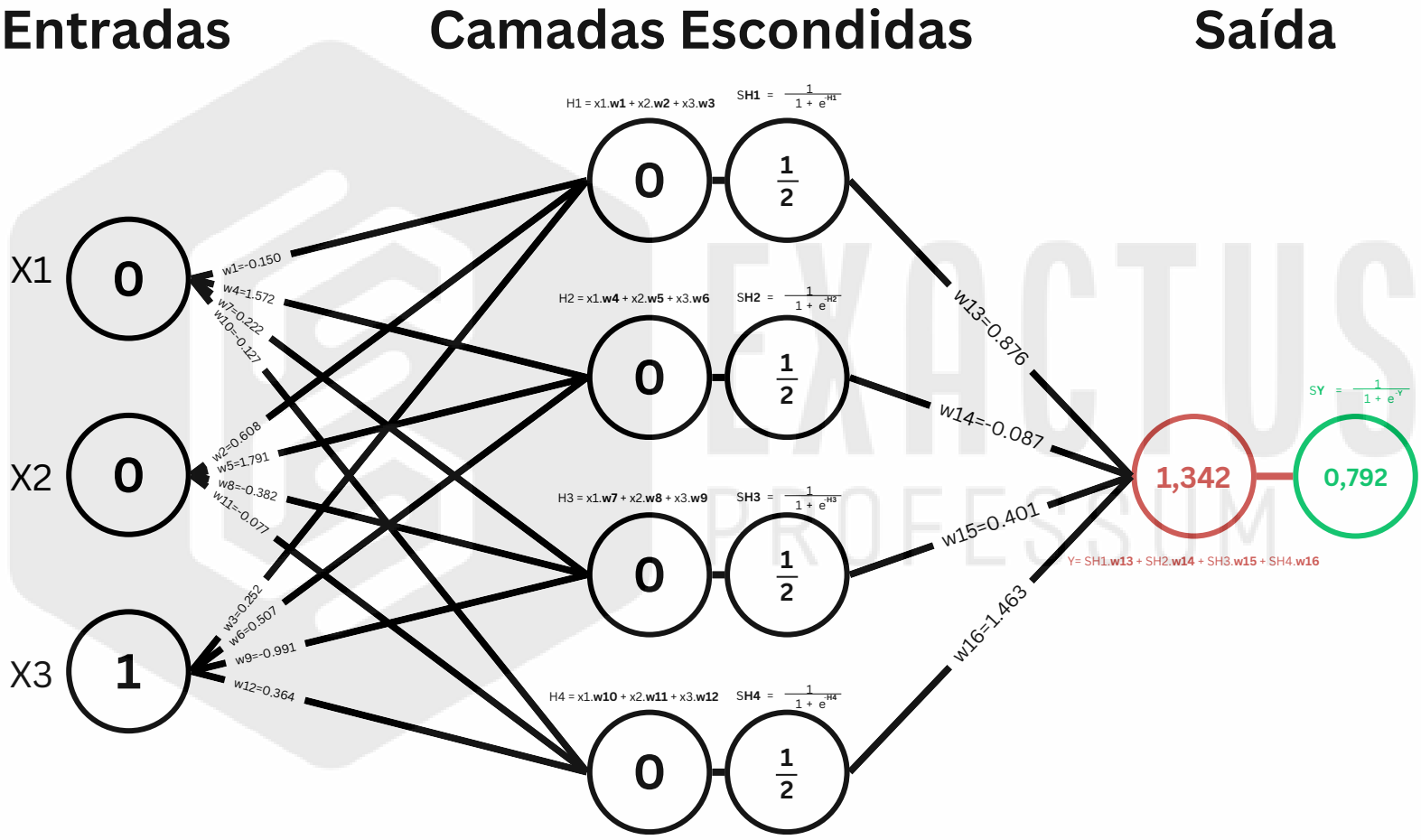
→ Forward Propagation →

Iteração 2

Modelo Backpropagation

→ Forward Propagation →

Iteração 2



$$SY = \frac{1}{1 + e^{-Y}} = \frac{1}{1 + e^{-1,342}} = 0.792$$

→ Forward Propagation →

Iteração 2

Modelo Backpropagation

Cálculo do Erro

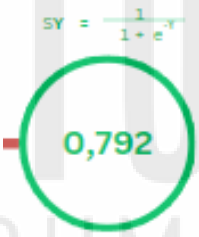
Iteração 2

$$Erro = 0,5 * (S - \mathbf{SY})^2$$

S: Saída Esperada

SY: Saída Calculada

	X1	X2	X3	S
Lição 2	0	0	1	1



$$Erro = 0,5 * (1 - 0,792)^2$$

$$Erro = 0,5 * (0,208)^2$$

$$Erro = 0,5 * 0,043$$

$$Erro = 0,021$$

Cálculo do Erro

Iteração 2

Modelo Backpropagation

← Backward Propagation ←

Iteração 2

E(w1, w2, w3, w4, w5, w6, w7, w8, w9, w10, w11, w12, w13, w14, w15 e w16)

