

核 1 0.1 0.2 0.3  
0.1 0.2 0.3 0.4 0.5 0.6  
0.1 0.2 0.3 0.4 0.5 0.6

核 2 0.3 0.2 0.1

$\ln(0.5)$

$+0.5$   
0.1 0.2 0.3 0.4 0.5 0.6  
0.1 0.2 0.3 0.4 0.5 0.6

0.1 0.2 0.3 0.4 0.5 0.6  
0.1 0.2 0.3 0.4 0.5 0.6

0.1 0.2 0.3 0.4 0.5 0.6  
0.1 0.2 0.3 0.4 0.5 0.6

-0.5 -0.36 -0.16 -0.16 -0.18

$\max \{0.646, 0.659\} > 0.653$   
 $\max \{0.673, 0.686\} > 0.680$

$\max \{0.411, 0.426\} > 0.419$   
 $\max \{0.440, 0.455\} > 0.448$

核 1 1 0 1 例 0 核 2 1 0 -1 例 0 核 3 1 1 0 例 0

0.653 0.680 0.419 0.448

-1

0

-1

0

$\max \{0.558, 0.558\}$

0.588

0.1

0.770

$\frac{2.160}{2.625}$

0.813

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0.653 0.680 0.419 0.448

-1

0

1

$\max \{0.442, 0.442\}$

0.448

0.2

$-0.77 \frac{0.460}{0.260}$

0.813

0.653 0.680 0.419 0.448

0

0

1

$\max \{0.750, 0.750\}$

0.750

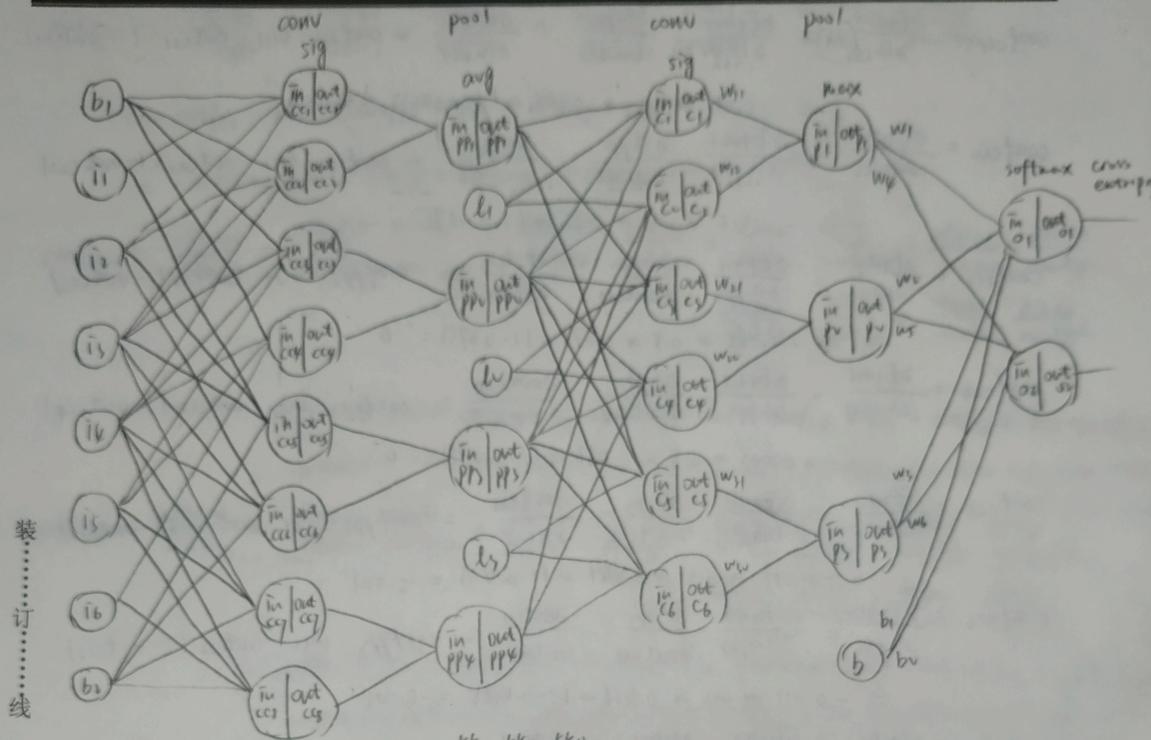
-0.5

$-0.77 \frac{0.460}{0.260}$

0.177

$$\text{loss} = -(1 \cdot \ln 0.813 + 2 \cdot \ln 0.177) \\ = 0.195$$

num



正向传播：

$$\begin{aligned}
 & \text{卷积核 } KK_1 = (0.1, 0.2, 0.3) \quad b_{b1} = 0.5 \\
 & \text{卷积核 } KK_2 = (0.1, 0.2, 0.1) \quad b_{b2} = -0.5 \\
 & \text{CC 层} \\
 & \bar{in}_{cc_1} = i_1 * KK_{11} + i_2 * KK_{12} + i_3 * KK_{13} + b_{b1} \\
 & \bar{in}_{cc_2} = i_2 * KK_{13} + i_3 * KK_{12} + i_4 * KK_{11} + b_{b1} \\
 & \bar{in}_{cc_3} = i_3 * KK_{13} + i_4 * KK_{12} + i_5 * KK_{11} + b_{b1} \\
 & \bar{in}_{cc_4} = i_4 * KK_{13} + i_5 * KK_{12} + i_6 * KK_{11} + b_{b1} \\
 & \bar{in}_{cc_5} = i_1 * KK_{23} + i_2 * KK_{22} + i_3 * KK_{21} + b_{b2} \\
 & \bar{in}_{cc_6} = i_2 * KK_{23} + i_3 * KK_{22} + i_4 * KK_{21} + b_{b2} \\
 & \bar{in}_{cc_7} = i_3 * KK_{23} + i_4 * KK_{22} + i_5 * KK_{21} + b_{b2} \\
 & \bar{in}_{cc_8} = i_4 * KK_{23} + i_5 * KK_{22} + i_6 * KK_{21} + b_{b2}
 \end{aligned}$$

