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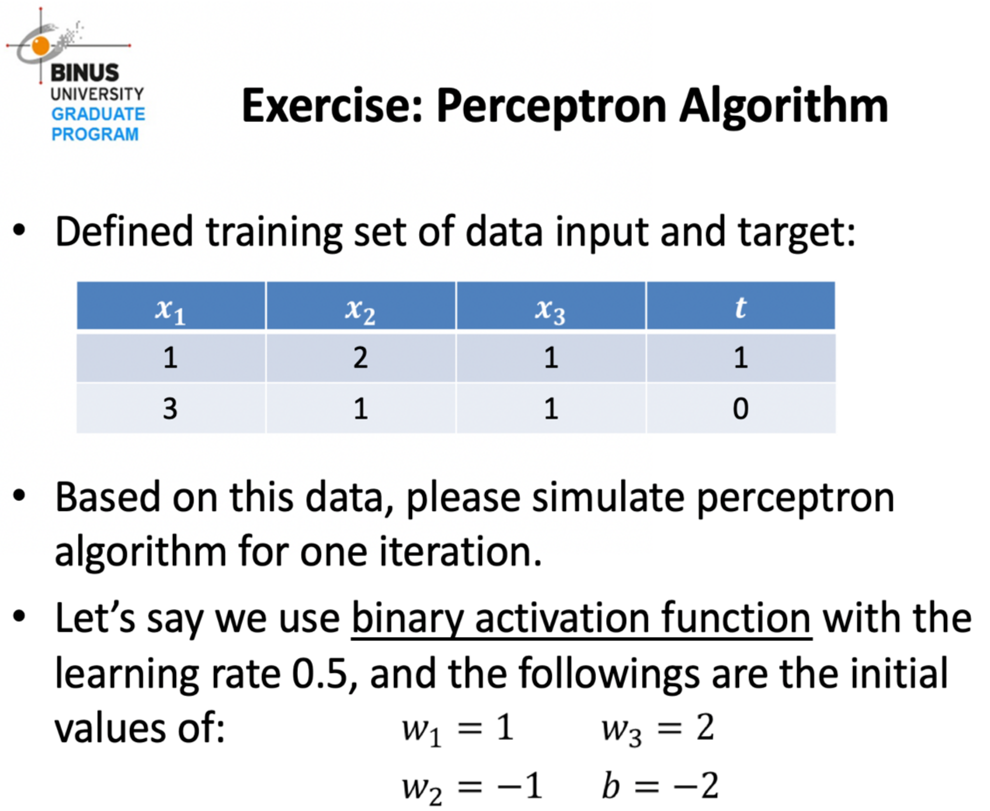
1. Perceptron Algorithm



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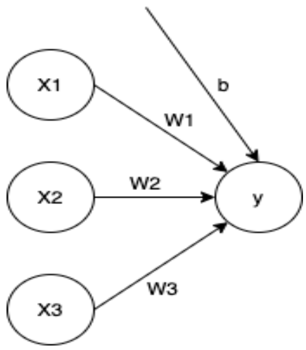
Exercise: Perceptron Algorithm

- Defined training set of data input and target:

x_1	x_2	x_3	t
1	2	1	1
3	1	1	0

- Based on this data, please simulate perceptron algorithm for one iteration.
- Let's say we use <u>binary activation function</u> with the learning rate 0.5, and the followings are the initial values of: $w_1 = 1$ $w_3 = 2$ $w_2 = -1$ $b = -2$

- Layer-1
  a. Design Architecture based on input variables



  b. Initialize weights (w) and bias (b). From the architecture we can see that this data needs 3 weights and 1 bias, so that;
  $w_1 = 1$ $w_3 = 2$
  $w_2 = -1$ $b = -2$

  c. Choose sample randomly from the training data input and target.
  For instance, we used 1st data input vector $x = \{x_1,x_2,x_3\} = \{1,2,1\}$ with $t = 1$
  Conduct linear combination of input vector and weights vector
  $u = w_1x_1 + w_2x_2 + w_3x_3 + b$
  $u = (1)(1)+(-1)(2)+(2)(1)+(-2) = -1$

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d. Apply step binary activation function
Since $u < 0$, then $y(u) = 0$

e. Calculate error
$E = t - y(u)$
$E = 1 - 0 = 1$
It means this classification is INCORRECT

f. Update weights using learning rate $\alpha = 0.5$
$w_{1(new)} = w_{1(old)} + \alpha x_1 E$
$w_{1(new)} = 1+(0.5)(1)(1) = 1.5$

