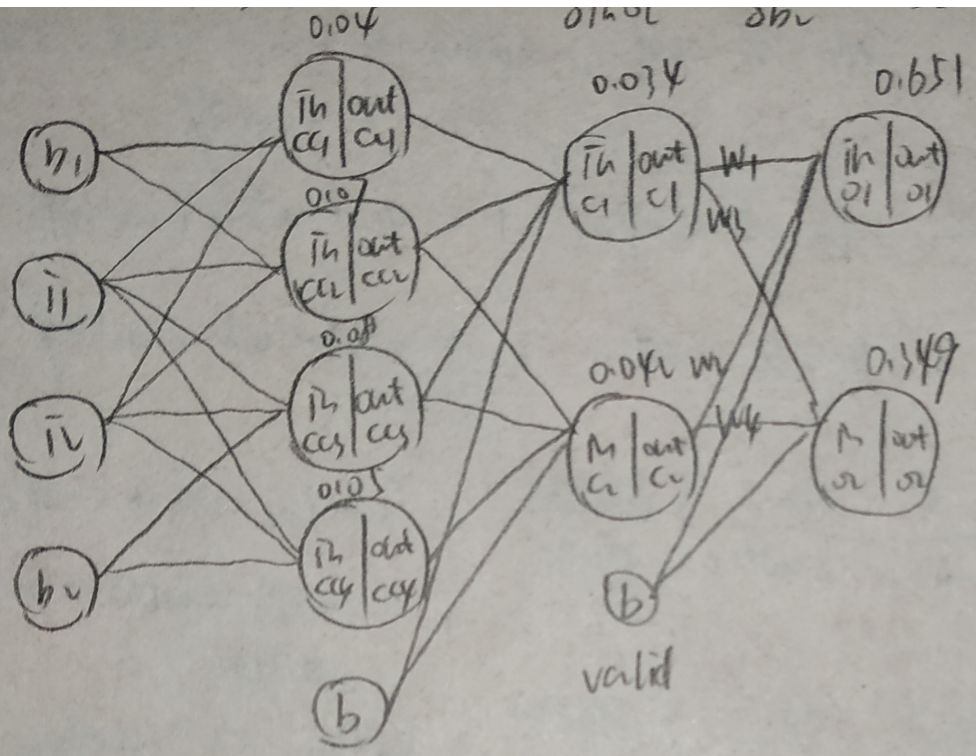
线



正向计算

$$kk_1 \begin{matrix} kk_{11} & kk_{12} & kk_{13} & bb_1 \\ (0.1 & 0.2 & 0.3 & 0) \end{matrix}$$

$$kk_2 \begin{matrix} kk_{21} & kk_{22} & kk_{23} & bb_2 \\ (0.3 & 0.2 & 0.1 & 0) \end{matrix}$$

$$inccc_1 = kk_{11} * 0 + kk_{12} * i_1 + kk_{11} * i_2 + bb_1$$

$$in\,cc_2 = kk_{13} * i_1 + kk_{12} * i_2 + kk_{11} * 0 + bb_1$$

$$in\,cc_3 = kk_{23} * 0 + kk_{22} * i_1 + kk_{21} * i_2 + bb_2$$

$$in\,cc_4 = kk_{13} * i_1 + kk_{12} * i_2 + kk_{21} * 0 + bb_2$$

$k_{11}\ k_{12}\ k_{13}\ b_1$

k_1 (0.1 0.2 0.3 0)

$in_{c1} = k_{13} * out_{i1} + k_{12} * out_{i2} + k_{11} * out_{i3} + b_1$

$in_{c2} = k_{13} * out_{i2} + k_{12} * out_{i3} + k_{11} * out_{i4} + b_1$

$in_{o1} = w_1 * out_{c1} + w_2 * out_{c2} + b_1$

$in_{o2} = w_3 * out_{c1} + w_4 * out_{c2} + b_2$

反向的推

$coef_{o1} = \frac{\partial E_{total}}{\partial in_{o1}} = out_1 - o_1 = 0.659 - 1 = -0.341$

$coef_{o2} = \frac{\partial E_{total}}{\partial in_{o2}} = out_2 - o_2 = 0.596 - 0 = 0.596$

$w_1 = w_1 - \alpha \cdot \frac{\partial E_{total}}{\partial w_1} = w_1 - \alpha \frac{\partial E_{total}}{\partial in_{o1}} \cdot \frac{\partial in_{o1}}{\partial w_1} = w_1 - \alpha \cdot coef_{o1} \cdot out_{c1} = 0.1 - 0.5 * (-0.341) * 0.03$
$= 0.106$

