References

[1] Laurene Fausett. Fundamentals of Neural Network Architecture, Algorithm and Application. Singapore: Prentice Hall International Edition, 1994.

[2] J.G.taylor. The Promise of Neural Network. Berlin:Springer-Verlag, 1993.

[3] Joachim Angstenberger. "Blast Furnace Analysis with Neural Networks", Solving Engineering Problems with Neural Networks, Proceeding of the International Conference on Engineering Applications of Neural Networks (EANN'96), London, England, 1996.

[4] Mats Nikus and Henrik Saxen. "Neural Model of Blast Furnace Burden Distribution", Solving Engineering Problems with Neural Networks, Proceeding of the International Conference on Engineering Applications of Neural Networks (EANN'96), London, England, 1996

[5] Yudong Cai. "Optimization of a BOF's Lining Resistance by Application of Artificial Neural Network", Steel Research 65. No. 11, 1994.

[6] Amlan Datta, Mavoori Hareesh, Prem Kumar Kalra, Brahma Deo and Rob Boom. "Adaptive Neural Net(ANN) Models for Desulfurization of Hot Metal and Steel", Steel Research 65, No. 11, 1994.

[7] M.A.Reuter, T.J.Van der Walt, and J.S.J. Van Deventer. "Modeling of Metal-Slag Equilibrium Process Using Neural Nets", Metallurgical Transaction B. Vol.23B, 1992.

[8] H.Kominami, S.Naitoh, N.kamada, C.Hamaguchi, T.Tanka, H.Endoch. "Neural Network System for Breakout Prediction in ContinuousCasting Process", Nippon Steel Technical Report. No. 49, 1991.

[9] P.Myllykoski and J.Larkiola. "Use of Artificial Neural Networks on Optimisation of Mechanical Properties of Batch Annealed Thin Steel Strips", Solving Engineering Problems with Neural Networks, Proceeding of the International Conference on Engineering Applicationsof Neural Networks (EANN'96). London, England, 1996.

[10] Sungzoon Cho, Min Jang, Yong-Joong Cho, SungCheol Yoon and Hyungsuk Cho. " Improvement of Cold Mill Precalculation Accuracy Using A Corrective Neural Network", Solving Engineering Problems with Neural Networks, Proceeding of the International Conference on Engineering Applications of Neural Networks (EANN'96). London, England, 1996.

[11] W.G. Vermeulen, P.F. Mmorris, A.P. de Weijer, and S. Van der Zwaag, "Prediction of Martensite Start Temperature Using Artificial Neural Networks.", Ironmaking and Steelmaking. Vol 23, No 25, 1996.

[12] D.E.Rumelhart, J.L.McCleland, and G.E.Hinton, "Parallel Distributed Processing". Vol 1, 1986, Cambrige, MA, MIT Press.

[13] Stephen I. Gallant. Neural Network Learning and Expert System, MIT Press, p222.

[14] Dan W. Patterson. Artificial Neural Networks Theory and Applications. New York : Prentice Hall International Edition, 1994.

Appendix

Example of Calculation of Multilayer Perceptron with Backpropagation Algorithm

The architecture for this example is [11,6,1] 11 input node, 6 hidden node, 1 output node. Use 0.01 learning rate, 0.9 momentum, sigmoid activation function. The input data set is listed as below:

$X_1 = 0.89$	$X_7 = 0.34$
$X_2 = 0.02$	$X_8 = 0.75$
$X_3 = 0.18$	$X_9 = 0$
$X_4 = 0.25$	$X_{10} = 0.68$
$X_5 = 0.069$	$X_{11} = 0.93$
$X_6 = 0.58$	target output $O_1 = 0.781$

1.Initialize all weights W in range [-0.1, 0.1].