PP 层 average pool

$$\begin{aligned}
 \bar{in}_{pp_1} &= \frac{1}{2} (\bar{in}_{cc_1} + \bar{in}_{cc_2}) \\
 \bar{in}_{pp_2} &= \frac{1}{2} (\bar{in}_{cc_3} + \bar{in}_{cc_4}) \\
 \bar{in}_{pp_3} &= \frac{1}{2} (\bar{in}_{cc_5} + \bar{in}_{cc_6}) \\
 \bar{in}_{pp_4} &= \frac{1}{2} (\bar{in}_{cc_7} + \bar{in}_{cc_8})
 \end{aligned}$$

卷积核  $k_1 (-1, 0, 1)$        $b_1 = 0$   
 $k_2 (1, 0, -1)$        $b_2 = 0$   
 $k_3 (1, 1, 0)$        $b_3 = 0$

$$\bar{in}_{C1} = \text{outpp}_1 * k_{13} + \text{outpp}_2 * k_{12} + \text{outpp}_3 * k_{11} + b_1$$

$$\bar{in}_{C2} = \text{outpp}_2 * k_{13} + \text{outpp}_3 * k_{12} + \text{outpp}_4 * k_{11} + b_2$$

$$\bar{in}_{C3} = \text{outpp}_1 * k_{13} + \text{outpp}_2 * k_{12} + \text{outpp}_3 * k_{11} + b_3$$

$$\bar{in}_{C4} = \text{outpp}_2 * k_{13} + \text{outpp}_3 * k_{12} + \text{outpp}_4 * k_{11} + b_4$$

$$\bar{in}_{C5} = \text{outpp}_1 * k_{13} + \text{outpp}_2 * k_{12} + \text{outpp}_3 * k_{11} + b_5$$

$$\bar{in}_{C6} = \text{outpp}_2 * k_{13} + \text{outpp}_3 * k_{12} + \text{outpp}_4 * k_{11} + b_6$$

$p\bar{P}_m$  max pool

$$\bar{in}_{p1} = \text{out}_{C1} * w_{11} + \text{out}_{C2} * w_{12}$$

$$\bar{in}_{p2} = \text{out}_{C3} * w_{21} + \text{out}_{C4} * w_{22}$$

$$\bar{in}_{p3} = \text{out}_{C5} * w_{31} + \text{out}_{C6} * w_{32}$$

$FC\bar{P}_m$

$$\bar{in}_{o1} = w_1 * \text{out}_{p1} + w_2 * \text{out}_{p2} + w_3 * \text{out}_{p3} + b_1$$

$$\bar{in}_{o2} = w_4 * \text{out}_{p1} + w_5 * \text{out}_{p2} + w_6 * \text{out}_{p3} + b_2$$

反向传播

$$\text{coef}_{o1} = \frac{\partial E_{\text{total}}}{\partial \bar{in}_{o1}} = \text{out}_{o1} - o_1 = 0.8v_3 - 1 = -0.17$$

$$\text{coef}_{o2} = \frac{\partial E_{\text{total}}}{\partial \bar{in}_{o2}} = \text{out}_{o2} - o_2 = 0.177 - 0 = 0.177$$

$p\bar{P}_m$

$$w_1 = w_1 - \alpha \cdot \frac{\partial E_{\text{total}}}{\partial \bar{in}_{o1}} \cdot \frac{\partial \bar{in}_{o1}}{\partial w_1} = w_1 - \alpha \cdot \text{coef}_{o1} \cdot \text{out}_{p1} = 0.1 - 0.7 \cdot (-0.17) \cdot 0.558 = 0.189$$

$$w_2 = w_2 - \alpha \cdot \frac{\partial E_{\text{total}}}{\partial \bar{in}_{o1}} \cdot \frac{\partial \bar{in}_{o1}}{\partial w_2} = w_2 - \alpha \cdot \text{coef}_{o1} \cdot \text{out}_{p2} = 0.2 - 0.7 \cdot (-0.17) \cdot 0.442 = 0.235$$

$$w_3 = w_3 - \alpha \cdot \frac{\partial E_{\text{total}}}{\partial \bar{in}_{o1}} \cdot \frac{\partial \bar{in}_{o1}}{\partial w_3} = w_3 - \alpha \cdot \text{coef}_{o1} \cdot \text{out}_{p3} = 0.3 - 0.7 \cdot (-0.17) \cdot 0.750 = 0.393$$

$$w_4 = w_4 - \alpha \cdot \frac{\partial E_{\text{total}}}{\partial \bar{in}_{o2}} \cdot \frac{\partial \bar{in}_{o2}}{\partial w_4} = w_4 - \alpha \cdot \text{coef}_{o2} \cdot \text{out}_{p1} = -0.1 - 0.7 \cdot 0.177 \cdot 0.558 = -0.169$$

$$w_5 = w_5 - \alpha \cdot \frac{\partial E_{\text{total}}}{\partial \bar{in}_{o2}} \cdot \frac{\partial \bar{in}_{o2}}{\partial w_5} = w_5 - \alpha \cdot \text{coef}_{o2} \cdot \text{out}_{p2} = -0.2 - 0.7 \cdot 0.177 \cdot 0.442 = -0.235$$

$$w_6 = w_6 - \alpha \cdot \frac{\partial E_{\text{total}}}{\partial \bar{in}_{o2}} \cdot \frac{\partial \bar{in}_{o2}}{\partial w_6} = w_6 - \alpha \cdot \text{coef}_{o2} \cdot \text{out}_{p3} = -0.3 - 0.7 \cdot 0.177 \cdot 0.750 = -0.393$$