$w_2 = w_2 - \alpha \cdot \frac{\partial E_{total}}{\partial w_2} = w_2 - \alpha \frac{\partial E_{total}}{\partial in_{o1}} \cdot \frac{\partial in_{o1}}{\partial w_2} = w_2 - \alpha \cdot coef_{o1} \cdot out_{c2} = 0.2 - 0.5 * (-0.341) * 0.08$
$= 0.207$

$w_3 = w_3 - \alpha \cdot \frac{\partial E_{total}}{\partial w_3} = w_3 - \alpha \frac{\partial E_{total}}{\partial in_{o2}} \cdot \frac{\partial in_{o2}}{\partial w_3} = w_3 - \alpha \cdot coef_{o2} \cdot out_{c1} = -0.1 - 0.5 * 0.596 * 0.03$
$= -0.106$

$w_4 = w_4 - \alpha \frac{\partial E_{total}}{\partial w_4} = w_4 - \alpha \frac{\partial E_{total}}{\partial in_{o2}} \cdot \frac{\partial in_{o2}}{\partial w_4} = w_4 - \alpha \cdot coef_{o2} \cdot out_{c2} = -0.2 - 0.5 * 0.596 * 0.08$
$= -0.207$

$b_1 = b_1 - \alpha \frac{\partial E_{total}}{\partial b_1} = b_1 - \alpha \frac{\partial E_{total}}{\partial in_{o1}} \cdot \frac{\partial in_{o1}}{\partial b_1} = b_1 - \alpha \cdot coef_{o1} \cdot 1 = 0.5 - 0.5 * (-0.341) = 0.675$

$b_2 = b_2 - \alpha \frac{\partial E_{total}}{\partial b_2} = b_2 - \alpha \frac{\partial E_{total}}{\partial in_{o2}} \cdot \frac{\partial in_{o2}}{\partial b_2} = b_2 - \alpha \cdot coef_{o2} \cdot 1 = -0.5 - 0.5 * 0.596 = -0.675$

$coef_{c1} = \frac{\partial E_{total}}{\partial in_{c1}} = \left(\frac{\partial E_{total}}{\partial in_{o1}} \cdot \frac{\partial in_{o1}}{\partial out_{c1}} + \frac{\partial E_{total}}{\partial in_{o2}} \cdot \frac{\partial in_{o2}}{\partial out_{c1}} \right) \frac{\partial out_{c1}}{\partial in_{c1}} = (coef_{o1} \cdot w_1 + coef_{o2} \cdot w_3) \cdot 1$
$= (-0.341) * 0.106 + 0.596 * (-0.106) * 1$
$= -0.074$

$coef_{c2} = \frac{\partial E_{total}}{\partial in_{c2}} = \left(\frac{\partial E_{total}}{\partial in_{o1}} \cdot \frac{\partial in_{o1}}{\partial out_{c2}} + \frac{\partial E_{total}}{\partial in_{o2}} \cdot \frac{\partial in_{o2}}{\partial out_{c2}} \right) \frac{\partial out_{c2}}{\partial in_{c2}} = (coef_{o1} \cdot w_2 + coef_{o2} \cdot w_4) \cdot 1$
$= (-0.341) * 0.207 + 0.596 * (-0.207) * 1$
$= -0.144$

$k_{11} = k_{11} - \alpha \frac{\partial E_{total}}{\partial k_{11}} = k_{11} - \alpha \left(\frac{\partial E_{total}}{\partial in_{c1}} \cdot \frac{\partial in_{c1}}{\partial k_{11}} + \frac{\partial E_{total}}{\partial in_{c2}} \cdot \frac{\partial in_{c2}}{\partial k_{11}} \right) = k_{11} - \alpha (coef_{c1} \cdot out_{c3} + coef_{c2} \cdot out_{c4})$
$= 0.1 - 0.5 * (-0.074) * 0.03 + (-0.144) * 0.05)$
$= 0.107$

$k_{12} = k_{12} - \alpha \frac{\partial E_{total}}{\partial k_{12}} = k_{12} - \alpha \left(\frac{\partial E_{total}}{\partial in_{c1}} \cdot \frac{\partial in_{c1}}{\partial k_{12}} + \frac{\partial E_{total}}{\partial in_{c2}} \cdot \frac{\partial in_{c2}}{\partial k_{12}} \right) = k_{12} - \alpha (coef_{c1} \cdot out_{c2} + coef_{c2} \cdot out_{c3})$
$= 0.2 - 0.5 * (-0.074) * 0.07 + (-0.144) * 0.08)$
$= 0.208$