1.1 Weight between input layer and hidden layer: W_{ji}

$W_{1,1} = 0.1$	$W_{2,1} = -0.08$	$W_{3,1} = 0.1$
$W_{1,2} = 0.05$	$W_{2,2} = -0.03$	$W_{3,2} = 0.03$
$W_{1,3} = -0.09$	$W_{2,3} = 0.004$	$W_{3,3} = 0.06$
$W_{1,4} = 0.02$	$W_{2,4} = 0.08$	$W_{3,4} = -0.07$
$W_{1,5} = 0.1$	$W_{2,5} = 0.01$	$W_{3,5} = -0.08$
$W_{1,6} = -0.04$	$W_{2.6} = -0.1$	$W_{3,6} = -0.03$
$W_{1,7} = -0.01$	$W_{2,7} = -0.006$	$W_{3,7} = 0.045$
$W_{1,8} = -0.1$	$W_{2,8} = 0.006$	$W_{3,8} = 0.0013$

$W_{1,9} = 0.07$	$W_{2,9} = 0.03$	$W_{3,9} = -0.002$
$W_{1,10} = 0.006$	$W_{2,10} = 0.02$	$W_{3,10} = 0.08$
$W_{1,11} = -0.005$	$W_{2,11} = -0.008$	$W_{3,11} = -0.09$

$W_{4,1} = 0.0023$	$W_{5,1} = 0.017$	$W_{6,1} = 0.01$
$W_{4,2} = 0.028$	$W_{5,2} = -0.028$	$W_{6,2} = 0.097$
$W_{4,3} = -0.037$	$W_{5,3} = 0.039$	$W_{6,3} = -0.067$
$W_{4,4} = 0.07$	$W_{5,4} = -0.059$	$W_{6,4} = 0.082$
$W_{4,5} = 0.087$	$W_{5,5} = 0.069$	$W_{6,5} = 0.065$
$W_{4,6} = 0.095$	$W_{5,6} = 0.087$	$W_{6,6} = -0.045$
$W_{4,7} = -0.015$	$W_{5,7} = 0.055$	$W_{6,7} = -0.035$
$W_{4,8} = -0.012$	$W_{5,8} = -0.02$	$W_{6,8} = -0.072$
$W_{4,9} = 0.023$	$W_{5,9} = -0.03$	$W_{6,9} = 0.1$
$W_{4,10} = 0.071$	$W_{5,10} = -0.04$	$W_{6,10} = -0.1$
$W_{4,11} = 0.011$	$W_{5,11} = -0.04$	$W_{6,11} = 0.001$

1.2 Weights between hidden layer and output layer: W_{kj}

$W_{1,1} = -0.025$

$W_{1,2} = -0.012$

$W_{1,3} = 0.025$

$W_{1,4} = 0.045$

$W_{1,5} = 0.065$

$W_{1,6} = 0.01$

2. Compute the output

2.1 For hidden layer

$$H_j = \Sigma W_{ji} X_i$$

$$Y_j = f(H_j)$$

H_1 = 0.89*0.1 + 0.02*0.05 + 0.18*(-0.09) + 0.25*0.02 + 0.069*0.1 + 0.58*(- 0.04) + 0.34*(-0.01) + 0.75*(-0.1) + 0*0.07 + 0.68*(0.006) + 0.93*(-0.005)

= -0.0165

Y_1 = 0.5041

H_2 = 0.89*(-0.08) + 0.02*(-0.03) + 0.18*0.004 + 0.25*0.08 + 0.069*0.01 + 0.58*0.1 + 0.34*(-0.006) + 0.75*0.006 + 0*0.03 + 0.68*0.02 + 0.93*(-0.008)

= 0.01623

Y_2 = 0.4959

H_3 = 0.89*0.1 + 0.02*0.03 + 0.18*0.06 + 0.25*(-0.07) + 0.069*(-0.08) + 0.58*(-0.03) + 0.34* 0.045 + 0.75*0.0013 + 0*(-0.002) + 0.68*0.08 + 0.93*(-0.09)

= 0.04695

Y_3 = 0.4883

H_4 = 0.89*0.0023 + 0.02*0.028 + 0.18*(-0.037) + 0.25*0.07 + 0.069*0.087 + 0.58*0.095 + 0.34*(-0.015) + 0.75*(-0.012) + 0*0.023 + 0.68*0.071 + 0.93*0.011