$w_{2(new)} = w_{2(old)} + \alpha x_2 E$
$w_{2(new)} = (-1)+(0.5)(2)(1) = 1.5$

$w_{3(new)} = w_{3(old)} + \alpha x_3 E$
$w_{3(new)} = 2+(0.5)(1)(1) = 2.5$

$b_{(new)} = b_{(old)} + \alpha E$
$b_{(new)} = (-2)+(0.5)(1) = -1.5$

these new weights will be used for next iteration using different data input and target

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- Layer-2
  a. Initialize new weights (w) and new bias (b), so that;
     $w_1 = 1.5$ $w_3 = 2.5$
     $w_2 = 1.5$ $b = -1.5$

  b. Choose sample randomly from the training data input and target.
     For instance, we used 2nd data input vector $x = \{x_1,x_2,x_3\} = \{3,1,1\}$ with $t = 0$
     Conduct linear combination of input vector and weights vector
     $u = w_1x_1 + w_2x_2 + w_3x_3 + b$
     $u = (1.5)(3)+(1.5)(1)+(2.5)(1)+(-1.5) = 7$

  c. Apply step binary activation function
     Since $u > 0$, then $y(u) = 1$

  d. Calculate error
     $E = t - y(u)$
     $E = 0 - 1 = -1$
     It means this classification is INCORRECT

  e. Update weights using learning rate $\alpha = 0.5$
     $w_{1(new)} = w_{1(old)} + \alpha x_1 E$
     $w_{1(new)} = 1.5+(0.5)(3)(-1) = 0$

     $w_{2(new)} = w_{2(old)} + \alpha x_2 E$
     $w_{2(new)} = 1.5+(0.5)(1)(-1) = 1$

     $w_{3(new)} = w_{3(old)} + \alpha x_3 E$
     $w_{3(new)} = 2.5+(0.5)(1)(-1) = 2$

     $b_{(new)} = b_{(old)} + \alpha E$
     $b_{(new)} = (-1.5)+(0.5)(-1) = -2$

     these new weights will be used for next iteration using different data input and target

- MSE Layer-1 and Layer-2
  $$\text{MSE} = \frac{(E\_layer-1)^2 + (E\_layer-2)^2}{n(E\_layer-1 + E\_layer-2)}$$
  $$\text{MSE} = \frac{(1)^2 + (-1)^2}{2} = 1$$

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- Iteration Layer-1
    a. Initialize new weights (w) and new bias (b), so that;
    $w_1 = 0$ $w_3 = 2$
    $w_2 = 1$ $b = -2$

    b. Choose sample randomly from the training data input and target.
    For instance, we used 1st data input vector $x = \{x_1, x_2, x_3\} = \{1,2,1\}$ with $t = 1$
    Conduct linear combination of input vector and weights vector
    $u = w_1x_1 + w_2x_2 + w_3x_3 + b$
    $u = (0)(1)+(1)(2)+(2)(1)+(-2) = 3$

    c. Apply step binary activation function
    Since $u > 0$, then $y(u) = 1$

    d. Calculate error
    $E = t - y(u)$
    $E = 1 - 1 = 0$
    It means this classification is CORRECT

    e. Update weights using learning rate $\alpha = 0.5$
    $w_{1(new)} = w_{1(old)} + \alpha x_1 E$
    $w_{1(new)} = 0+(0.5)(1)(0) = 0$

    $w_{2(new)} = w_{2(old)} + \alpha x_2 E$
    $w_{2(new)} = 1+(0.5)(2)(0) = 1$

    $w_{3(new)} = w_{3(old)} + \alpha x_3 E$
    $w_{3(new)} = 2+(0.5)(1)(0) = 2$

    $b_{(new)} = b_{(old)} + \alpha E$
    $b_{(new)} = (-2)+(0.5)(0) = -2$

    these new weights will be used for next iteration using different data input and target

