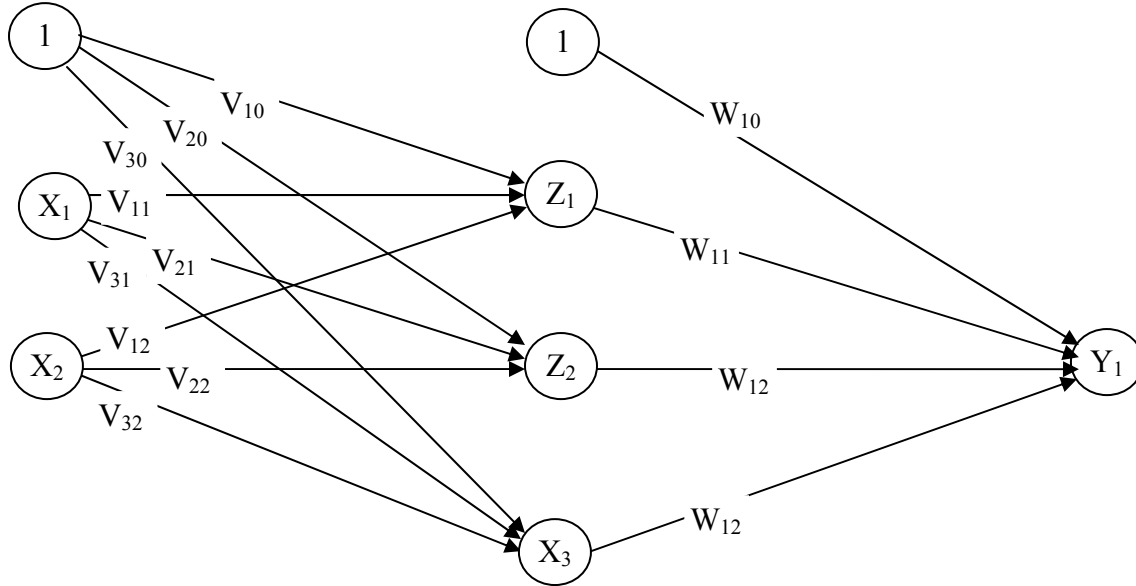


Contoh:

Gunakan backpropagation dengan sebuah layer tersembunyi (dengan 3 unit), untuk mengenali fungsi logika XOR dengan 2 masukan X_1 dan X_2 . Buatlah iterasi untuk menghitung bobot jaringan untuk pola pertama ($X_1=1, X_2=1$ dan $t=0$). Gunakan laju pemahaman $\alpha=0.2$.

Penyelesaian



Bobot-bobot diberikan nilai acak dengan range -1 sampai dengan 1. Missal bobot dari layer input ke layer tersembunyi seperti pada table a dan bobot-bobot dari layer tersembunyi ke layer output seperti pada table b.

Langkah 0

Inisialisasi semua bobot dengan bilangan acak kecil.

Table a

	z_1	Z_2	Z_3
X_1	0.2	0.3	-0.1
X_2	0.3	0.1	-0.1
1	-0.3	0.3	0.3

Table b

	Y
Z_1	0.5
Z_2	-0.3
Z_3	-0.4
1	-0.1

Langkah 1

Jika kondisi penghentian belum terpenuhi, lakukan langkah 2 sampai dengan 8

Langkah 2

Untuk setiap pasang data pelatihan, lakukan langkah 3 sampai dengan 8

Fase I: Propagasi Maju

Langkah 3

Tiap unit masukkan menerima sinyal dan meneruskan ke unit tersembunyi

Langkah 4

Hitung semua keluaran di unit tersembunyi (Z_j):

$$z_{net_j} = v_{j0} + \sum_{i=1}^n x_i v_{ji}$$

$$z_{net_1} = v_{10} + \sum_{i=1}^2 x_i v_{1i} = v_{10} + x_1 v_{11} + x_2 v_{12} = -0,3 + 1 \cdot 0,2 + 1 \cdot 0,3 = 0,2$$

$$z_{net_2} = v_{20} + \sum_{i=1}^2 x_i v_{2i} = v_{20} + x_1 v_{21} + x_2 v_{22} = 0,3 + 1 \cdot 0,3 + 1 \cdot 0,1 = 0,7$$

$$z_{net_3} = v_{30} + \sum_{i=1}^2 x_i v_{3i} = v_{30} + x_1 v_{31} + x_2 v_{32} = 0,3 + 1 \cdot (-0,1) + 1 \cdot (-0,1) = 0,1$$

$$z_j = f(z_{net_j}) = \frac{1}{1 + e^{-z_{net_j}}}$$

$$z_1 = f(z_{net_1}) = \frac{1}{1 + e^{-z_{net_1}}} = \frac{1}{1 + e^{-0,2}} = 0,55$$

$$z_2 = f(z_{net_2}) = \frac{1}{1 + e^{-z_{net_2}}} = \frac{1}{1 + e^{-0,7}} = 0,67$$

$$z_3 = f(z_{net_3}) = \frac{1}{1 + e^{-z_{net_3}}} = \frac{1}{1 + e^{-0,1}} = 0,52$$