$$\text{coefp}_1 = \frac{\partial E_{\text{total}}}{\partial \bar{I}_{\text{in}p_1}} = \frac{\partial E_{\text{total}}}{\partial I_{\text{in}1}} \cdot \frac{\partial I_{\text{in}1}}{\partial \bar{I}_{\text{in}p_1}} + \frac{\partial E_{\text{total}}}{\partial I_{\text{in}2}} \cdot \frac{\partial I_{\text{in}2}}{\partial \bar{I}_{\text{in}p_1}}$$

$$= \text{coef}_{f1} \cdot w_1 + \text{coef}_{f2} \cdot w_4 = -0.177 \times 0.169 + 0.177 \times (-0.169) = -0.060$$

$$\text{coefp}_2 = \frac{\partial E_{\text{total}}}{\partial \bar{I}_{\text{in}p_2}} = \frac{\partial E_{\text{total}}}{\partial I_{\text{in}1}} \cdot \frac{\partial I_{\text{in}1}}{\partial \bar{I}_{\text{in}p_2}} + \frac{\partial E_{\text{total}}}{\partial I_{\text{in}2}} \cdot \frac{\partial I_{\text{in}2}}{\partial \bar{I}_{\text{in}p_2}}$$

$$= \text{coef}_{f1} \cdot w_2 + \text{coef}_{f2} \cdot w_5 = -0.177 \times 0.255 + 0.177 \times (-0.255) = -0.090$$

$$\text{coefp}_3 = \frac{\partial E_{\text{total}}}{\partial \bar{I}_{\text{in}p_3}} = \frac{\partial E_{\text{total}}}{\partial I_{\text{in}1}} \cdot \frac{\partial I_{\text{in}1}}{\partial \bar{I}_{\text{in}p_3}} + \frac{\partial E_{\text{total}}}{\partial I_{\text{in}2}} \cdot \frac{\partial I_{\text{in}2}}{\partial \bar{I}_{\text{in}p_3}}$$

$$= \text{coef}_{f1} \cdot w_3 + \text{coef}_{f2} \cdot w_6 = -0.177 \times 0.393 + 0.177 \times (-0.393) = -0.139$$

$$\text{coefc}_1 = \frac{\partial E_{\text{total}}}{\partial \bar{I}_{\text{in}c_1}} = \frac{\partial E_{\text{total}}}{\partial I_{\text{in}p_1}} \cdot \frac{\partial I_{\text{in}p_1}}{\partial \text{outc}_1} \cdot \frac{\partial \text{outc}_1}{\partial \bar{I}_{\text{in}c_1}}$$

$$= \text{coefp}_1 \cdot w_{11} \cdot \text{outc}_1 (1 - \text{outc}_1)$$

$$= -0.06 \times 1 \times 0.558 (1 - 0.558) = -0.015$$

$$\text{coefc}_2 = \frac{\partial E_{\text{total}}}{\partial \bar{I}_{\text{in}c_2}} = \frac{\partial E_{\text{total}}}{\partial I_{\text{in}p_1}} \cdot \frac{\partial I_{\text{in}p_1}}{\partial \text{outc}_2} \cdot \frac{\partial \text{outc}_2}{\partial \bar{I}_{\text{in}c_2}}$$

$$= \text{coefp}_1 \cdot w_{12} \cdot \text{outc}_2 (1 - \text{outc}_2)$$

$$= -0.06 \times 0 \times 0.558 (1 - 0.558) = 0$$

$$\text{coefc}_3 = \frac{\partial E_{\text{total}}}{\partial \bar{I}_{\text{in}c_3}} = \frac{\partial E_{\text{total}}}{\partial I_{\text{in}p_2}} \cdot \frac{\partial I_{\text{in}p_2}}{\partial \text{outc}_3} \cdot \frac{\partial \text{outc}_3}{\partial \bar{I}_{\text{in}c_3}}$$

$$= \text{coefp}_2 \cdot w_{21} \cdot \text{outc}_3 (1 - \text{outc}_3)$$

$$= -0.09 \times 0 \times 0.446 (1 - 0.446) = 0$$

$$\text{coefc}_4 = \frac{\partial E_{\text{total}}}{\partial \bar{I}_{\text{in}c_4}} = \frac{\partial E_{\text{total}}}{\partial I_{\text{in}p_2}} \cdot \frac{\partial I_{\text{in}p_2}}{\partial \text{outc}_4} \cdot \frac{\partial \text{outc}_4}{\partial \bar{I}_{\text{in}c_4}}$$

$$= \text{coefp}_2 \cdot w_{22} \cdot \text{outc}_4 (1 - \text{outc}_4)$$

$$= -0.09 \times 1 \times 0.446 (1 - 0.446) = -0.012$$

$$\text{coefc}_5 = \frac{\partial E_{\text{total}}}{\partial \bar{I}_{\text{in}c_5}} = \frac{\partial E_{\text{total}}}{\partial I_{\text{in}p_3}} \cdot \frac{\partial I_{\text{in}p_3}}{\partial \text{outc}_5} \cdot \frac{\partial \text{outc}_5}{\partial \bar{I}_{\text{in}c_5}}$$

$$= \text{coefp}_3 \cdot w_{31} \cdot \text{outc}_5 (1 - \text{outc}_5)$$

$$= -0.139 \times 1 \times 0.75 (1 - 0.75) = -0.026$$

$$\text{coefc}_6 = \frac{\partial E_{\text{total}}}{\partial \bar{I}_{\text{in}c_6}} = \frac{\partial E_{\text{total}}}{\partial I_{\text{in}p_3}} \cdot \frac{\partial I_{\text{in}p_3}}{\partial \text{outc}_6} \cdot \frac{\partial \text{outc}_6}{\partial \bar{I}_{\text{in}c_6}}$$

$$= \text{coefp}_3 \cdot w_{32} \cdot \text{outc}_6 (1 - \text{outc}_6)$$

$$= -0.139 \times 0 \times 0.704 (1 - 0.704) = 0$$

$$k_{11} = k_{11} - \alpha \cdot \frac{\partial E_{\text{total}}}{\partial k_{11}} = k_{11} - \alpha \left( \frac{\partial E_{\text{total}}}{\partial \bar{m}_{C_1}} \cdot \frac{\partial \bar{m}_{C_1}}{\partial k_{11}} + \frac{\partial E_{\text{total}}}{\partial \bar{m}_{C_2}} \cdot \frac{\partial \bar{m}_{C_2}}{\partial k_{11}} \right)$$