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- Iteration Layer-2
  a. Initialize new weights (w) and new bias (b), so that;
     $w_1 = 0$ $w_3 = 2$
     $w_2 = 1$ $b = -2$

  b. Choose sample randomly from the training data input and target.
     For instance, we used 2nd data input vector $x = \{x_1,x_2,x_3\} = \{3,1,1\}$ with $t = 0$
     Conduct linear combination of input vector and weights vector
     $u = w_1x_1 + w_2x_2 + w_3x_3 + b$
     $u = (0)(3)+(1)(1)+(2)(1)+(-2) = 1$

  c. Apply step binary activation function
     Since $u > 0$, then $y(u) = 1$

  d. Calculate error
     $E = t - y(u)$
     $E = 0 - 1 = -1$
     It means this classification is INCORRECT

  e. Update weights using learning rate $\alpha = 0.5$
     $w_{1(new)} = w_{1(old)} + \alpha x_1 E$
     $w_{1(new)} = 0+(0.5)(3)(-1) = -1.5$

     $w_{2(new)} = w_{2(old)} + \alpha x_2 E$
     $w_{2(new)} = 1+(0.5)(1)(-1) = 0.5$

     $w_{3(new)} = w_{3(old)} + \alpha x_3 E$
     $w_{3(new)} = 2+(0.5)(1)(-1) = 1.5$

     $b_{(new)} = b_{(old)} + \alpha E$
     $b_{(new)} = (-2)+(0.5)(-1) = -2.5$

     these new weights will be used for next iteration using different data input and target

- MSE Iteration Layer-1 and Layer-2
  $$MSE = \frac{(E\_layer-1)^2 + (E\_layer-2)^2}{n(E\_layer-1 + E\_layer-2)}$$
  $$MSE = \frac{(0)^2 + (-1)^2}{2} = 0.5$$

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2. BackPropagation Network (BPPN)

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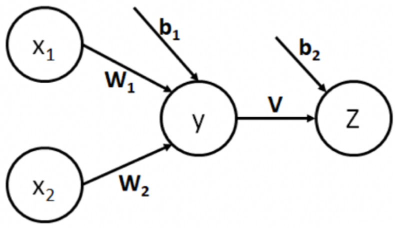
Exercise

- Given pair of input and target data $P_1 = (1,2)$, $T_1 = (1)$. Architecture of BPPN is given as follows:



- Initial weights are $W_1 = 0.5$ $W_2 = 0.1$ $V = 1$ $b_1 = 1$ $b_2 = -1$
- Please simulate BPPN for one iteration based on information given with learning rate 0.5 and momentum 0.5.

a. Create a table

X_1	X_2	T_1
1	2	1

b. Forward Pass

- Input-hidden

  $u = w_1x_1 + w_2x_2 + b_1$

  $u = (0.5)(1)+(0.1)(2)+1 = 1.7$

  $y = \frac{1}{1+e^{(-u)}}$

  $y = \frac{1}{1+e^{(-1.7)}} = 0.8$

- Hidden-output

  $o = v \times y + b_2$

  $o = 1(0.8)+(-1) = -0.2$

c. Activation Function

- If using linear activation function

  $z = o = -0.2$

  check the error

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$E = \frac{1}{2}(t - z)^2$
$E = 0.5(1-(-0.2))^2 = 0.72$

- If using logistic sigmoid activation function
  $z = \frac{1}{1+e^{(-o)}}$
  $z = \frac{1}{1+e^{(0.2)}} = 0.45$

  check the error
  $E = \frac{1}{2}(t - z)^2$
  $E = 0.5(1-(0.45))^2 = 0.15$

d. Backward Pass
- If using linear activation function
  $V_{(it+1)} = V_{it} + \mu\Delta V_{(it-1)} - \alpha(z\text{-}t)(y)$
  $V_{new} = 1 + (0.5)(0) - (0.5)(-0.2-1)(0.8) = 1.48$

  $b_{(2)(it+1)} = b_{(2)(it)} + \mu\Delta b_{(2)(it-1)} - \alpha(z\text{-}t)$
  $b_{(2)(it+1)} = (-1) + (0.5)(0) - (0.5)(-0.2-1) = -0.4$

  $w_{(1)(it+1)} = w_{(1)(it)} + \mu\Delta w_{(1)(it-1)} - \alpha(z\text{-}t)(V)(1\text{-}y)(y)(x_1)$
  $w_{(1)(it+1)} = 0.5 + (0.5)(0) - (0.5)(-0.2-1)(1)(1-0.8)(0.8)(1) = 0.596$