Langkah 5

Hitung semua jaringan di unit keluaran (y_k)

$$y_{net_k} = w_{k0} + \sum_{j=1}^p z_j w_{kj}$$

$$\begin{aligned} y_{net_1} &= w_{10} + \sum_{j=1}^3 z_j w_{1j} = w_{10} + z_1 w_{11} + z_2 w_{12} + z_3 w_{13} \\ &= -0,1 + 0,55 \cdot 0,5 + 0,67 \cdot (-0,3) + 0,52 \cdot (-0,4) = 0,24 \end{aligned}$$

$$y_k = f(y_{net_k}) = \frac{1}{1 + e^{-y_{net_k}}} = \frac{1}{1 + e^{-0,24}} = 0,44$$

Fase II : Propagasi Maju

Langkah 6

$$\delta_k = (t_k - y_k) f'(y_{net_k}) = (t_k - y_k) y_k (1 - y_k)$$

$$\delta_1 = (t_1 - y_1) f'(y_{net1}) = (t_1 - y_1) y_1 (1 - y_1) = (0 - 0,44) 0,44 (1 - 0,44) = -0,11$$

$$\Delta w_{kj} = \alpha \delta_k z_j$$

$$\Delta w_{10} = \alpha \delta_1 (1) = 0,2 \cdot (-0,11) \cdot (1) = -0,022$$

$$\Delta w_{11} = \alpha \delta_1 (z_1) = 0,2 \cdot (-0,11) \cdot (0,55) = -0,01$$

$$\Delta w_{12} = \alpha \delta_1 (z_2) = 0,2 \cdot (-0,11) \cdot (0,67) = -0,01$$

$$\Delta w_{13} = \alpha \delta_1 (z_3) = 0,2 \cdot (-0,11) \cdot (0,52) = -0,01$$

Langkah 7

Hitung factor δ unit tersembunyi berdasarkan kesalahan di setiap unit tersembunyi z_j ($j=1,2,3,\dots,p$)

$$\delta_{net_j} = \sum_{k=1}^m \delta_k w_{kj}$$

$$\delta_{net_1} = \delta_1 \cdot w_{11} = (-0,11) \cdot 0,5 = -0,055$$

$$\delta_{net_2} = \delta_1 \cdot w_{12} = (-0,11) \cdot (-0,3) = 0,033$$

$$\delta_{net_3} = \delta_1 \cdot w_{13} = (-0,11) \cdot (-0,4) = 0,044$$

Faktor kesalahan δ unit tersembunyi

$$\delta_j = \delta_{net_j} f'(z_{net_j}) = \delta_{net_j} z_j (1 - z_j)$$

$$\delta_1 = \delta_{net_1} z_1 (1 - z_1) = (-0,055) \cdot 0,55 \cdot (1 - 0,55) = -0,01$$

$$\delta_2 = \delta_{net_2} z_2 (1 - z_2) = (0,033) \cdot 0,67 \cdot (1 - 0,67) = 0,01$$

$$\delta_3 = \delta_{net_3} z_3 (1 - z_3) = (0,044) \cdot 0,52 \cdot (1 - 0,52) = 0,01$$

