# NEURAL NETWORKS

# Learning in Neural Networks

Lecture 5

*These lecture notes are based on the textbook;*

- Simon Haykin, **Neural Networks: A Comprehensive Foundation**, Macmillan College Publishing Company, 1994.

Asst. Prof.Dr. Sibel SENAN
ssenan@istanbul.edu.tr

# Introduction

- The property that is of primary significance for a neural network is the ability of the network to learn from its environment.
- Learning involves adjustments to the synaptic connections that exist between the neurons.
- Ideally the network becomes more knowledgable about its environment after each iteration of the learning process.

- Definition of *learning* in the context of neural networks :

*Learning is process by which the free parameters of a neural network are adaped through a process of stimulation by the environment in which the network is embedded. The type of learning is determined by the manner in which the parameter changes take place.*

- Definition of *learning process* implies the following sequence of events :

1. The neural network is *stimulated* by an environment.
2. The neural network *undergoes changes* in its free parameters as a result of this stimulation.
3. The neural network *responds in a new way* to the environment because of the changes that have occured in its internal structure.

- A set of well-defined rules for the solution of a learning problem is called a *learning algorithm*.
- Learning algorithms differ from each other in the way in which the adjustment to a synaptic weight of a neuron is formulated.
- Another factor to be considered is the manner in which a neural network relates to its environment. In this context we speak of a *learning paradigm* that refers to a model of the environment in which the neural network operates.

- Two fundamental learning paradigms :

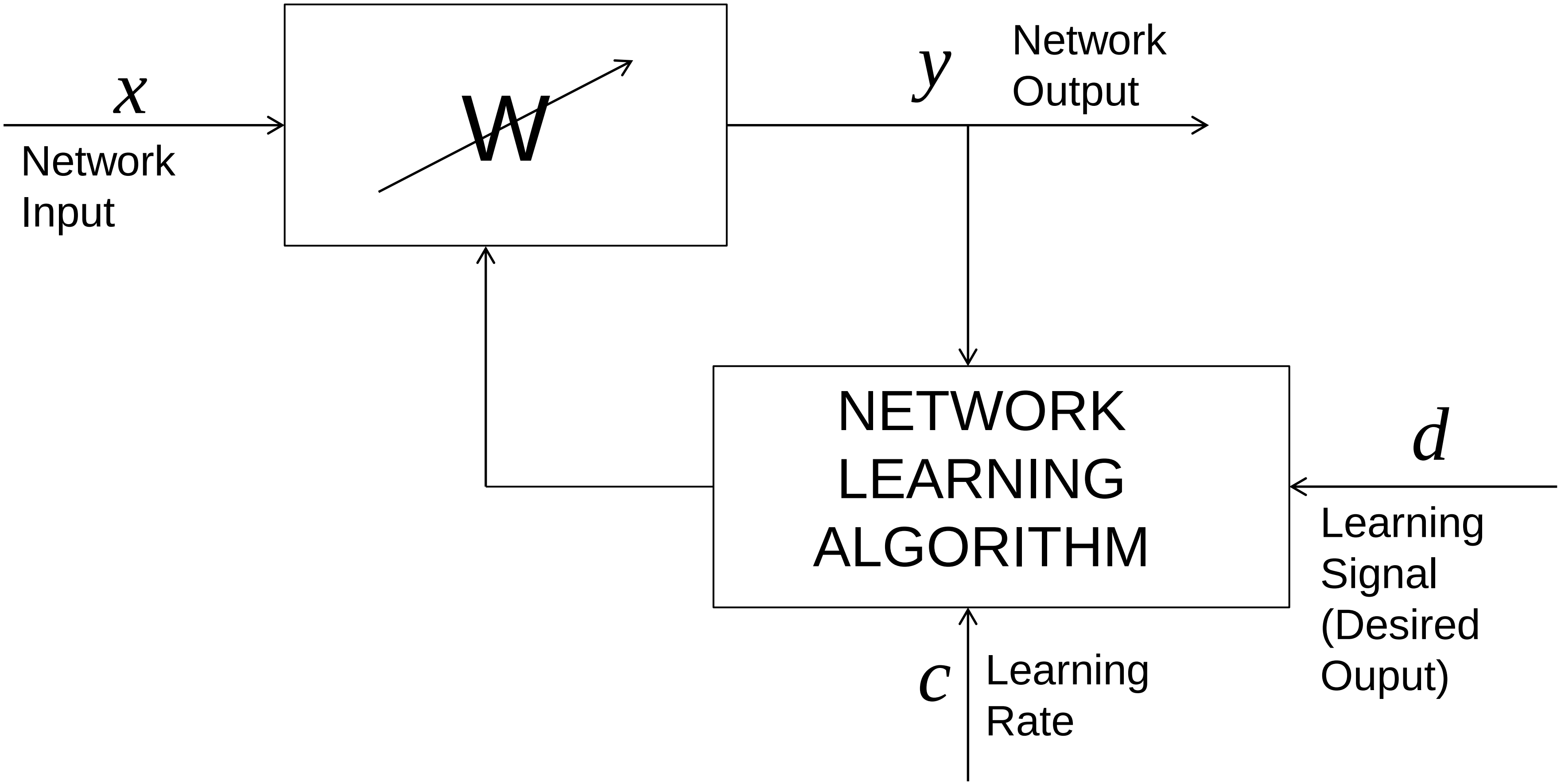
1. Learning with a teacher (SUPERVISED LEARNING)