$$= k_{11} - \alpha (\text{coef}_{C_1} \cdot \text{outpp}_3 + \text{coef}_{C_2} \cdot \text{outpp}_4) = -1 - 0.7 (-0.015 \cdot 0.419 + 0 \cdot 0.448)$$

$$= -0.995$$

$$k_{12} = k_{12} - \alpha \frac{\partial E_{\text{total}}}{\partial k_{12}} = k_{12} - \alpha \left( \frac{\partial E_{\text{total}}}{\partial \bar{m}_{C_1}} \cdot \frac{\partial \bar{m}_{C_1}}{\partial k_{12}} + \frac{\partial E_{\text{total}}}{\partial \bar{m}_{C_2}} \cdot \frac{\partial \bar{m}_{C_2}}{\partial k_{12}} \right)$$

$$= k_{12} - \alpha (\text{coef}_{C_1} \cdot \text{outpp}_2 + \text{coef}_{C_2} \cdot \text{outpp}_3) = 0 - 0.7 (-0.015 \cdot 0.680 + 0 \times 0.419)$$

$$= 0.007$$

$$k_{13} = k_{13} - \alpha \frac{\partial E_{\text{total}}}{\partial k_{13}} = k_{13} - \alpha \left( \frac{\partial E_{\text{total}}}{\partial \bar{m}_{C_1}} \cdot \frac{\partial \bar{m}_{C_1}}{\partial k_{13}} + \frac{\partial E_{\text{total}}}{\partial \bar{m}_{C_2}} \cdot \frac{\partial \bar{m}_{C_2}}{\partial k_{13}} \right)$$

$$= k_{13} - \alpha (\text{coef}_{C_1} \cdot \text{outpp}_1 + \text{coef}_{C_2} \cdot \text{outpp}_2) = 1 - 0.7 (-0.015 \cdot 0.653 + 0 \times 0.680)$$

$$= 1.007$$

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$$k_{21} = k_{21} - \alpha \frac{\partial E_{\text{total}}}{\partial k_{21}} = k_{21} - \alpha \left( \frac{\partial E_{\text{total}}}{\partial \bar{m}_{C_3}} \cdot \frac{\partial \bar{m}_{C_3}}{\partial k_{21}} + \frac{\partial E_{\text{total}}}{\partial \bar{m}_{C_4}} \cdot \frac{\partial \bar{m}_{C_4}}{\partial k_{21}} \right)$$

$$= k_{21} - \alpha (\text{coef}_{C_3} \cdot \text{outpp}_3 + \text{coef}_{C_4} \cdot \text{outpp}_4) = 1 - 0.7 (0 \times 0.419 + (-0.015) \times 0.448)$$

$$= 1.007$$

$$k_{22} = k_{22} - \alpha \frac{\partial E_{\text{total}}}{\partial k_{22}} = k_{22} - \alpha \left( \frac{\partial E_{\text{total}}}{\partial \bar{m}_{C_3}} \cdot \frac{\partial \bar{m}_{C_3}}{\partial k_{22}} + \frac{\partial E_{\text{total}}}{\partial \bar{m}_{C_4}} \cdot \frac{\partial \bar{m}_{C_4}}{\partial k_{22}} \right)$$

$$= k_{22} - \alpha (\text{coef}_{C_3} \cdot \text{outpp}_2 + \text{coef}_{C_4} \cdot \text{outpp}_3) = 0 - 0.7 (0 \times 0.680 + (-0.015) \times 0.419)$$

$$= 0.006$$

$$k_{23} = k_{23} - \alpha \frac{\partial E_{\text{total}}}{\partial k_{23}} = k_{23} - \alpha \left( \frac{\partial E_{\text{total}}}{\partial \bar{m}_{C_3}} \cdot \frac{\partial \bar{m}_{C_3}}{\partial k_{23}} + \frac{\partial E_{\text{total}}}{\partial \bar{m}_{C_4}} \cdot \frac{\partial \bar{m}_{C_4}}{\partial k_{23}} \right)$$

$$= k_{23} - \alpha (\text{coef}_{C_3} \cdot \text{outpp}_1 + \text{coef}_{C_4} \cdot \text{outpp}_2) = -1 - 0.7 (0 \times 0.653 + (-0.015) \times 0.680)$$

$$= -0.990$$

$$k_{31} = k_{31} - \alpha \frac{\partial E_{\text{total}}}{\partial k_{31}} = k_{31} - \alpha \left( \frac{\partial E_{\text{total}}}{\partial \bar{m}_{C_5}} \cdot \frac{\partial \bar{m}_{C_5}}{\partial k_{31}} + \frac{\partial E_{\text{total}}}{\partial \bar{m}_{C_6}} \cdot \frac{\partial \bar{m}_{C_6}}{\partial k_{31}} \right)$$

$$= k_{31} - \alpha (\text{coef}_{C_5} \cdot \text{outpp}_3 + \text{coef}_{C_6} \cdot \text{outpp}_4) = 1 - 0.7 ((-0.015) \times 0.419 + 0 \times 0.448)$$

$$= 1.008$$

$$k_{32} = k_{32} - \alpha \frac{\partial E_{\text{total}}}{\partial k_{32}} = k_{32} - \alpha \left( \frac{\partial E_{\text{total}}}{\partial \bar{m}_{C_5}} \cdot \frac{\partial \bar{m}_{C_5}}{\partial k_{32}} + \frac{\partial E_{\text{total}}}{\partial \bar{m}_{C_6}} \cdot \frac{\partial \bar{m}_{C_6}}{\partial k_{32}} \right)$$