$$\Delta v_{ji} = \alpha \delta_j x_i$$

$$\Delta v_{10} = \alpha \delta_1 = 0,2 \cdot (-0,01) = -0,002$$

$$\Delta v_{20} = \alpha \delta_2 = 0,2 \cdot (0,01) = 0,002$$

$$\Delta v_{30} = \alpha \delta_3 = 0,2 \cdot (0,01) = 0,002$$

$$\Delta v_{11} = \alpha \delta_1 x_1 = 0,2 \cdot (-0,01) \cdot 1 = -0,002$$

$$\Delta v_{21} = \alpha \delta_2 x_1 = 0,2 \cdot (0,01) \cdot 1 = 0,002$$

$$\Delta v_{31} = \alpha \delta_3 x_1 = 0,2 \cdot (0,01) \cdot 1 = 0,002$$

$$\Delta v_{12} = \alpha \delta_1 x_2 = 0,2 \cdot (-0,01) \cdot 1 = -0,002$$

$$\Delta v_{22} = \alpha \delta_2 x_2 = 0,2 \cdot (0,01) \cdot 1 = 0,002$$

$$\Delta v_{32} = \alpha \delta_3 x_2 = 0,2 \cdot (0,01) \cdot 1 = 0,002$$

Fase III : Perubahan Bobot

Langkah 8

Perubahan bobot garis yang menuju unit keluaran

$$w_{kj} (\text{baru}) = w_{kj} (\text{lama}) + \Delta w_{kj}$$

$$w_{10}(\text{baru}) = w_{10}(\text{lama}) + \Delta w_{10} = -0,1 - 0,022 = -0,122$$

$$w_{11}(\text{baru}) = w_{11}(\text{lama}) + \Delta w_{11} = 0,5 - 0,01 = 0,49$$

$$w_{12}(\text{baru}) = w_{12}(\text{lama}) + \Delta w_{12} = -0,3 - 0,01 = -0,31$$

$$w_{13}(\text{baru}) = w_{13}(\text{lama}) + \Delta w_{13} = -0,4 - 0,01 = -0,41$$

$$V_{ji}(\text{baru}) = v_{ji}(\text{lama}) + \Delta v_{ji}$$

$$V_{10}(\text{baru}) = v_{10}(\text{lama}) + \Delta v_{10} = -0,3 - 0,002 = -0,302$$

$$V_{20}(\text{baru}) = v_{20}(\text{lama}) + \Delta v_{20} = 0,3 + 0,002 = 0,302$$

$$V_{30}(\text{baru}) = v_{30}(\text{lama}) + \Delta v_{30} = 0,3 + 0,002 = 0,302$$

$$V_{11}(\text{baru}) = v_{11}(\text{lama}) + \Delta v_{11} = 0,2 - 0,002 = 0,198$$

$$V_{21}(\text{baru}) = v_{21}(\text{lama}) + \Delta v_{21} = 0,3 + 0,002 = 0,302$$

$$V_{31}(\text{baru}) = v_{31}(\text{lama}) + \Delta v_{31} = -0,1 + 0,002 = -0,098$$

$$V_{12}(\text{baru}) = v_{12}(\text{lama}) + \Delta v_{12} = 0,3 - 0,002 = 0,298$$

$$V_{22}(\text{baru}) = v_{22}(\text{lama}) + \Delta v_{22} = 0,1 + 0,002 = 0,102$$

$$V_{32}(\text{baru}) = v_{32}(\text{lama}) + \Delta v_{32} = -0,1 + 0,002 = -0,098$$

Untuk Pola yang kedua, $X_1=1$, $X_2=0$ dan $t=1$

Fase I: Propagasi Maju

Langkah 3

Tiap unit masukkan menerima sinyal dan meneruskan ke unit tersembunyi

Langkah 4

Hitung semua keluaran di unit tersembunyi (Z_j):

$$z_{net_j} = v_{j0} + \sum_{i=1}^n x_i v_{ji}$$

$$z_{net_1} = v_{10} + \sum_{i=1}^2 x_i v_{1i} = v_{10} + x_1 v_{11} + x_2 v_{12} = -0,3 + 1 \cdot 0,2 + 1 \cdot 0,3 = 0,2$$

$$z_{net_2} = v_{20} + \sum_{i=1}^2 x_i v_{2i} = v_{20} + x_1 v_{21} + x_2 v_{22} = 0,3 + 1 \cdot 0,3 + 1 \cdot 0,1 = 0,7$$

$$z_{net_3} = v_{30} + \sum_{i=1}^2 x_i v_{3i} = v_{30} + x_1 v_{31} + x_2 v_{32} = 0,3 + 1 \cdot (-0,1) + 1 \cdot (-0,1) = 0,1$$

$$z_j = f(z_{net_j}) = \frac{1}{1 + e^{-z_{net_j}}}$$

$$z_1 = f(z_{net_1}) = \frac{1}{1 + e^{-z_{net_1}}} = \frac{1}{1 + e^{-0,2}} = 0,55$$

$$z_2 = f(z_{net_2}) = \frac{1}{1 + e^{-z_{net_2}}} = \frac{1}{1 + e^{-0,7}} = 0,67$$

$$z_3 = f(z_{net_3}) = \frac{1}{1 + e^{-z_{net_3}}} = \frac{1}{1 + e^{-0,1}} = 0,52$$