= 0.11896

Y_4 = 0.4703

H_5 = 0.89*0.017 + 0.02*(-0.028) + 0.18*(-0.639) + 0.25*(-0.059) + 0.069*0.069 + 0.58*0.087 + 0.34*0.055 + 0.75*(-0.02) + 0*(-0.03) + 0.678*(-0.04) + .93*(-0.09)

= -0.0347

Y_5 = 0.5087

H_6 = 0.89*.001 + .02*.097 + .18*(-.067) + .25*.082 + .069*.065 + .58*(-.045) + .34*(-.035) + .75*(-.072) + 0 + .68*(-.1) + .93*.001

= -0.1433

Y_6 = 0.5358

2.2 For output layer

$$I_k = \Sigma W_{kj} Y_j$$

$$Z = f(I_k)$$

I_k = 0.5041*(-0.025) + 0.4959*(-0.012) + 0.4883*0.025 + 0.4703* 0.045 +0.5087*0.065 + 0.5358*0.01

Z = 0.4867

3. Adjust weights connection

3.1 For output layer

$$\Delta W_{kj} = \eta\ (t-z) f'(I) Y_j$$

(t-z) = 0.7813-0.4867

= 0.2936

$f'(I)$ = 0.7236

η = 0.01

$\Delta W_{1,1}$ = 0.01*.02946*0.7236*0.5041

=0.0011

$W_{1,1}$(new) = $W_{1,1}$(old) + $\Delta W_{1,1}$

= -0.025 + 0.0011 = 0.0239

$\Delta W_{1,2}$ = 0.01*0.2946*0.7236*0.4959

= 0.011

$W_{1,2}$(new) = $W_{1,2}$ (old) + $\Delta W_{1,2}$

= -0.012 + 0.0011 = 0.0109

$\Delta W_{1,3}$ = 0.01*0.2946*0.7236*0.4883

= 0.001

$W_{1,3}$(new) = $W_{1,3}$(old) + $\Delta W_{1,3}$

= 0.025+0.001 = 0.026

$\Delta W_{1,4}$ = 0.01*0.2946*0.7236*0.4703

= 0.001

$W_{1,4}$(new) = $W_{1,4}$(old) + $\Delta W_{1,4}$

= 0.045+0.001 = 0.046

$\Delta W_{1,5}$ = 0.01*0.2946*0.7236*0.5087

= 0.0011

$W_{1,5}$(new) = $W_{1,5}$(old) + $\Delta W_{1,5}$

= 0.065+0.0011 = 0.0661

$\Delta W_{1,6}$ = 0.01*0.2946*0.7236*0.5358

= 0.0012

$W_{1,6}$(new) = $W_{1,6}$(old) + $\Delta W_{1,6}$

= 0.01+0.0012 = 0.0112

3.2 For hidden layer

$$\Delta w_{ji} = \eta x_I f'(H_j) \Sigma \delta_k w_{kj}$$

$$w_{ji(new)} = w_{ji(old)} + \Delta w$$

$\Delta w_{1,1} = 6.26*10^{-7}$ $\quad w_{1,1(new)} = 0.1+6.26*10^{-7}$

$\Delta w_{1,2} = 1.73*10^{-8}$ $\quad w_{1,2(new)} = 0.05+1.73*10^{-8}$

$\Delta w_{1,3} = 1.55*10^{-7}$ $\quad w_{1,3(new)} = -0.09+1.55*10^{-7}$

$\Delta w_{1,4} = 2.16*10^{-7}$ $\quad w_{1,4(new)} = 0.02+2.16*10^{-7}$

$\Delta w_{1,5} = 5.96*10^{-7}$ $\quad w_{1,5(new)} = 0.1+5.96*10^{-7}$

$\Delta w_{1,6} = 5.01*10^{-7}$ $\quad w_{1,6(new)} = -0.04+5.01*10^{-7}$

$\Delta w_{1,7} = 2.94*10^{-7}$ $\quad w_{1,7(new)} = -0.01+2.94*10^{-7}$

