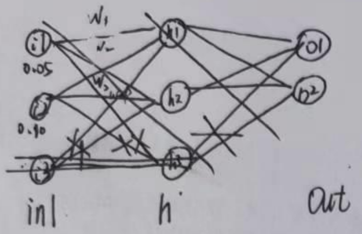
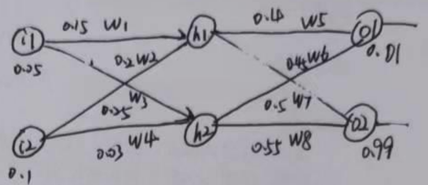
神经网络训练过程.

推理： 输入数据，对输入神经元乘以相应权重，经过隐藏神经元，再输出到输出层
最后出现 得到值与期望值相差过.

训练：从结果向前推导计算输入神经元的权重（倒推）





~~前向传播~~：

神经元$h_{1,2}$加权输入和：z_{h_1}、z_{h_2}

$z_{h_1} = i1 * w1 + i2 * w2$ ~~$+ i3 * w3$~~ $=$ ~~0.3775~~ 0.0275

$z_{h_2} = i1 * w3 + i2 * w4 = 0.0155$

神经元$h_{1,2}$的输出a_{h_1}、a_{h_2}

$a_{h_1} = \frac{1}{1+e^{-z_{h_1}}} =$ ~~0.593269992~~ 0.5068745668

$a_{h_2} = \frac{1}{1+e^{-z_{h_2}}} =$ ~~0.596884378~~ 0.5038749224

输出层神经元 O_1 和 O_2 的值.

$z_{o_1} = a_{h_1} * w5 + a_{h_2} * w6 =$ ~~1.1059~~ 0.4294935418

$z_{o_2} = a_{h_1} * w7 + a_{h_2} * w8 =$ ~~1.2249214039~~ 0.5305684907

$a_{o_1} = \frac{1}{1+e^{-z_{o_1}}} = \frac{1}{1+e^{-1.1059}} =$ ~~0.7513~~ 0.6057527244

$a_{o_2} = \frac{1}{1+e^{-z_{o_2}}} = \frac{1}{1+e^{-\ldots}} =$ ~~0.7729~~ 0.6296156936

前向传播结果 [~~0.7513~~, ~~0.7729~~]　(0.6057527244　0.6296156936)

实际值 [0.01, 0.99]

> 相差较大，进行反向传播，调整权重值.

反向传播.

1. 计算损失函数.

$E_{total} = \sum \frac{1}{2}(target - output)^2$

$E_{o1} = \frac{1}{2}(0.01 - 0.751365)^2 = 0.274811.$

$E_{o2} = \frac{1}{2}(0.99 - 0.772928465)^2 = 0.023560026.$

$E_{total} = E_{o1} + E_{o2} = 0.274811 + 0.023560026 = 0.298371109$

2. 隐藏层→输出层的权值更新.

$$\frac{\partial E_{total}}{\partial w_5} = \frac{\partial E_{total}}{\partial a_{o1}} \cdot \frac{\partial a_{o1}}{\partial z_{h1}} \cdot \frac{\partial z_{h1}}{\partial w_5}$$

$$\frac{\partial E_{total}}{\partial a_{o1}} = 2 \cdot \frac{1}{2}(target - a_{o1}) * (-1)$$

$$= (0.01 - 0.751365) * (-1) = 0.741365$$

$$\frac{\partial a_{o1}}{\partial z_{h1}} = a_{o1} \cdot (1 - a_{o1}) = 0.186815602$$

$$\frac{\partial z_{o1}}{\partial w_5} = a_{h1} = 0.593269992 \cdot 0.596884378$$

$$\frac{\partial E_{total}}{\partial w_5} = 0.082167041$$

$$w_5^+ = w_5 - \frac{\partial E_{total}}{\partial w_5} * \eta = 0.35891648$$

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$$\frac{\partial E_{total}}{\partial w_6} = \frac{\partial E_{total}}{\partial a_{o1}} \cdot \frac{\partial a_{o1}}{\partial z_{h2}} \cdot \frac{\partial z_{h2}}{\partial w_6}$$