$$= k_{32} - \alpha (\text{coef}_{C_5} \cdot \text{outpp}_2 + \text{coef}_{C_6} \cdot \text{outpp}_3) = 1 - 0.7 ((-0.015) \times 0.680 + 0 \times 0.419)$$

$$= 1.012$$

$$k_{33} = k_{33} - \alpha \frac{\partial E_{\text{total}}}{\partial k_{33}} = k_{33} - \alpha \left( \frac{\partial E_{\text{total}}}{\partial \bar{m}_{C_5}} \cdot \frac{\partial \bar{m}_{C_5}}{\partial k_{33}} + \frac{\partial E_{\text{total}}}{\partial \bar{m}_{C_6}} \cdot \frac{\partial \bar{m}_{C_6}}{\partial k_{33}} \right)$$

$$= k_{33} - \alpha (\text{coef}_{C_5} \cdot \text{outpp}_1 + \text{coef}_{C_6} \cdot \text{outpp}_2) = 0 - 0.7 ((-0.015) \times 0.653 + 0 \times 0.680)$$

$$= 0.012$$

$$b_1 = b_1 - \alpha \frac{\partial E_{FH}}{\partial b_1} = b_1 - \alpha \left( \frac{\partial E_{FH}}{\partial m_{C1}} \cdot \frac{\partial m_{C1}}{\partial b_1} + \frac{\partial E_{FH}}{\partial m_{C2}} \cdot \frac{\partial m_{C2}}{\partial b_1} \right)$$
$$= b_1 - \alpha (\text{coef}_{C1} + \text{coef}_{C2}) = 0 - 0.71 (-0.015) + 0 = 0.011$$

$$b_2 = b_2 - \alpha \frac{\partial E_{FH}}{\partial b_2} = b_2 - \alpha \left( \frac{\partial E_{FH}}{\partial m_{C3}} \cdot \frac{\text{others}}{\partial b_2} + \frac{\partial E_{FH}}{\partial m_{C4}} \cdot \frac{\partial m_{C4}}{\partial b_2} \right)$$
$$= b_2 - \alpha (\text{coef}_{C3} + \text{coef}_{C4}) = 0 - 0.7 (0 + 1 - 0.011) = 0.015$$

$$b_3 = b_3 - \alpha \frac{\partial E_{FH}}{\partial b_3} = b_3 - \alpha \left( \frac{\partial E_{FH}}{\partial m_{C5}} \cdot \frac{\partial m_{C5}}{\partial b_3} + \frac{\partial E_{FH}}{\partial m_{C6}} \cdot \frac{\partial m_{C6}}{\partial b_3} \right)$$
$$= b_3 - \alpha (\text{coef}_{B5} + \text{coef}_{B6}) = 0 - 0.7 ((-0.016) + 0) = 0.018$$

$$\begin{aligned}
 \text{coef}_{pp1} &= \frac{\partial E_{\text{total}}}{\partial \bar{m}_{pp1}} = \frac{\partial E_{\text{total}}}{\partial m_{c1}} \cdot \frac{\partial \bar{m}_{c1}}{\partial \bar{m}_{pp1}} + \frac{\partial E_{\text{total}}}{\partial m_{c3}} \cdot \frac{\partial \bar{m}_{c3}}{\partial \bar{m}_{pp1}} + \frac{\partial E_{\text{total}}}{\partial m_{c5}} \cdot \frac{\partial \bar{m}_{c5}}{\partial \bar{m}_{pp1}} \\
 &= \text{coef}_{c1} \cdot k_{13} + \text{coef}_{c3} \cdot k_{33} + \text{coef}_{c5} \cdot k_{33} \\
 &= -0.015 \cdot 1.007 + 0 \cdot (-0.990) + (-0.026) \cdot 0.012 = -0.015 \\
 \text{coef}_{pp2} &= \frac{\partial E_{\text{total}}}{\partial \bar{m}_{pp2}} = \frac{\partial E_{\text{total}}}{\partial m_{c1}} \cdot \frac{\partial \bar{m}_{c1}}{\partial \bar{m}_{pp2}} + \frac{\partial E_{\text{total}}}{\partial m_{c2}} \cdot \frac{\partial \bar{m}_{c2}}{\partial \bar{m}_{pp2}} + \frac{\partial E_{\text{total}}}{\partial m_{c3}} \cdot \frac{\partial \bar{m}_{c3}}{\partial \bar{m}_{pp2}} + \frac{\partial E_{\text{total}}}{\partial m_{c4}} \cdot \frac{\partial \bar{m}_{c4}}{\partial \bar{m}_{pp2}} \\
 &\quad + \frac{\partial E_{\text{total}}}{\partial m_{c5}} \cdot \frac{\partial \bar{m}_{c5}}{\partial \bar{m}_{pp2}} + \frac{\partial E_{\text{total}}}{\partial m_{c6}} \cdot \frac{\partial \bar{m}_{c6}}{\partial \bar{m}_{pp2}} \\
 &= \text{coef}_{c1} \cdot k_{12} + \text{coef}_{c2} \cdot k_{13} + \text{coef}_{c3} \cdot k_{11} + \text{coef}_{c4} \cdot k_{13} + \text{coef}_{c5} \cdot k_{11} + \text{coef}_{c6} \cdot k_{13} \\
 &= -0.015 \cdot 0.007 + 0 \cdot 1.007 + 0 \cdot 0.006 + (-0.026) \cdot (-0.990) + (-0.026) \cdot 1.012 + 0 \cdot 0.012 \\
 \text{coef}_{pp3} &= \frac{\partial E_{\text{total}}}{\partial \bar{m}_{pp3}} = \frac{\partial E_{\text{total}}}{\partial m_{c1}} \cdot \frac{\partial \bar{m}_{c1}}{\partial \bar{m}_{pp3}} + \frac{\partial E_{\text{total}}}{\partial m_{c2}} \cdot \frac{\partial \bar{m}_{c2}}{\partial \bar{m}_{pp3}} + \frac{\partial E_{\text{total}}}{\partial m_{c3}} \cdot \frac{\partial \bar{m}_{c3}}{\partial \bar{m}_{pp3}} + \frac{\partial E_{\text{total}}}{\partial m_{c4}} \cdot \frac{\partial \bar{m}_{c4}}{\partial \bar{m}_{pp3}} \\
 &\quad + \frac{\partial E_{\text{total}}}{\partial m_{c5}} \cdot \frac{\partial \bar{m}_{c5}}{\partial \bar{m}_{pp3}} + \frac{\partial E_{\text{total}}}{\partial m_{c6}} \cdot \frac{\partial \bar{m}_{c6}}{\partial \bar{m}_{pp3}} \\
 &= \text{coef}_{c1} \cdot k_{11} + \text{coef}_{c2} \cdot k_{12} + \text{coef}_{c3} \cdot k_{11} + \text{coef}_{c4} \cdot k_{11} + \text{coef}_{c5} \cdot k_{31} + \text{coef}_{c6} \cdot k_{32} \\
 &= -0.015 \cdot (-0.995) + 0 \cdot 0.007 + 0 \cdot 1.007 + (-0.026) \cdot 0.006 + (-0.026) \cdot 1.008 + 0 \cdot 1.012 \\
 &= -0.011 \\
 \text{coef}_{pp4} &= \frac{\partial E_{\text{total}}}{\partial \bar{m}_{pp4}} = \frac{\partial E_{\text{total}}}{\partial m_{c2}} \cdot \frac{\partial \bar{m}_{c2}}{\partial \bar{m}_{pp4}} + \frac{\partial E_{\text{total}}}{\partial m_{c4}} \cdot \frac{\partial \bar{m}_{c4}}{\partial \bar{m}_{pp4}} + \frac{\partial E_{\text{total}}}{\partial m_{c6}} \cdot \frac{\partial \bar{m}_{c6}}{\partial \bar{m}_{pp4}} \\
 &= \text{coef}_{c2} \cdot k_{11} + \text{coef}_{c4} \cdot k_{11} + \text{coef}_{c6} \cdot k_{31} \\
 &= 0 \cdot (-0.995) + (-0.026) \cdot 1.007 + 0 \cdot 1.008 = -0.022
 \end{aligned}$$

