523414 :
Artificial Neural Networks (ANN)
trimester 1/2561

Lecture 03:
Widrow-Hoff Learning
(ADALINE , Linear Network)

Institute of Engineering
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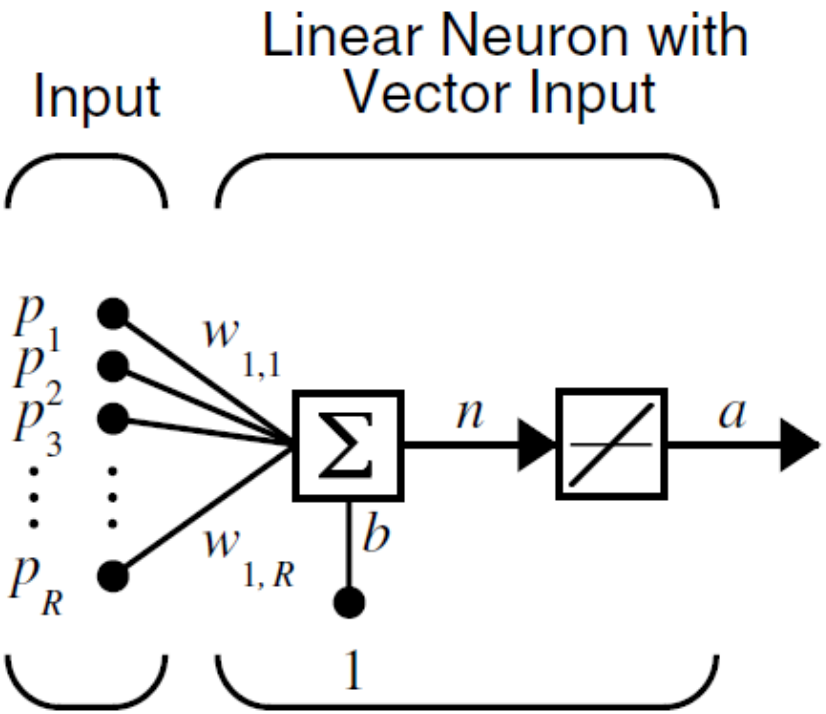
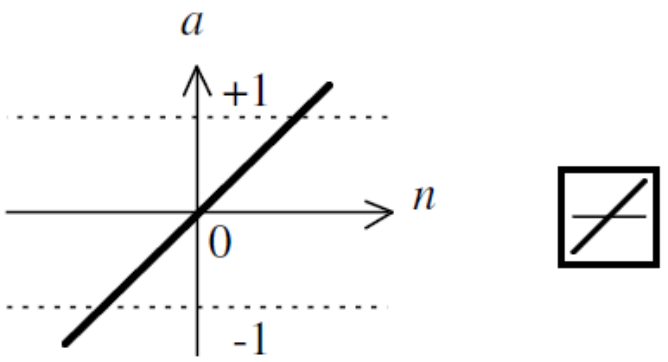
Linear Neuron Model (ADALINE) : Single Neuron