$$\frac{\partial E_{total}}{\partial a_{o1}} = \frac{1}{2} \cdot 2 \cdot (target - a_{o1}) \cdot (-1)$$

$$= 0.60575272404 - 0.01$$

$$= 0.59575272404.$$

$$\frac{\partial a_{o1}}{\partial z_{h2}} = \frac{0.60575272404}{a_{o1} \cdot (1 - a_{o1})}$$

$$= 0.60575272404 \cdot (1 - 0.60575272404).$$

$$= 0.23910545791$$

$$\frac{\partial z_{h2}}{\partial w_6} = a_{h2} = 0.50384922240 = 0.071772213 58$$

$$\frac{\partial E_{total}}{\partial w_6} = 0.071772213 58$$

$$w_6^+ = w_6 - \eta \cdot \frac{\partial E_{total}}{\partial w_6} = 0.41411389 32.$$

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W_7

$$\frac{\partial E_{total}}{\partial W_7} = \frac{\partial E_{total}}{\partial a_{o2}} \cdot \frac{\partial a_{o2}}{\partial z_{h1}} \cdot \frac{\partial z_{h1}}{\partial W_7}$$

$$\frac{\partial E_{total}}{\partial a_{o2}} = \frac{1}{2} \cdot 2 (target - output) \cdot (-1)$$

$$= 0.629615936 - 0.99 = -0.360384064$$

$$\frac{\partial a_{o2}}{\partial z_{h1}} = a_{o2} \cdot (1 - a_{o2}) = 0.233199772$$

$$\frac{\partial z_{h1}}{\partial W_7} = a_{h1} = 0.506874568$$

$$\frac{\partial E_{total}}{\partial W_7} = -0.042598518$$

$$W_7^+ = W_7 - \eta \cdot \frac{\partial E_{total}}{\partial W_7} = 0.5 - 0.5 \times (-0.042598518) =$$

$$= 0.521299259$$

W_8^+

$$\frac{\partial E_{total}}{\partial W_8} = \frac{\partial E_{total}}{\partial a_{o2}} \cdot \frac{\partial E_{total}}{\partial z_{h2}} \cdot \frac{\partial z_{h2}}{\partial W_8}$$

$$\frac{\partial E_{total}}{\partial a_{o2}} = \frac{1}{2} \cdot 2 \cdot (target - a_{o2}) \cdot (-1) = 0.629615936 - 0.99 = -0.360384064$$

$$\frac{\partial a_{o2}}{\partial z_{h2}} = 0.233199772$$

$$\frac{\partial z_{h2}}{\partial W_8} = a_{h2} = 0.503874224$$

$$\frac{\partial E_{total}}{\partial W_8} = -0.042346429$$

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$$w_8^+ = w_8 - \eta * \frac{\partial E_{total}}{\partial w_8} = 0.571173211\,7$$

隐藏层 → 输入层权重值 w_1^+

$$\frac{\partial E_{total}}{\partial w_1} = \left(\frac{\partial E_{o1}}{\partial a_{h1}} + \frac{\partial E_{o2}}{\partial w_4}\right) \cdot$$

~~$\frac{\partial E_{o1}}{\partial w_1} = \frac{\partial E_{o1}}{\partial a_{h1}} \cdot \frac{\partial a_{h1}}{\partial z_{o1}} \cdot \partial z_{o1}$~~

$$\frac{\partial E_{total}}{\partial w_1} = \frac{\partial E_{total}}{\partial a_{h1}} \cdot \frac{\partial a_{h1}}{\partial z_{h1}} \cdot \frac{\partial z_{o1}}{\partial w_1}$$