$\circ$	$\text{coef}_{c1}$	$\text{coef}_{c2}$	$\circ$	$\text{coef}_{c3}$	$\text{coef}_{c4}$	$\text{coef}_{c5}$	$\text{coef}_{c6}$
$k_{11}$	$k_{13}$		$k_{13}$	$k_{11}$	$k_{11}$	$k_{33}$	
$k_{12}$	$k_{13}$		$k_{11}$	$k_{13}$	$k_{11}$	$k_{32}$	$k_{33}$
$k_{11}$	$k_{12}$	$k_{13}$	$k_{11}$	$k_{11}$	$k_{11}$	$k_{31}$	$k_{31}$
$k_{11}$	$k_{12}$	$k_{13}$		$k_{11}$		$k_{11}$	$k_{11}$

$$\text{coef}_{cc1} = \frac{\partial E_{\text{total}}}{\partial in_{cc1}} = \frac{\partial E_{\text{total}}}{\partial m_{pp1}} \cdot \frac{\partial m_{pp1}}{\partial out_{cc1}} \cdot \frac{\partial out_{cc1}}{\partial in_{cc1}} = \text{coef}_{pp1} \cdot w_{11} \cdot out_{cc1} \cdot (1 - out_{cc1})$$

$$= -0.015 * 0.5 * 0.646 * (1 - 0.646) = -0.002$$

$$\text{coef}_{cc2} = \frac{\partial E_{\text{total}}}{\partial in_{cc2}} = \frac{\partial E_{\text{total}}}{\partial m_{pp1}} \cdot \frac{\partial m_{pp1}}{\partial out_{cc2}} \cdot \frac{\partial out_{cc2}}{\partial in_{cc2}} = \text{coef}_{pp1} \cdot w_{12} \cdot out_{cc2} \cdot (1 - out_{cc2})$$

$$= -0.015 * 0.5 * 0.659 * (1 - 0.659) = -0.002$$

$$\text{coef}_{cc3} = \frac{\partial E_{\text{total}}}{\partial in_{cc3}} = \frac{\partial E_{\text{total}}}{\partial m_{pp2}} \cdot \frac{\partial m_{pp2}}{\partial out_{cc3}} \cdot \frac{\partial out_{cc3}}{\partial in_{cc3}} = \text{coef}_{pp2} \cdot w_{21} \cdot out_{cc3} \cdot (1 - out_{cc3})$$

$$= -0.005 * 0.5 * 0.673 * (1 - 0.673) = 0$$

$$\text{coef}_{cc4} = \frac{\partial E_{\text{total}}}{\partial in_{cc4}} = \frac{\partial E_{\text{total}}}{\partial m_{pp2}} \cdot \frac{\partial m_{pp2}}{\partial out_{cc4}} \cdot \frac{\partial out_{cc4}}{\partial in_{cc4}} = \text{coef}_{pp2} \cdot w_{22} \cdot out_{cc4} \cdot (1 - out_{cc4})$$

$$= -0.005 * 0.5 * 0.686 * (1 - 0.686) = 0$$

$$\text{coef}_{cc5} = \frac{\partial E_{\text{total}}}{\partial in_{cc5}} = \frac{\partial E_{\text{total}}}{\partial m_{pp3}} \cdot \frac{\partial m_{pp3}}{\partial out_{cc5}} \cdot \frac{\partial out_{cc5}}{\partial in_{cc5}} = \text{coef}_{pp3} \cdot w_{31} \cdot out_{cc5} \cdot (1 - out_{cc5})$$