$k_{13} = k_{13} - \alpha \frac{\partial E_{total}}{\partial k_{13}} = k_{13} - \alpha \left(\frac{\partial E_{total}}{\partial in_{c1}} \cdot \frac{\partial in_{c1}}{\partial k_{13}} + \frac{\partial E_{total}}{\partial in_{c2}} \cdot \frac{\partial in_{c2}}{\partial k_{13}} \right) = k_{13} - \alpha (coef_{c1} \cdot out_{c1} + coef_{c2} \cdot out_{c2})$
$= 0.3 - 0.5 * (-0.074) * 0.04 + (-0.144) * 0.07)$
$= 0.307$

$b_1 = b_1 - \alpha \frac{\partial E_{total}}{\partial b_1} = b_1 - \alpha \left(\frac{\partial E_{total}}{\partial in_{c1}} \cdot \frac{\partial in_{c1}}{\partial b_1} + \frac{\partial E_{total}}{\partial in_{c2}} \cdot \frac{\partial in_{c2}}{\partial b_1} \right) = b_1 - \alpha (coef_{c1} \cdot 1 + coef_{c2} \cdot 1)$
$= 0 - 0.5 * (-0.074 + (-0.144)) = 0.109$

$$coef_{o1} = \frac{\partial E_{tot}}{\partial in_{o1}} = \frac{\partial E_{tot}}{\partial out_{o1}} \cdot \frac{\partial out_{o1}}{\partial in_{o1}} * \frac{\partial in_{o1}}{\partial w_{o1}} = coef_{o1} * k_{13} * 1 = -0.074 * 0.307 * 1 = -0.023$$

$$coef_{o2} = \frac{\partial E_{tot}}{\partial in_{o2}} = \left(\frac{\partial E_{tot}}{\partial in_{o1}} \cdot \frac{\partial in_{o1}}{\partial out_{o2}} + \frac{\partial E_{tot}}{\partial in_{o2}} \cdot \frac{\partial in_{o2}}{\partial out_{o2}}\right) \cdot \frac{\partial out_{o2}}{\partial in_{o2}} = (coef_{o1} * k_{12} + coef_{o2} * k_{23}) * 1$$

$$= -0.074 * 0.208 + (-0.144) * 0.307 = -0.060$$

$$coef_{o3} = \frac{\partial E_{tot}}{\partial in_{o3}} = \left(\frac{\partial E_{tot}}{\partial in_{o1}} \cdot \frac{\partial in_{o1}}{\partial out_{o3}} + \frac{\partial E_{tot}}{\partial in_{o2}} \cdot \frac{\partial in_{o2}}{\partial out_{o3}}\right) \frac{\partial out_{o3}}{\partial in_{o3}} = (coef_{o1} * k_{11} + coef_{o2} * k_{12}) * 1$$

$$= -0.074 * 0.107 + (-0.144) * 0.208 = -0.038$$

$$coef_{w4} = \frac{\partial E_{tot}}{\partial in_{w4}} = \frac{\partial E_{tot}}{\partial in_{o1}} \cdot \frac{\partial in_{o1}}{\partial out_{w4}} \cdot \frac{\partial out_{w4}}{\partial in_{w4}} = coef_{o1} * k_{11} * 1 = -0.144 * 0.107 * 1 = -0.015$$

o o $coef_{o1}$ $coef_{o2}$ o o

k_{13}

k_{12} k_{23}

k_{11} k_{22}

k_{21}

$$kk_{11} = kk_{11} - \alpha \frac{\partial E_{tot}}{\partial kk_{11}} = kk_{11} - \alpha\left(\frac{\partial E_{tot}}{\partial in_{o1}} \cdot \frac{\partial in_{o1}}{\partial kk_{11}} + \frac{\partial E_{tot}}{\partial in_{o2}} \cdot \frac{\partial in_{o2}}{\partial kk_{11}}\right)$$

$$= kk_{11} - \alpha\,(coef_{o1} * i_1 + coef_{o2} * 0) = 0.1 - 0.5(-0.023 * 0.2 + (-0.060) * 0)$$