$$a = purelin(\mathbf{W}\mathbf{p} + b)$$

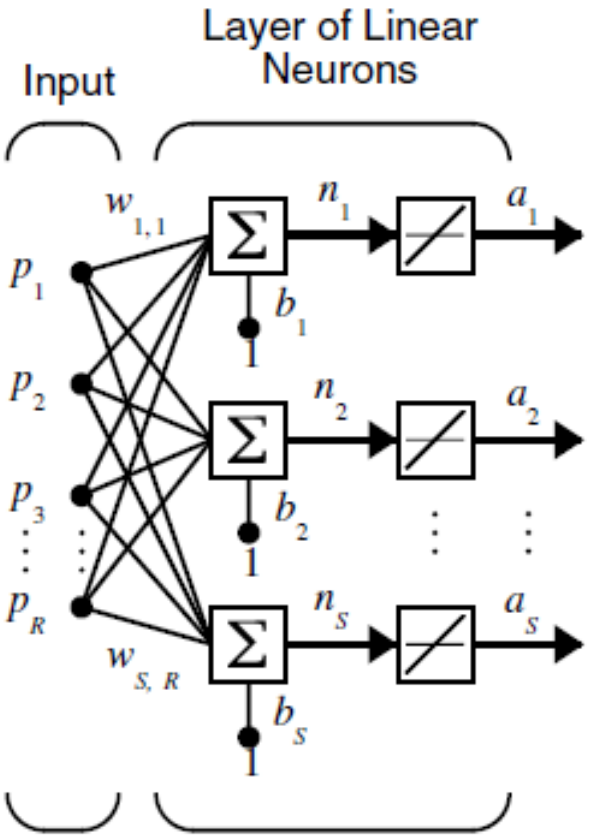


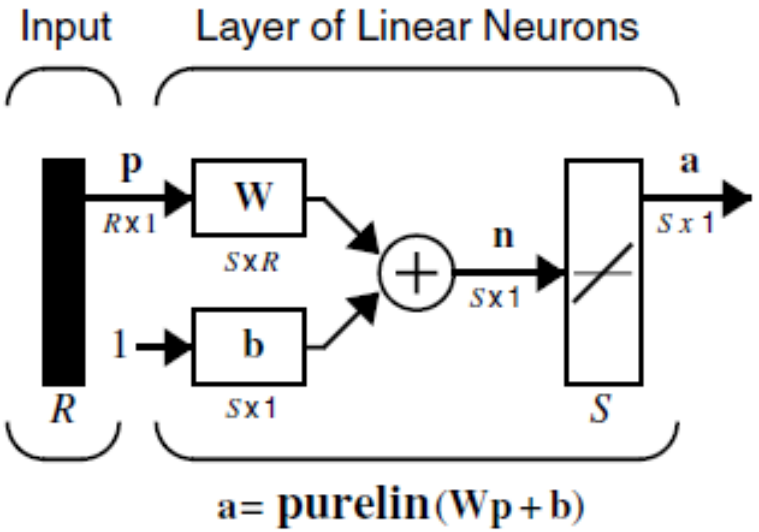
$$a = purelin(n)$$

Linear Transfer Function

Fig. Ref. NN Toolbox User's Guide Version 6

Multi-Neuron Linear Network





Where...

R = number of elements in input vector

S = number of neurons in layer

Fig. Ref. NN Toolbox User's Guide Version 6

Linear Network

Like the perceptron, the linear network has a *decision boundary that is* determined by the input vectors for which the net input *n is zero. For n = 0 the* equation **Wp + *b = 0 specifies such a decision boundary, as shown below***

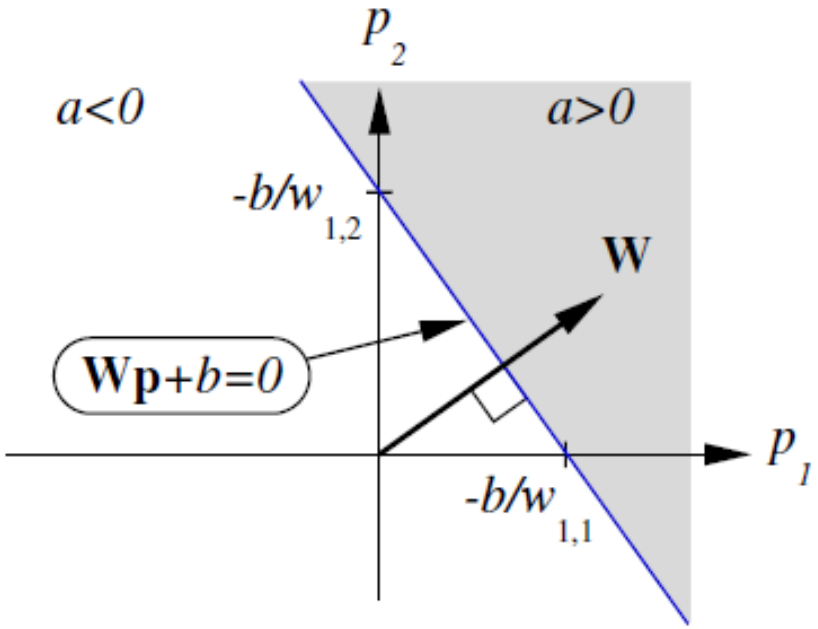


Fig. Ref. NN Toolbox User's Guide Version 6

Widrow-Hoff (ADALINE) Learning Rule

เป็นกฎของเดลตา (**delta rule**) ที่ใช้อัลกอริทึม **LMS (Least Mean Square)** ในการฝึกสอนเครือข่าย **ADALINE** โดยการฝึกสอนเป็นแบบมีผู้ฝึกสอน