$\Delta w_{1,8} = 6.48*10^{-7}$ $\quad w_{1,8(new)} = -0.1+6.48*10^{-7}$

$\Delta w_{1,9} = 0$ $\quad w_{1,9(new)} = 0.07+0$

$\Delta w_{1,10} = 5.87*10^{-7}$ $\quad w_{1,10(new)} = 0.006+5.87*10^{-7}$

$\Delta w_{1,11} = 8.03*10^{-7}$ $\quad w_{1,11(new)} = -0.005+8.03*10^{-7}$

$\Delta w_{2,1} = -3.8*10^{-7}$ $\quad w_{2,1(new)} = -0.08-3.8*10^{-7}$

$\Delta w_{2,2} = -8.4*10^{-9}$ $\quad w_{2,2(new)} = -0.03-8.4*10^{-9}$

$\Delta w_{2,3} = -7.6*10^{-8}$ $\quad w_{2,3(new)} = 0.004-7.6*10^{-8}$

$\Delta w_{2,4} = -1.1*10^{-7}$ $\quad w_{2,4(new)} = 0.08-1.1*10^{-7}$

$\Delta w_{2,5} = -2.9*10^{-8}$ $\quad w_{2,5(new)} = 0.01-2.9*10^{-8}$

$\Delta w_{2,6} = -2.4*10^{-7}$ $w_{2,6(new)} = -0.1-2.4*10^{-7}$

$\Delta w_{2,7} = -1.4*10^{-7}$ $w_{2,7(new)} = -0.006-1.4*10^{-7}$

$\Delta w_{2,8} = -3.2*10^{-7}$ $w_{2,8(new)} = 0.006-3.2*10^{-7}$

$\Delta w_{2,9} = 0$ $w_{2,9(new)} = 0.03-0$

$\Delta w_{2,10} = -2.9*10^{-7}$ $w_{2,10(new)} = 0.02-2.9*10^{-7}$

$\Delta w_{2,11} = -3.9*10^{-7}$ $w_{2,11(new)} = -0.008-3.9*10^{-7}$

$\Delta w_{3,1} = 2.33*10^{-6}$ $w_{3,1(new)} = 0.1+2.33*10^{-6}$

$\Delta w_{3,2} = 5.24*10^{-8}$ $w_{3,2(new)} = 0.03+5.24*10^{-8}$

$\Delta w_{3,3} = 4.72*10^{-7}$ $w_{3,3(new)} = 0.06+4.72*10^{-7}$

$\Delta w_{3,4} = 6.56*10^{-7}$ $w_{3,4(new)} = -0.07+6.56*10^{-7}$

$\Delta w_{3,5} = 1.81*10^{-7}$ $w_{3,5(new)} = -0.08+1.81*10^{-7}$

$\Delta w_{3,6} = 1.52*10^{-6}$ $w_{3,6(new)} = -0.03+1.52*10^{-6}$

$\Delta w_{3,7} = 8.92*10^{-7}$ $w_{3,7(new)} = 0.045+8.92*10^{-7}$

$\Delta w_{3,8} = 1.97*10^{-6}$ $w_{3,8(new)} = 0.0013+1.97*10^{-6}$

$\Delta w_{3,9} = 0$ $w_{3,9(new)} = -0.002+0$

$\Delta w_{3,10} = 1.78*10^{-6}$ $w_{3,10(new)} = 0.08+1.78*10^{-6}$

$\Delta w_{3,11} = 2.44*10^{-6}$ $w_{3,11(new)} = -0.09+2.44*10^{-6}$

$\Delta w_{4,1} = 2.9*10^{-5}$ $w_{4,1(new)} = 0.0023+5.9*10^{-5}$

$\Delta w_{4,2} = 1.33*10^{-6}$ $w_{4,2(new)} = 0.028+1.33*10^{-6}$

$\Delta w_{4,3} = 1.19*10^{-5}$ $w_{4,3(new)} = -0.037+1.19*10^{-5}$

$\Delta w_{4,4} = 1.66*10^{-5}$ $w_{4,4(new)} = 0.07+1.66*10^{-5}$

$\Delta w_{4,5} = 4.58*10^{-6}$ $w_{4,5(new)} = 0.087+4.58*10^{-6}$

$\Delta w_{4,6} = 3.85*10^{-5}$ $w_{4,6(new)} = 0.095+3.85*10^{-5}$