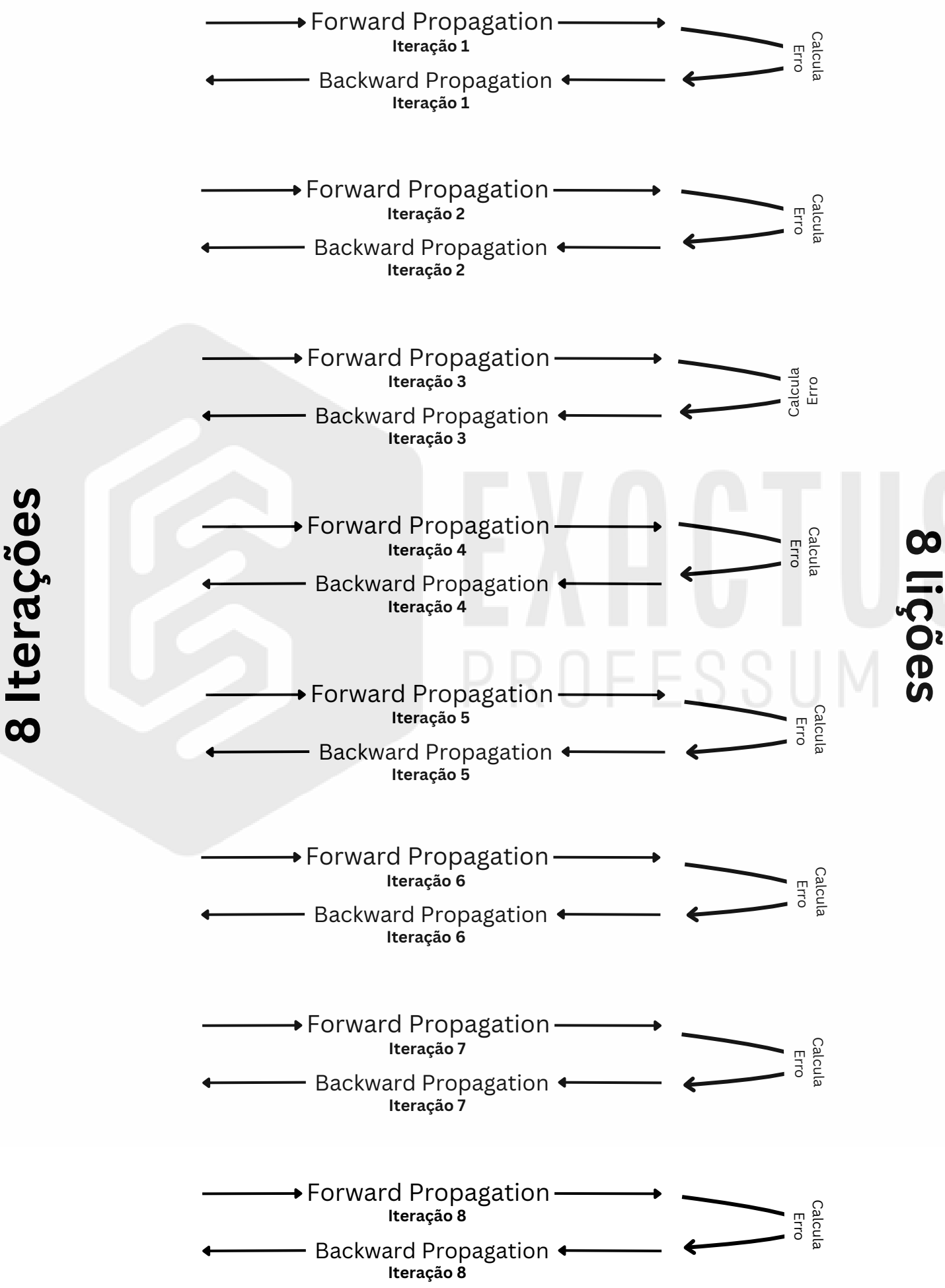
O
Backward Propagation
consiste
em
realizar a **correção** dos
pesos (variáveis)
w1, **w2**, **w3**, **w4**, **w5**, **w6**, **w7**, **w8**, **w9**, **w10**, **w11**, **w12**, **w13**, **w14**, **w15** e **w16**
para
minimizar
o
Erro