$$\{\mathbf{p}_1, \mathbf{t}_1\}, \{\mathbf{p}_2, \mathbf{t}_2\}, \ldots, \{\mathbf{p}_Q, \mathbf{t}_Q\}$$

$$mse = \frac{1}{Q}\sum_{k=1}^{Q} e(k)^2 = \frac{1}{Q}\sum_{k=1}^{Q} (t(k) - a(k))^2$$

$$\mathbf{W}(k+1) = \mathbf{W}(k) + 2\alpha \mathbf{e}(k)\mathbf{p}^T(k)$$

$$\mathbf{b}(k+1) = \mathbf{b}(k) + 2\alpha \mathbf{e}(k)$$

Least Mean Square Error

The LMS algorithm, or Widrow-Hoff learning algorithm, is based on an approximate steepest descent procedure. Here again, linear networks are trained on examples of correct behavior.

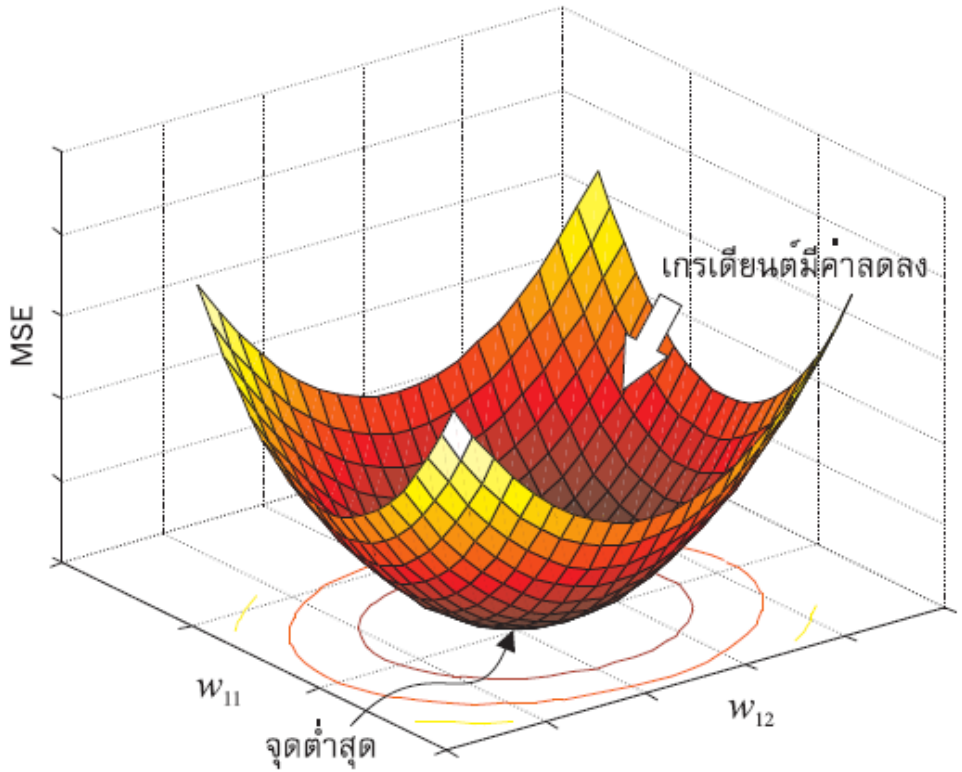


Fig. Ref. *ปัญญาเชิงคำนวณ, ผศ.ดร. อาทิตย์ ศรีแก้ว*

LMS Algorithm Modifications (α -LMS)

$$\mathbf{W}^{new} = \mathbf{W}^{old} + \frac{\alpha \mathbf{e}\mathbf{p}^T}{\| \mathbf{p} \|_2^2}$$

$$\begin{aligned}
\Delta \mathbf{e} &= \mathbf{e}^{new} - \mathbf{e}^{old} \\
&= [\mathbf{t} - \mathbf{W}^{new}\mathbf{p}] - \mathbf{e}^{old} \\
&= \left\{ \mathbf{t} - [\mathbf{W}^{old} + \frac{\alpha \mathbf{e}\mathbf{p}^T}{\| \mathbf{p} \|_2^2}]\mathbf{p} \right\} - \mathbf{e}^{old} \\
&= \left[\mathbf{e}^{old} - \frac{\alpha \mathbf{e}\mathbf{p}^T\mathbf{p}}{\| \mathbf{p} \|_2^2} \right] - \mathbf{e}^{old} \\
&= -\alpha \mathbf{e}
\end{aligned}$$