$$= -0.011 * 0.5 * 0.411 * (1 - 0.411) = -0.001$$

$$\text{coef}_{cc6} = \frac{\partial E_{\text{total}}}{\partial in_{cc6}} = \frac{\partial E_{\text{total}}}{\partial m_{pp3}} \cdot \frac{\partial m_{pp3}}{\partial out_{cc6}} \cdot \frac{\partial out_{cc6}}{\partial in_{cc6}} = \text{coef}_{pp3} \cdot w_{32} \cdot out_{cc6} \cdot (1 - out_{cc6})$$

$$= -0.011 * 0.5 * 0.426 * (1 - 0.426) = -0.001$$

$$\text{coef}_{cc7} = \frac{\partial E_{\text{total}}}{\partial in_{cc7}} = \frac{\partial E_{\text{total}}}{\partial m_{pp4}} \cdot \frac{\partial m_{pp4}}{\partial out_{cc7}} \cdot \frac{\partial out_{cc7}}{\partial in_{cc7}} = \text{coef}_{pp4} \cdot w_{41} \cdot out_{cc7} \cdot (1 - out_{cc7})$$

$$= -0.021 * 0.5 * 0.44 (1 - 0.44) = -0.003$$

$$\text{coef}_{cc8} = \frac{\partial E_{\text{total}}}{\partial in_{cc8}} = \frac{\partial E_{\text{total}}}{\partial m_{pp4}} \cdot \frac{\partial m_{pp4}}{\partial out_{cc8}} \cdot \frac{\partial out_{cc8}}{\partial in_{cc8}} = \text{coef}_{pp4} \cdot w_{42} \cdot out_{cc8} \cdot (1 - out_{cc8})$$

$$= -0.021 * 0.5 * 0.455 (1 - 0.455) = -0.003$$

CC<sub>2</sub>

$$KK_{11} = KK_{11} - \alpha \frac{\partial E_{\text{total}}}{\partial KK_{11}} = KK_{11} - \alpha \left( \frac{\partial E_{\text{total}}}{\partial in_{cc1}} \cdot \frac{\partial in_{cc1}}{\partial KK_{11}} + \frac{\partial E_{\text{total}}}{\partial m_{cc1}} \cdot \frac{\partial m_{cc1}}{\partial KK_{11}} \right. \\ \left. + \frac{\partial E_{\text{total}}}{\partial in_{cc3}} \cdot \frac{\partial in_{cc3}}{\partial KK_{11}} + \frac{\partial E_{\text{total}}}{\partial m_{cc3}} \cdot \frac{\partial m_{cc3}}{\partial KK_{11}} \right)$$

$$= KK_{11} - \alpha (\text{coef}_{cc1} \cdot i_1 + \text{coef}_{cc2} \cdot i_2 + \text{coef}_{cc3} \cdot i_3 + \text{coef}_{cc4} \cdot i_4)$$

$$= 0.1 + 0.7 (0.002 * 0.3 + 0.002 * 0.4 + 0 * 0.5 + 0 * 0.6) = 0.101$$

$$KK_{12} = KK_{12} - \alpha \frac{\partial E_{\text{total}}}{\partial KK_{12}} = KK_{12} - \alpha \left( \frac{\partial E_{\text{total}}}{\partial in_{cc1}} \cdot \frac{\partial m_{cc1}}{\partial KK_{12}} + \frac{\partial E_{\text{total}}}{\partial m_{cc1}} \cdot \frac{\partial in_{cc1}}{\partial KK_{12}} \right. \\ \left. + \frac{\partial E_{\text{total}}}{\partial in_{cc3}} \cdot \frac{\partial m_{cc3}}{\partial KK_{12}} + \frac{\partial E_{\text{total}}}{\partial m_{cc3}} \cdot \frac{\partial in_{cc3}}{\partial KK_{12}} \right)$$

$$= KK_{12} - \alpha (\text{coef}_{cc1} \cdot i_1 + \text{coef}_{cc2} \cdot i_2 + \text{coef}_{cc3} \cdot i_3 + \text{coef}_{cc4} \cdot i_4)$$

$$= 0.2 + 0.7 (0.002 * 0.2 + 0.002 * 0.3 + 0 * 0.4 + 0 * 0.5) = 0.201$$

$$kk_{13} = kk_{13} - \alpha \frac{\partial E_{\text{futu}}}{\partial kk_{13}} = kk_{13} - \alpha \left( \frac{\partial E_{\text{futu}}}{\partial m_{\text{CC1}}} \cdot \frac{\partial m_{\text{CC1}}}{\partial kk_{13}} + \frac{\partial E_{\text{futu}}}{\partial m_{\text{CC4}}} \cdot \frac{\partial m_{\text{CC4}}}{\partial kk_{13}} \right. \\ \left. + \frac{\partial E_{\text{futu}}}{\partial n_{\text{CC3}}} \cdot \frac{\partial n_{\text{CC3}}}{\partial kk_{13}} + \frac{\partial E_{\text{futu}}}{\partial n_{\text{CC4}}} \cdot \frac{\partial n_{\text{CC4}}}{\partial kk_{13}} \right) \\ = kk_{13} - \alpha (\text{coef}_{\text{CC1}} \cdot i_1 + \text{coef}_{\text{CC4}} \cdot i_1 + \text{coef}_{\text{CC3}} \cdot i_3 + \text{coef}_{\text{CC4}} \cdot i_4) \\ = 0.3 + 0.7(0.002 * 0.1 + 0.003 * 0.4 + 0 * 0.3 + 0 * 0.4) = 0.3$$

$$kk_{21} = kk_{21} - \alpha \frac{\partial E_{\text{futu}}}{\partial kk_{21}} = kk_{21} - \alpha \left( \frac{\partial E_{\text{futu}}}{\partial m_{\text{CC5}}} \cdot \frac{\partial m_{\text{CC5}}}{\partial kk_{21}} + \frac{\partial E_{\text{futu}}}{\partial m_{\text{CC6}}} \cdot \frac{\partial m_{\text{CC6}}}{\partial kk_{21}} \right. \\ \left. + \frac{\partial E_{\text{futu}}}{\partial n_{\text{CC7}}} \cdot \frac{\partial n_{\text{CC7}}}{\partial kk_{21}} + \frac{\partial E_{\text{futu}}}{\partial n_{\text{CC8}}} \cdot \frac{\partial n_{\text{CC8}}}{\partial kk_{21}} \right)$$

$$= kk_{21} - \alpha (\text{coef}_{\text{CC5}} \cdot i_3 + \text{coef}_{\text{CC6}} \cdot i_4 + \text{coef}_{\text{CC7}} \cdot i_5 + \text{coef}_{\text{CC8}} \cdot i_6) \\ = 0.3 + 0.7(0.001 * 0.3 + 0.001 * 0.4 + 0.003 * 0.5 + 0.003 * 0.6) = 0.303$$