$$= \left(\frac{\partial E_{total}}{\partial a_{h1}} + \frac{\partial E_{o2}}{\partial a_{h1}}\right) \cdot \frac{\partial a_{h1}}{\partial z_{o1}} \cdot \frac{\partial z_{o1}}{\partial w_1}$$

$$= \left(\frac{\partial E_{o1}}{\partial a_{o1}} \cdot \frac{\partial a_{o1}}{\partial z_{o1}} \cdot \frac{\partial z_{o1}}{\partial a_{h1}} + \frac{\partial E_{o2}}{\partial a_{o2}} \cdot \frac{\partial a_{o2}}{\partial z_{o2}} \cdot \frac{\partial z_{o2}}{\partial a_{h1}}\right) \cdot \cdot$$

$$= (0.5957527244 \cdot 0.2388163613 \cdot 0.4 + (-0.3608840644) \cdot 0.2233159772 \cdot 0.45)$$

$$\cdot\ 0.5068745668 \cdot (1 - 0.5068745668) \cdot 0.05$$

$$= 0.01909150701.$$

$$w_1^+ = w_1 - \eta \cdot \frac{\partial E_{total}}{\partial w_1} = 0.15 - 0.5 \times 0.01909150701 = \text{~~0.14[illegible]~~}$$

$$= 0.1498807006$$

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W_2^+

$$\frac{\partial E_{total}}{\partial w_2} = \frac{\partial E_{total}}{\partial a_{h1}} \cdot \frac{\partial a_{h1}}{\partial z_{h1}} \cdot \frac{\partial z_{h1}}{\partial w_2}$$

$$= \left(\frac{\partial E_{o1}}{\partial a_{h1}} + \frac{\partial E_{o2}}{\partial a_{h1}}\right) \cdot \frac{\partial a_{h1}}{\partial z_{h1}} \cdot \frac{\partial z_{h1}}{\partial w_2}$$

$$= \left(\frac{\partial E_{o1}}{\partial a_{o1}} \cdot \frac{\partial a_{o1}}{\partial z_{o1}} \cdot \frac{\partial z_{o1}}{\partial a_{h1}} + \frac{\partial E_{o2}}{\partial a_{o2}} \cdot \frac{\partial a_{o2}}{\partial z_{o2}} \cdot \frac{\partial z_{o2}}{\partial a_{h1}}\right) \cdot \frac{\partial a_{h1}}{\partial z_{h1}} \cdot \frac{\partial z_{h1}}{\partial w_2}$$

$$= 0.1997614013$$

W_3^+

$$\frac{\partial E_{total}}{\partial w_3} = \frac{\partial E_{total}}{\partial a_{h2}} \cdot \frac{\partial a_{h2}}{\partial z_{h2}} \cdot \frac{\partial z_{h2}}{\partial w_3}$$

$$= \left(\frac{\partial E_{o1}}{\partial a_{h2}} + \frac{\partial E_{o2}}{\partial a_{h2}}\right) \cdot \frac{\partial a_{h2}}{\partial z_{h2}} \cdot \frac{\partial z_{h2}}{\partial w_3}$$

$$= \left(\frac{\partial E_{o1}}{\partial a_{o1}} \cdot \frac{\partial a_{o1}}{\partial z_{o1}} \cdot \frac{\partial z_{o1}}{\partial a_{h2}} + \frac{\partial E_{o2}}{\partial a_{o2}} \cdot \frac{\partial a_{o2}}{\partial z_{o2}} \cdot \frac{\partial z_{o2}}{\partial a_{h2}}\right) \cdot \frac{\partial a_{h2}}{\partial z_{h2}} \cdot \frac{\partial z_{h2}}{\partial w_3}$$

$$= (0.0711377489\% +$$

$$= 0.0249149029\% \cdot (0.5038749224\% \cdot (1 - 0.5038749224\%)) \cdot 0.05$$