Learning rate $0.1 < \alpha < 1.0$

MADALINE I (Multiple ADALINE I)

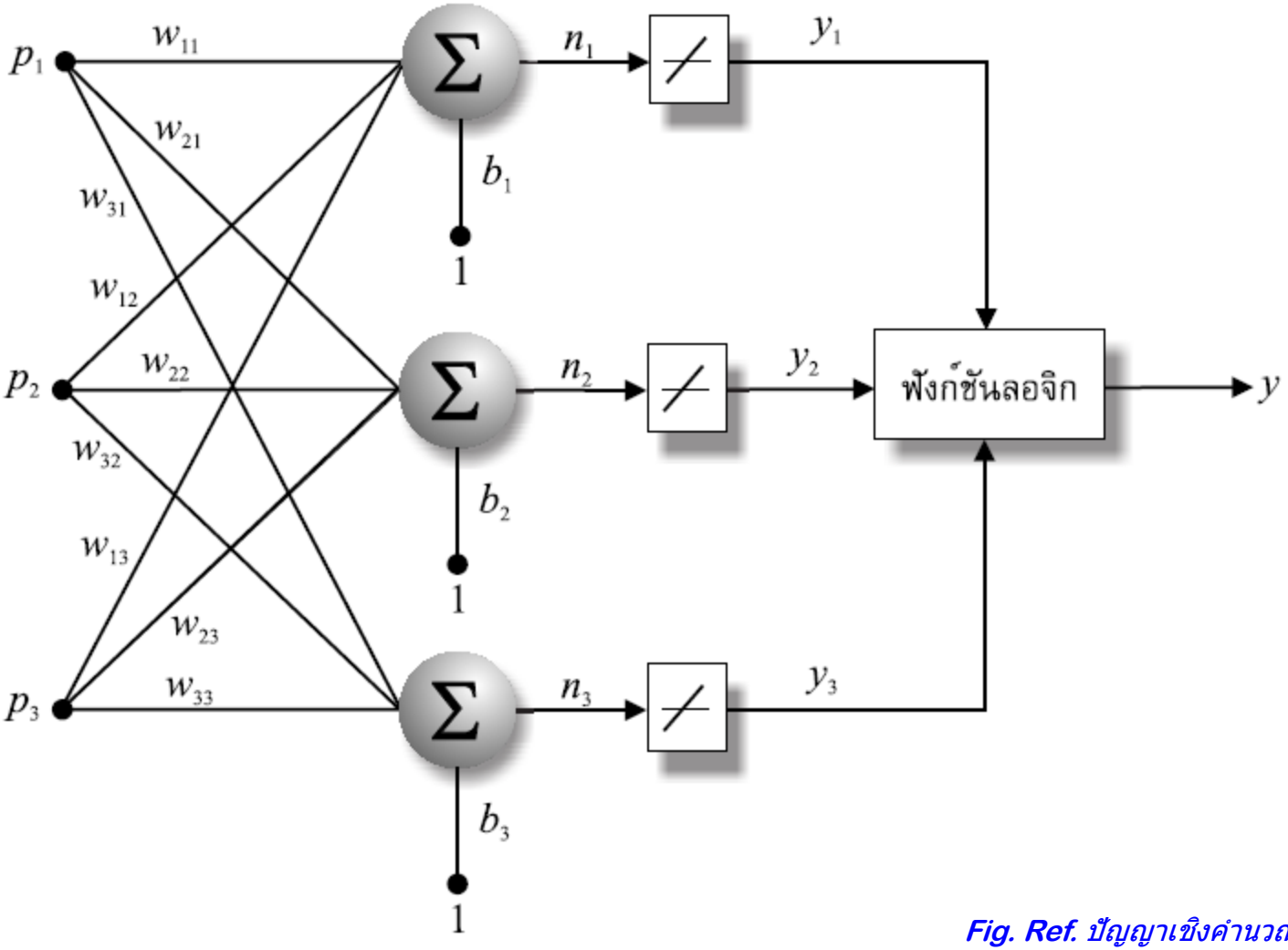


Fig. Ref. *ปัญญาเชิงคำนวณ, ผศ.ดร. อาทิตย์ ศรีแก้ว*