  $w_{(2)(it+1)} = w_{(2)(it)} + \mu\Delta w_{(2)(it-1)} - \alpha(z\text{-}t)(V)(1\text{-}y)(y)(x_2)$
  $w_{(2)(it+1)} = 0.1 + (0.5)(0) - (0.5)(-0.2-1)(1)(1-0.8)(0.8)(2) = 0.29$

  $b_{(1)(it+1)} = b_{(1)(it)} + \mu\Delta b_{(1)(it-1)} - \alpha(z\text{-}t)(V)(1\text{-}y)(y)$
  $b_{(1)(it+1)} = 1 + (0.5)(0) - (0.5)(-0.2-1)(1)(1-0.8)(0.8) = 1.096$

- If using logistic sigmoid activation function
  $V_{(it+1)} = V_{it} + \mu\Delta V_{(it-1)} - \alpha(z\text{-}t)(1\text{-}z)(z)(y)$
  $V_{new} = 1 + (0.5)(0) - (0.5)(0.45-1)(1-0.45)(0.45)(0.8) = 1.05$

  $b_{(2)(it+1)} = b_{(2)(it)} + \mu\Delta b_{(2)(it-1)} - \alpha(z\text{-}t)(1\text{-}z)(z)$
  $b_{(2)(it+1)} = (-1) + (0.5)(0) - (0.5)(0.45-1)(1-0.45)(0.45) = -0.93$

  $w_{(1)(it+1)} = w_{(1)(it)} + \mu\Delta w_{(1)(it-1)} - \alpha(z\text{-}t)(1\text{-}z)(z)(V)(1\text{-}y)(y)(x_1)$
  $w_{(1)(it+1)} = 0.5 + (0.5)(0) - (0.5)(0.45-1)(1-0.45)(0.45)(1)(1-0.8)(0.8)(1) = 0.511$

  $w_{(2)(it+1)} = w_{(2)(it)} + \mu\Delta w_{(2)(it-1)} - \alpha(z\text{-}t)(1\text{-}z)(z)(V)(1\text{-}y)(y)(x_2)$
  $w_{(2)(it+1)} = 0.1 + (0.5)(0) - (0.5)(0.45-1)(1-0.45)(0.45)(1)(1-0.8)(0.8)(2) = 0.12$

  $b_{(1)(it+1)} = b_{(1)(it)} + \mu\Delta b_{(1)(it-1)} - \alpha(z\text{-}t)(1\text{-}z)(z)(V)(1\text{-}y)(y)$
  $b_{(1)(it+1)} = 1 + (0.5)(0) - (0.5)(0.45-1)(1-0.45)(0.45)(1)(1-0.8)(0.8) = 1.010$

e. New nodes
   - Linear Activation Function
     $w_1 = 0.596$
     $w_2 = 0.29$
     $V = 1.48$
     $b_1 = 1.096$
     $b_2 = -0.4$

   - Logistic sigmoid activation function
     $w_1 = 0.511$
     $w_2 = 0.12$
     $V = 1.05$
     $b_1 = 1.010$
     $b_2 = -0.93$

- Iterasi BPNN

a. Forward Pass

1. Linear Activation function
   - Input-hidden
     $u = w_1x_1 + w_2x_2 + b_1$
     $u = (0.596)(1)+(0.29)(2)+1.096 = 2.27$

     $y = \frac{1}{1+e^{(-u)}}$
     $y = \frac{1}{1+e^{(-2.27)}} = 0.9$

   - Hidden-output
     $o = v\, y + b_2$
     $o = (1.48)(0.9)+(-0.4) = 0.932$

   - $z = o = 0.932$

   - $E = \frac{1}{2}(t - z)^2$
     $E = 0.5(1-0.932)^2 = 0.002312$

2. Logistic sigmoid activation function
   - Input-hidden
     $u = w_1x_1 + w_2x_2 + b_1$
     $u = (0.511)(1)+(0.12)(2)+1.010 = 1.76$

     $y = \frac{1}{1+e^{(-u)}}$
     $y = \frac{1}{1+e^{(-1.76)}} = 0.85$

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- Hidden-output
  $o = v\ y + b_2$
  $o = (1.05)(0.85)+(-0.93) = -0.0375$

- $z = o = -0.0375$

- $E = \frac{1}{2}(t - z)^2$
  $E = 0.5(1-(-0.375))^2 = 0.53820313$