$$= 5.9607157\times10^{-4}$$

$$w_3^+ = w_3 - \eta * \frac{\partial E_{total}}{\partial w_3} = 0.2497019342.$$

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W_4^+

$$\frac{\partial E_{total}}{\partial W_4} = \frac{\partial E_{o1}}{\partial W_4} + \frac{\partial E_{o2}}{\partial W_4}$$

$$= \frac{\partial E_{total}}{\partial a_{h2}} \cdot \frac{\partial a_{h2}}{\partial z_{h2}} \cdot \frac{\partial z_{h2}}{\partial W_4}$$

$$= \left(\frac{\partial E_{o1}}{\partial a_{h2}} + \frac{\partial E_{o1}}{\partial a_{h2}}\right) \cdot \frac{\partial a_{h2}}{\partial z_{h2}} \cdot \frac{\partial z_{h2}}{\partial W_4}$$

$$= \left(\frac{\partial E_{o1}}{\partial a_{o1}} \cdot \frac{\partial a_{o1}}{\partial z_{o1}} \cdot \frac{\partial z_{o1}}{\partial a_{h2}} + \frac{\partial E_{o2}}{\partial a_{o2}} \cdot \frac{\partial a_{o2}}{\partial z_{o2}} \cdot \frac{\partial z_{o2}}{\partial a_{h2}}\right) \cdot \frac{\partial a_{h2}}{\partial z_{h2}} \cdot \frac{\partial z_{h2}}{\partial W_4}$$

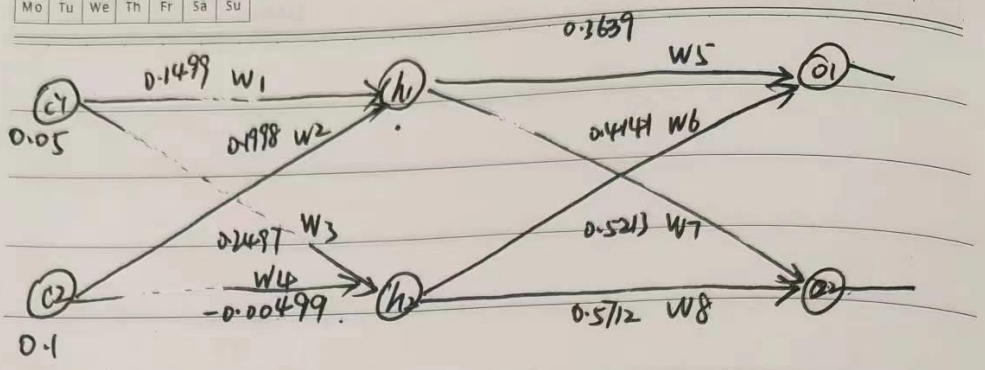
$= (0.5967527494 \cdot 0.2388163613 \cdot 0.5 + 0.3603843064 \cdot 0.2331997172 \cdot 0.55)$

$\cdot 0.5038749024 \cdot (1 - 0.5038749024) \cdot 0.1$

$= 0.0699822719$

$W_4^+ = W_4 - \eta \cdot \frac{\partial E_{total}}{\partial W_4} = 0.03 - 0.5 \times 0.0699822719$

$= -0.0499112595.$



a_{h1}: $0.05 \times 0.1499 + 0.1 \times 0.1998 = 0.009493$

$a_{h1} = \frac{1}{1+e^{-0.009493}} = 0.502371248 22$

$z_{h2} = 0.05 \times 0.2497 + 0.1 \times (-0.004999) = 0.011986$

$a_{h2} = \frac{1}{1+e^{-0.011986}} = 0.502998464 41$

z_{o1}: $0.502371248 22 \times 0.3639 + 0.502998464 41 \times 0.4414$

$= 0.391124182 1$

$a_{o1} = \frac{1}{1+e^{-0.391124182 1}} = 0.596548480 4$

$z_{o2} = 0.502371248 22 \times 0.5213 + 0.502998464 41 \times 0.5112$

$= 0.549198355 3$

$a_{o2} = \frac{1}{1+e^{-0.549198355 3}} = 0.633949583 3$