MADALINE II

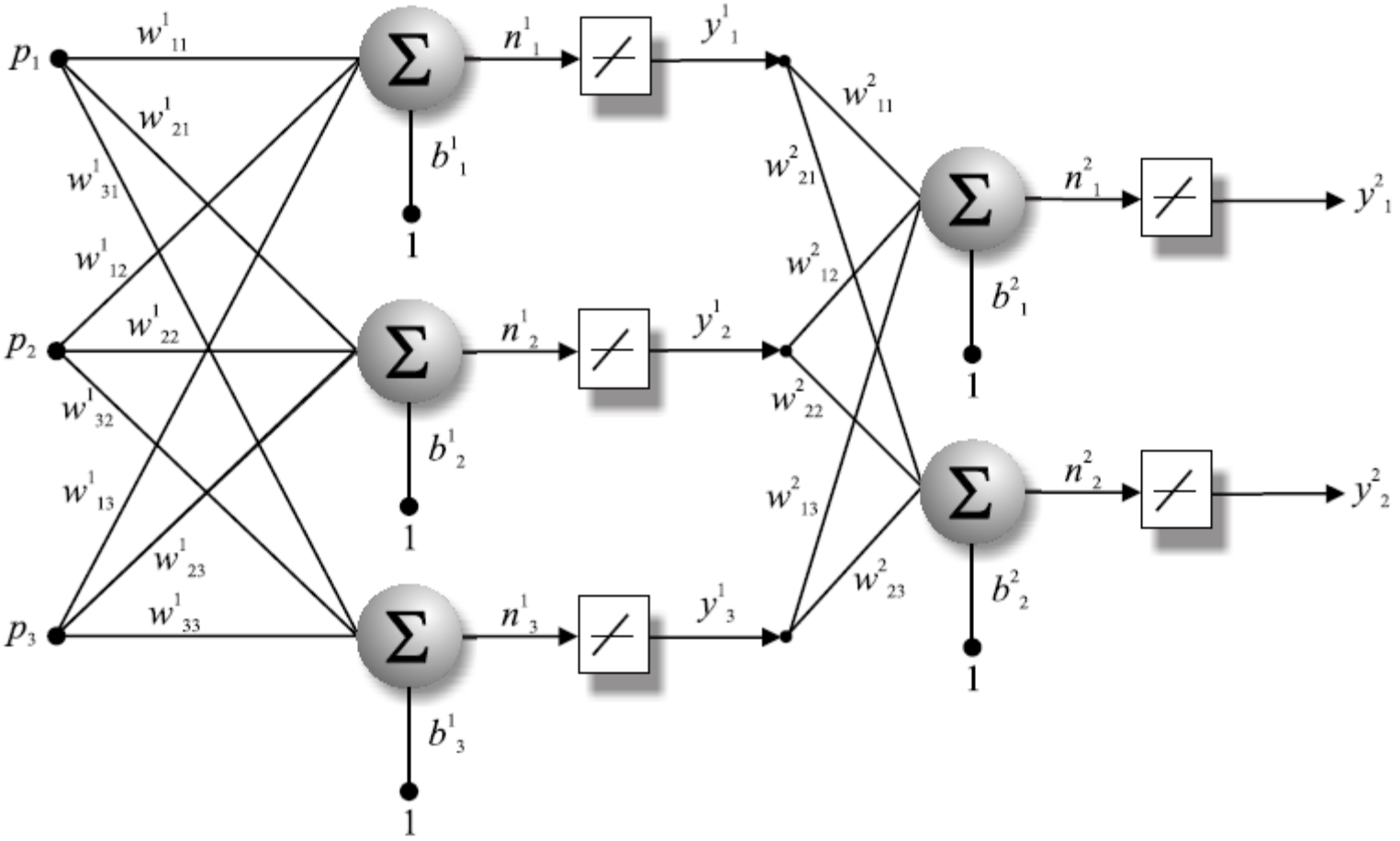
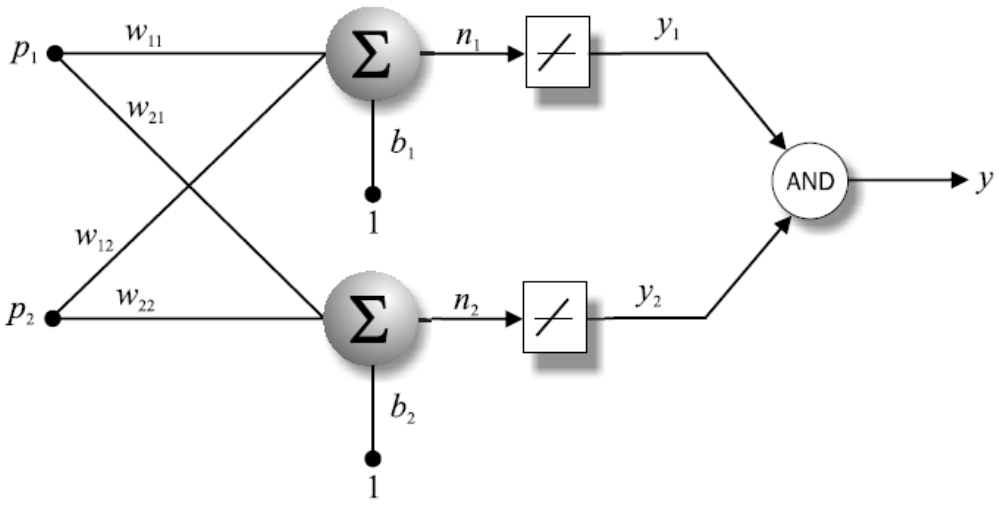
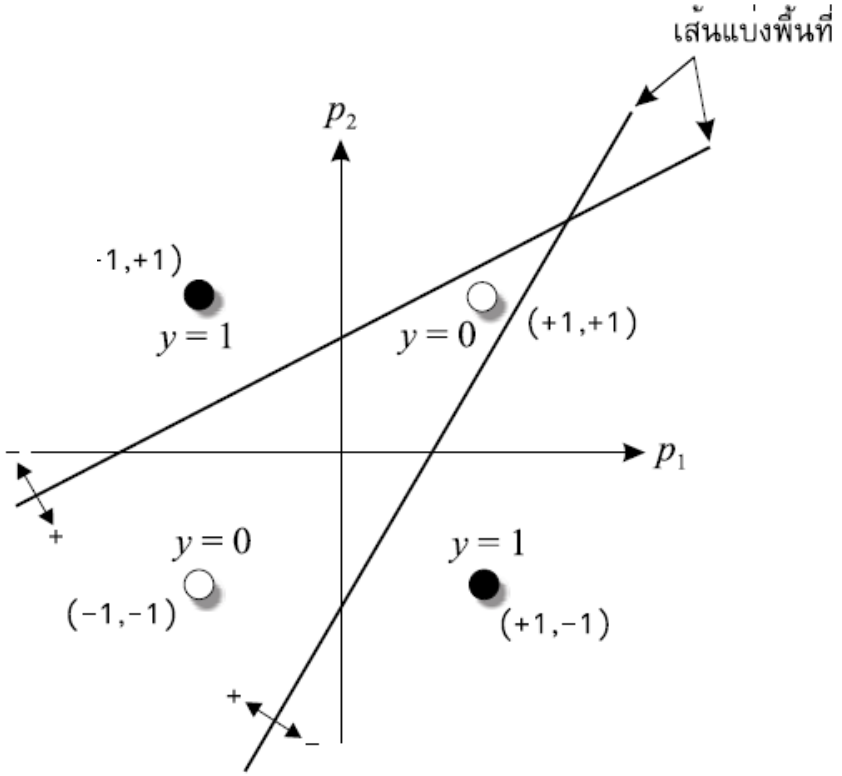


Fig. Ref. ปัญญาเชิงคำนวณ, ผศ.ดร. อาทิตย์ ศรีแก้ว

MADALINE I --- For XOR





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Example of ADALINE

- Follow Example 11.1 on student sheet reference