$\Delta w_{4,7} = 2.26*10^{-5}$ $w_{4,7(new)} = -0.015+2.26*10^{-5}$

$\Delta w_{4,8} = 4.98*10^{-5}$ $w_{4,8(new)} = -0.012+4.98*10^{-5}$

$\Delta w_{4,9} = 0$ $w_{4,9(new)} = 0.023+0$

$\Delta w_{4,10} = 4.51*10^{-5}$ $w_{4,10(new)} = 0.071+4.51*10^{-5}$

$\Delta w_{4,11} = 6.17*10^{-5}$ $w_{4,11(new)} = 0.011+6.17*10^{-5}$

$\Delta w_{5,1} = 9.47*10^{-5}$ $w_{5,1(new)} = 0.017+9.45*10^{-5}$

$\Delta w_{5,2} = 2.13*10^{-6}$ $w_{5,2(new)\ 0} = -0.028+2.13*10^{-6}$

$\Delta w_{5,3} = 1.19*10^{-5}$ $w_{5,3(new)} = -0.039+1.91*10^{-5}$

$\Delta w_{5,4} = 2.66*10^{-5}$ $w_{5,4(new)} = -0.059+2.66*10^{-5}$

$\Delta w_{5,5} = 7.34*10^{-6}$ $w_{5,5(new)} = 0.069+7.34*10^{-6}$

$\Delta w_{5,6} = 6.17*10^{-5}$ $w_{5,6(new)} = 0.087+6.17*10^{-5}$

$\Delta w_{5,7} = 3.62*10^{-5}$ $w_{5,7(new)} = 0.055+3.62*10^{-5}$

$\Delta w_{5,8} = 7.98*10^{-5}$ $w_{5,8(new)} = -0.02+7.98*10^{-5}$

$\Delta w_{5,9} = 0$ $w_{5,9(new)} = -0.03+0$

$\Delta w_{5,10} = 7.23*10^{-5}$ $w_{5,10(new)} = -0.04+7.23*10^{-5}$

$\Delta w_{5,11} = 9.89*10^{-5}$ $w_{5,11(new)} = -0.04+9.89*10^{-5}$

$\Delta w_{6,1} = 1.56*10^{-5}$ $w_{6,1(new)} = 0.001+1.56*10^{-5}$

$\Delta w_{6,2} = 3.51*10^{-7}$ $w_{6,2(new)} = 0.097+3.51*10^{-7}$

$\Delta w_{6,3} = 3.16*10^{-6}$ $w_{6,3(new)} = 3.16*^{10-6}-0.067$

$\Delta w_{6,4} = 4.39*10^{-6}$ $w_{6,4(new)} = 0.082+4.39*10^{-6}$

$\Delta w_{6,5} = 1.21*10^{-6}$ $w_{6,5(new)} = 0.065+1.21*10^{-6}$

$\Delta w_{6,6} = 1.02*10^{-5}$ $w_{6,6(new)} = -0.045+1.02*10^{-5}$

$\Delta w_{6,7} = 5.97*10^{-6}$ $w_{6,7(new)} = -0.035+5.97*10^{-6}$

$\Delta w_{6,8} = 1.32*10^{-5}$ $w_{6,8(new)} = -0.072+1.32*10^{-5}$

$\Delta w_{6,9} = 0$ $w_{6,9(new)} = 0.1+0$

$\Delta w_{6,10} = 1.19*10^{-5}$ $w_{6,10(new)} = -0.1+1.19*10^{-5}$

$\Delta w_{6,11} = 1.63*10^{-5}$ $w_{6,11(new)} = 0.001+1.63*10^{-5}$

4. Compute the output by new weights

4.1 For hidden layer

H_1 $= 0.02*(0.05+1.73*10^{-8}) + 0.18*(-0.0899) + 0.25*(0.02+2.16*10^{-7}) + 0.89*(0.1+6.26*10^{-7}) + 0.069*(0.1+5.96*10^{-7}) + 0.58*(-0.0399) + 0.34*(-0.01+2.94*10^{-7}) + 0.75*(-0.1+6.48*10^{-7}) + 0 + 0.68*(0.006+5.89*10^{-7}) + 0.93*(-0.005+8.03*10^{-7})$