$$Erro = 0{,}5 * (S - SY_{w12\ w11\ w10\ w9}^{w1\ w2\ w3\ w4\ w5\ w6\ w7\ w8\ w16\ w15\ w14\ w13})^2$$

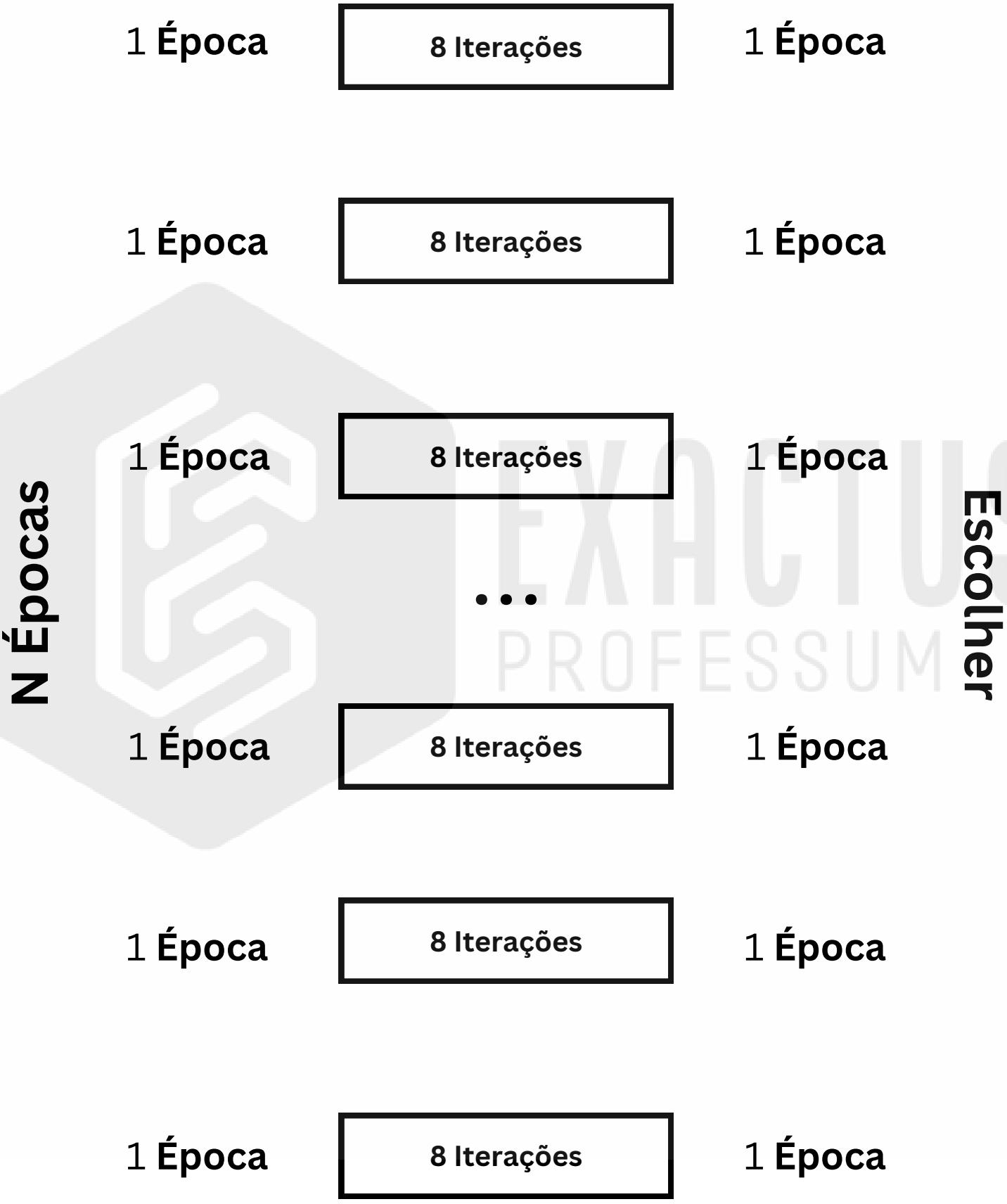
← Backward Propagation ←

Iteração 2

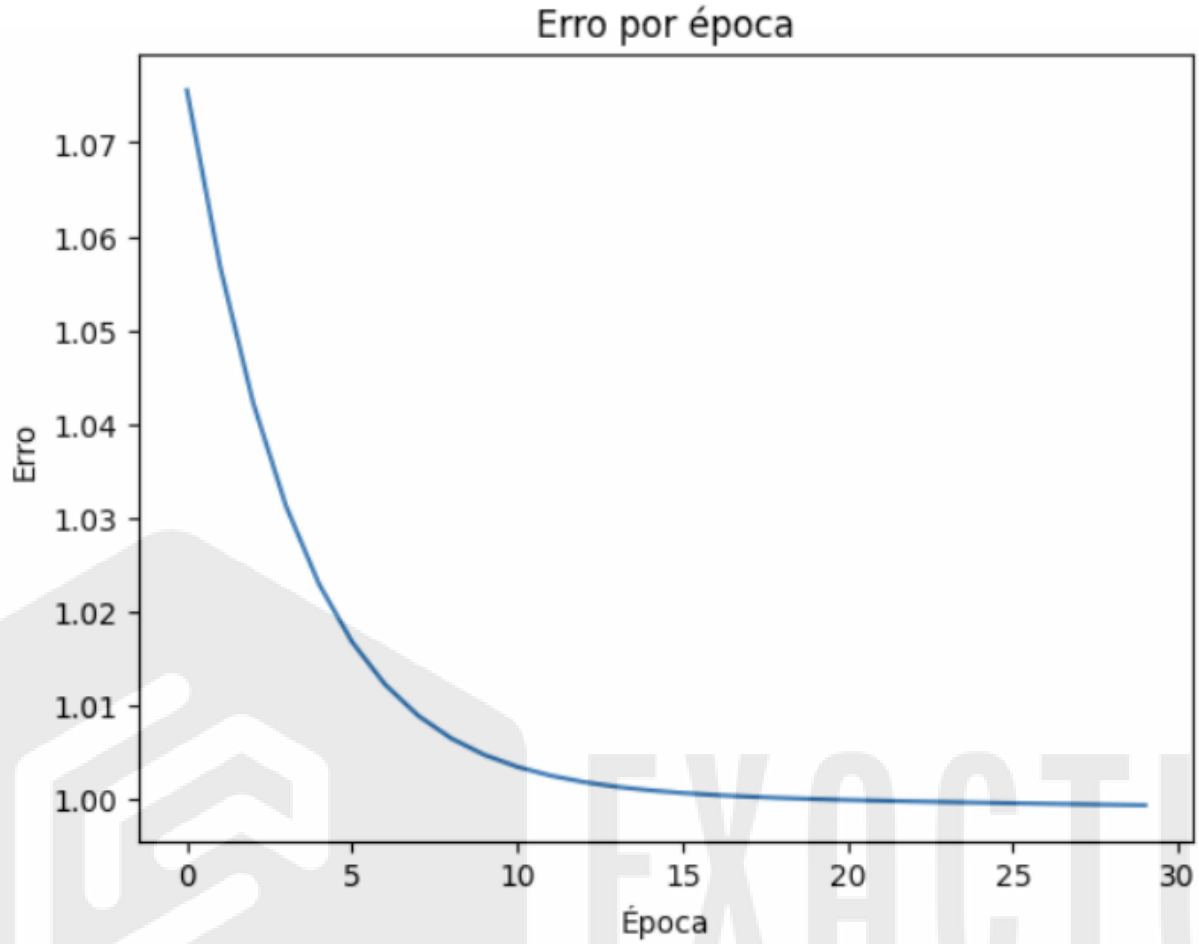
Modelo Backpropagation



Modelo Backpropagation



Modelo Backpropagation



Último Erro

0,000528

W1	-8,286	**W4**	-5,106	**W7**	-0,267	**W10**	3,985
W2	4,502	**W5**	9,349	**W8**	-4,102	**W11**	4,683
W3	3,904	**W6**	-5,191	**W9**	-0,294	**W12**	-8,395

W13	10,087
W14	-15,451
W15	-12,697
W16	10,165