$$= 0.102$$

$$kk_{12} = kk_{12} - \alpha \frac{\partial E_{tot}}{\partial kk_{12}} = kk_{12} - \alpha\left(\frac{\partial E_{tot}}{\partial in_{o1}} \cdot \frac{\partial in_{o1}}{\partial kk_{12}} + \frac{\partial E_{tot}}{\partial in_{o2}} \cdot \frac{\partial in_{o2}}{\partial kk_{12}}\right)$$

$$= kk_{12} - \alpha\,(coef_{o1} * i_1 + coef_{o2} * i_2) = 0.2 - 0.5(-0.023 * 0.1 + (-0.060) * 0.4)$$

$$= 0.207$$

$$kk_{13} = kk_{13} - \alpha \frac{\partial E_{tot}}{\partial kk_{13}} = kk_{13} - \alpha\left(\frac{\partial E_{tot}}{\partial in_{o1}} \cdot \frac{\partial in_{o1}}{\partial kk_{13}} + \frac{\partial E_{tot}}{\partial in_{o2}} \cdot \frac{\partial in_{o2}}{\partial kk_{13}}\right)$$

$$= kk_{13} - \alpha\,(coef_{o1} * 0 + coef_{o2} * i_1) = 0.3 - 0.5(-0.023 * 0 + (-0.060) * 0.1)$$

$$= 0.303$$

$$bb_1 = bb_1 - \alpha \frac{\partial E_{tot}}{\partial bb_1} = bb_1 - \alpha\left(\frac{\partial E_{tot}}{\partial in_{o1}} \cdot \frac{\partial in_{o1}}{\partial bb_1} + \frac{\partial E_{tot}}{\partial in_{o2}} \cdot \frac{\partial in_{o2}}{\partial bb_1}\right)$$

$$= bb_1 - \alpha\,(coef_{o1} \cdot 1 + coef_{o2} \cdot 1) = 0 - 0.5 * (-0.023 * 1 + (-0.060) * 1) = 0.042$$

$$kk_{21} = kk_{21} - \alpha \frac{\partial E_{tot}}{\partial kk_{21}} = kk_{21} - \alpha\left(\frac{\partial E_{tot}}{\partial in_{o3}} \cdot \frac{\partial in_{o3}}{\partial kk_{21}} + \frac{\partial E_{tot}}{\partial in_{w4}} \cdot \frac{\partial in_{w4}}{\partial kk_{21}}\right)$$

$$= kk_{21} - \alpha\,(coef_{o3} \cdot i_1 + coef_{w4} \cdot 0) = 0.3 - 0.5(-0.038 * 0.2 + (-0.015) * 0)$$

$$= 0.304$$

$$kk_{22} = kk_{22} - \alpha \frac{\partial E_{tot}}{\partial kk_{22}} = kk_{22} - \alpha\left(\frac{\partial E_{tot}}{\partial in_{o3}} \cdot \frac{\partial in_{o3}}{\partial kk_{22}} + \frac{\partial E_{tot}}{\partial in_{w4}} \cdot \frac{\partial in_{w4}}{\partial kk_{22}}\right)$$

$$= kk_{22} - \alpha\,(coef_{o3} \cdot i_2 + coef_{w4} \cdot i_2) = 0.2 - 0.5(-0.038 * 0.1 + (-0.015) * 0.2)$$

$$= 0.203$$

$$kk_{23} = kk_{23} - \alpha \frac{\partial E_{tot}}{\partial kk_{23}} = kk_{23} - \alpha\left(\frac{\partial E_{tot}}{\partial in_{o3}} \cdot \frac{\partial in_{o3}}{\partial kk_{23}} + \frac{\partial E_{tot}}{\partial in_{w4}} \cdot \frac{\partial in_{w4}}{\partial kk_{23}}\right)$$

$$= kk_{23} - \alpha\,(coef_{o3} \cdot 0 + coef_{w4} \cdot i_2) = 0.1 - 0.5(-0.038 * 0 + (-0.015) * 0.1)$$

$$= 0.101$$

$$bb_2 = bb_2 - \alpha \frac{\partial E_{tot}}{\partial bb_2} = bb_2 - \alpha\left(\frac{\partial E_{tot}}{\partial in_{o3}} \cdot \frac{\partial in_{o3}}{\partial bb_2} + \frac{\partial E_{tot}}{\partial in_{w4}} \cdot \frac{\partial in_{w4}}{\partial bb_2}\right) = bb_2 - \alpha\,(coef_{o3} \cdot 1 + coef_{w4} \cdot 1)$$

$$= 0 - 0.5\,(-0.038 * 1 + (-0.015) * 1)$$

$$= 0.027$$