$= -0.01639$

y_1 $= 0.5040$

H_2 = 0.89*(-0.08-3.8*10^{-7}) + 0.02*(-0.03-8.4*10^{-9}) + 0.18*(0.004-7.6*10^{-8}) + 0.25*(0.08-1.1*10^{-7}) + 0.069*(0.01-2.9*10^{-8}) + 0.58*(-0.1-2.4*10^{-7}) + 0.34*(-0.006-1.4*10^{-7}) + 0.75*(0.006-3.2*10^{-7}) + 0 + 0.68*(0.02-2.9*10^{-7}) + 0.93*(-0.008-3.9*10^{-7})

= -0.09977

y_2 **= 0.5249**

H_3 = 0.89*(0.1+2.33*10^{-6}) + 0.02*(0.03+5.24*10^{-8}) + 0.18*(0.06+4.72*10^{-7}) + 0.25*(-0.07+6.56*10^{-7}) + 0.069*(-0.08+1.81*10^{-7}) + 0.58*(-0.03+1.52*10^{-6}) + 0.34*(0.045+8.92*10^{-7}) + 0.75*(0.0013+1.97*10^{-6}) + 0 + 0.68*(0.08+1.78*10^{-6}) + 0.93*(-0.09+2.44*10^{-6})

= 0.04696

y_3 **= 0.4883**

H_4 = 0.89*(0.0023+5.9*10^{-5}) + 0.02*(0.028+1.33*10^{-6}) + 0.18*(-0.037+1.19*10^{-5}) + 0.25*(0.07+1.66*10^{-5}) + 0.069*(0.087+4.58*10^{-6}) + 0.58*(0.095+3.85*10^{-5}) + 0.34*(-0.015+2.26*10^{-5}) + 0.75*(-0.012+4.98*10^{-5}) + 0 + 0.68*(0.071+4.51*10^{-5}) + 0.93*(0.011+6.17*10^{-5})

= 0.11917

y_4 **= 0.4703**

H_5 = 0.89*(0.017+9.45*10^{-5}) + 0.02*(-0.028+2.13*10^{-6}) + 0.018*(-0.039+1.91*10^{-5}) + 0.25*(-0.059+2.66*10^{-5}) + 0.069*(0.069+7.34*10^{-6}) + 0.58*(0.087+6.17*10^{-5}) + 0.34*(0.055+3.62*10^{-5}) + 0.75*(-0.02+7.98*10^{-5}) + 0 + 0.68*(-0.04+7.23*10^{-5}) + 0.93*(-0.04+9.89*10^{-5})

$= 0.13015$

$y_5 = 0.4675$

$H_6 = 0.89*(0.001+1.56*10^{-5}) + 0.02*(0.097+3.51*10^{-7}) + 0.018*(-0.067+3.16*10^{-7}) + 0.25*(0.082+4.39*10^{-6}) + 0.069*(0.065+1.21*10^{-6}) + 0.58*(1.02*10^{-5}-0.045) + 0.34*(5.97*10^{-6}-0.035) + 0.75*(1.32*10^{-5}-0.072) + 0 + 0.68*(1.19*10^{-5}-0.1) + 0.93*(0.001+1.63*10^{-5})$

$= -0.05252$

$y_6 = 0.5132$

4.2 For output layer

$I = 0.5040*0.023 + 0.5249*0.0109 + 0.4883*0.026 + 0.4703*0.046 + 0.4675*0.0661 + 0.5132*0.0112$

$= 0.0887$

$Z = 0.4778$

The new output of this iteration is used to calculate the error between output and target, and then adjust the weight for calculating the next iteration and continue the iteration until the expected error is obtain. The all parameter of last iteration is the parameter of the model.

BIOGRAPHY

Mr. Kitisak Ngamjaruskochakorn was born on November 15, 1974 in Bangkok, Thailand. He received a B.Eng. (Metallurgy) from Chulalongkorn University in 1995. He began to study his master degree in Metallurgical Engineering at Chulalongkorn University in 1995.