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$$kk_{21} = kk_{21} - \alpha \frac{\partial E_{\text{futu}}}{\partial kk_{21}} = kk_{21} - \alpha \left( \frac{\partial E_{\text{futu}}}{\partial m_{\text{CC5}}} \cdot \frac{\partial m_{\text{CC5}}}{\partial kk_{21}} + \frac{\partial E_{\text{futu}}}{\partial m_{\text{CC6}}} \cdot \frac{\partial m_{\text{CC6}}}{\partial kk_{21}} \right. \\ \left. + \frac{\partial E_{\text{futu}}}{\partial n_{\text{CC7}}} \cdot \frac{\partial n_{\text{CC7}}}{\partial kk_{21}} + \frac{\partial E_{\text{futu}}}{\partial n_{\text{CC8}}} \cdot \frac{\partial n_{\text{CC8}}}{\partial kk_{21}} \right)$$

$$= kk_{21} - \alpha (\text{coef}_{\text{CC5}} \cdot i_3 + \text{coef}_{\text{CC6}} \cdot i_4 + \text{coef}_{\text{CC7}} \cdot i_5 + \text{coef}_{\text{CC8}} \cdot i_6) \\ = 0.2 + 0.7(0.001 * 0.2 + 0.001 * 0.3 + 0.003 * 0.4 + 0.003 * 0.5) = 0.202$$

$$kk_{13} = kk_{13} - \alpha \frac{\partial E_{\text{futu}}}{\partial kk_{13}} = kk_{13} - \alpha \left( \frac{\partial E_{\text{futu}}}{\partial m_{\text{CC5}}} \cdot \frac{\partial m_{\text{CC5}}}{\partial kk_{13}} + \frac{\partial E_{\text{futu}}}{\partial m_{\text{CC6}}} \cdot \frac{\partial m_{\text{CC6}}}{\partial kk_{13}} \right. \\ \left. + \frac{\partial E_{\text{futu}}}{\partial n_{\text{CC7}}} \cdot \frac{\partial n_{\text{CC7}}}{\partial kk_{13}} + \frac{\partial E_{\text{futu}}}{\partial n_{\text{CC8}}} \cdot \frac{\partial n_{\text{CC8}}}{\partial kk_{13}} \right)$$

$$= kk_{13} - \alpha (\text{coef}_{\text{CC5}} \cdot i_1 + \text{coef}_{\text{CC6}} \cdot i_1 + \text{coef}_{\text{CC7}} \cdot i_3 + \text{coef}_{\text{CC8}} \cdot i_4) \\ = 0.1 + 0.7(0.001 * 0.1 + 0.001 * 0.1 + 0.003 * 0.3 + 0.003 * 0.4) = 0.102$$

$$bb_1 = bb_1 - \alpha \frac{\partial E_{\text{futu}}}{\partial bb_1} = bb_1 - \alpha \left( \frac{\partial E_{\text{futu}}}{\partial n_{\text{CC1}}} \cdot \frac{\partial n_{\text{CC1}}}{\partial bb_1} + \frac{\partial E_{\text{futu}}}{\partial n_{\text{CC4}}} \cdot \frac{\partial n_{\text{CC4}}}{\partial bb_1} \right. \\ \left. + \frac{\partial E_{\text{futu}}}{\partial n_{\text{CC3}}} \cdot \frac{\partial n_{\text{CC3}}}{\partial bb_1} + \frac{\partial E_{\text{futu}}}{\partial n_{\text{CC4}}} \cdot \frac{\partial n_{\text{CC4}}}{\partial bb_1} \right)$$

$$= bb_1 - \alpha (\text{coef}_{\text{CC1}} \cdot i_1 + \text{coef}_{\text{CC4}} \cdot i_1 + \text{coef}_{\text{CC3}} \cdot i_1 + \text{coef}_{\text{CC4}} \cdot i_1) \\ = 0.5 + 0.7(0.002 * 0.002 + 0.002 * 0.0) = 0.502$$

$$bb_1 = bb_1 - \alpha \frac{\partial E_{\text{futu}}}{\partial bb_1} = bb_1 - \alpha \left( \frac{\partial E_{\text{futu}}}{\partial n_{\text{CC5}}} \cdot \frac{\partial n_{\text{CC5}}}{\partial bb_1} + \frac{\partial E_{\text{futu}}}{\partial n_{\text{CC6}}} \cdot \frac{\partial n_{\text{CC6}}}{\partial bb_1} \right. \\ \left. + \frac{\partial E_{\text{futu}}}{\partial n_{\text{CC7}}} \cdot \frac{\partial n_{\text{CC7}}}{\partial bb_1} + \frac{\partial E_{\text{futu}}}{\partial n_{\text{CC8}}} \cdot \frac{\partial n_{\text{CC8}}}{\partial bb_1} \right)$$

$$= bb_1 - \alpha (\text{coef}_{\text{CC5}} \cdot i_1 + \text{coef}_{\text{CC6}} \cdot i_1 + \text{coef}_{\text{CC7}} \cdot i_1 + \text{coef}_{\text{CC8}} \cdot i_1) \\ = -0.5 + 0.7(0.001 * 0.001 + 0.001 * 0.003 + 0.0003 * 0.0) = -0.494$$