Langkah 5

Hitung semua jaringan di unit keluaran (y_k)

$$y_{net_k} = w_{k0} + \sum_{j=1}^p z_j w_{kj}$$

$$y_{net_1} = w_{10} + \sum_{j=1}^3 z_j w_{1j} = w_{10} + z_1 w_{11} + z_2 w_{12} + z_3 w_{13}$$

$$= -0,1 + 0,55 \cdot 0,5 + 0,67 \cdot (-0,3) + 0,52 \cdot (-0,4) = -0,24$$

$$y_k = f(y_{net_k}) = \frac{1}{1 + e^{-y_{net_k}}} = \frac{1}{1 + e^{-0,24}} = 0,44$$

Fase II : Propagasi Maju

Langkah 6

$$\delta_k = (t_k - y_k) f'(y_{net_k}) = (t_k - y_k) y_k (1 - y_k)$$

$$\delta_1 = (t_1 - y_1) f'(y_{net_1}) = (t_1 - y_1) y_1 (1 - y_1) = (0 - 0,44) \cdot 0,44 \cdot (1 - 0,44) = -0,11$$

$$\Delta w_{kj} = \alpha \delta_k z_j$$

$$\Delta w_{10} = \alpha \delta_1 (1) = 0,2 \cdot (-0,11) \cdot (1) = -0,022$$

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$$\Delta w_{13} = \alpha \delta_1 (z_3) = 0,2 \cdot (-0,11) \cdot (0,52) = -0,01$$

Langkah 7

Hitung factor δ unit tersembunyi berdasarkan kesalahan di setiap unit tersembunyi z_j ($j=1,2,3,\dots,p$)

$$\delta_{net_j} = \sum_{k=1}^m \delta_k w_{kj}$$

$$\delta_{net_1} = \delta_1 \cdot w_{11} = (-0,11) \cdot 0,5 = -0,055$$

$$\delta_{net_2} = \delta_1 \cdot w_{12} = (-0,11) \cdot (-0,3) = 0,033$$

$$\delta_{net_3} = \delta_1 \cdot w_{13} = (-0,11) \cdot (-0,4) = 0,044$$

Faktor kesalahan δ unit tersembunyi

$$\delta_j = \delta_{net_j} f'(z_{net_j}) = \delta_{net_j} z_j (1 - z_j)$$

$$\delta_1 = \delta_{\text{net}} z_1 (1-z_1) = (-0.055) \cdot 0,55 \cdot (1-(0,55)) = -0,01$$

$$\delta_2 = \delta_{\text{net}} z_2 (1-z_2) = (0.033) \cdot 0,67 \cdot (1-(0,67)) = 0,01$$

$$\delta_3 = \delta_{\text{net}} z_3 (1-z_3) = (0.044) \cdot 0,52 \cdot (1-(0,52)) = 0,01$$

$$\Delta v_{ji} = \alpha \delta_j x_i$$

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$$\Delta v_{12} = \alpha \delta_1 x_2 = 0,2 \cdot (-0,01) = -0,002$$

$$\Delta v_{22} = \alpha \delta_2 x_2 = 0,2 \cdot (0,01) = 0,002$$

$$\Delta v_{32} = \alpha \delta_3 x_2 = 0,2 \cdot (0,01) = 0,002$$

Fase III : Perubahan Bobot

Langkah 8

Perubahan bobot garis yang menuju unit keluaran

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$$w_{13} (\text{baru}) = w_{13} (\text{lama}) + \Delta w_{13} = -0,4 - 0,01 = -0,41$$

$$V_{ji} (\text{baru}) = v_{ji} (\text{lama}) + \Delta v_{ji}$$

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$$V_{20} (\text{baru}) = v_{20} (\text{lama}) + \Delta v_{20} = 0,3 + 0,002 = 0,302$$

$$V_{30} (\text{baru}) = v_{30} (\text{lama}) + \Delta v_{30} = 0,3 + 0,002 = 0,302$$

$$V_{11} (\text{baru}) = v_{11} (\text{lama}) + \Delta v_{11} = 0,2 - 0,002 = 0,198$$

$$V_{21} (\text{baru}) = v_{21} (\text{lama}) + \Delta v_{21} = 0,3 + 0,002 = 0,302$$

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$$V_{32} (\text{baru}) = v_{32} (\text{lama}) + \Delta v_{32} = -0,1 + 0,002 = -0,098$$

Pola ke 2 $X_1=1, X_2=0, t=1$

Pola ke 3 $X_1=0, X_2=1, t=1$

Pola ke 4 $X_1=0, X_2=0, t=0$