   *Desired output is given to the network*

2. Learning without a teacher (UNSUPERVISED LEARNING)

   *There is NO desired ouput*

# 1. SUPERVISED LEARNING



The learning rule is provided with a set of training set of proper network behavior :

$$\{x_1, d_1\}, \{x_2, d_2\}, \ldots., \{x_n, d_n\}$$

$x_n$: Input to the network
$d_n$: Corresponding correct desired output

As the inputs are applied to the network, the network outputs are compared with the desired outputs.

# GENERAL RULES FOR NEURON $i$

- The weight vector

$$w_i = [w_{i1} \quad w_{i2} \quad \dots \quad w_{in}]$$

- The learning signal

$$r = f(w_i, x, d_i)$$

- The increment of the weight vector $w_i$, ($\Delta w_i$) produced by the learning step at time t according to the general rule is:

$$\Delta w_i(t) = c.r[w_i(t), x(t), d_i(t)].x(t)$$

- The learning rate $c > 0$.
- The adapted weight vector

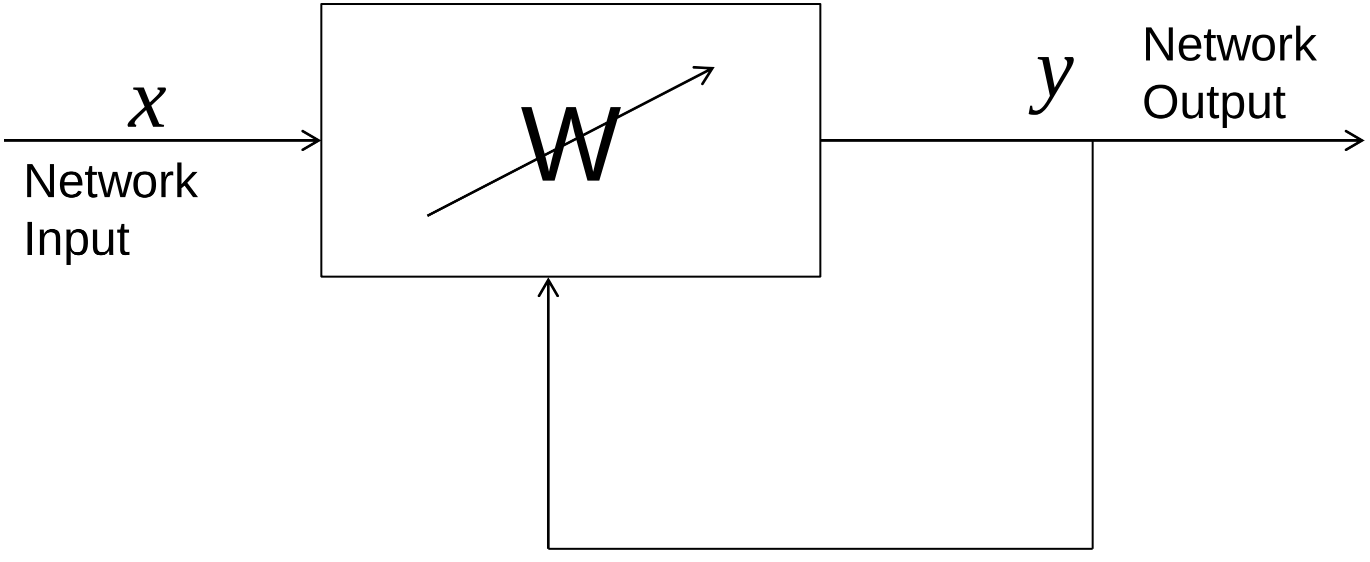
$$w_i(t+1) = w_i(t) + \Delta w_i(t)$$

## General Discrete-Time Form :

$$\boxed{{w_i}^{k+1} = {w_i}^k + \Delta w^k}$$

$$\boxed{{w_i}^{k+1} = {w_i}^k + c.r\left[{w_i}^k, x^k, {d_i}^k\right].x^k}$$

# 2. UNSUPERVISED LEARNING




- *Learning signal is not available*

# GENERAL RULES FOR NEURON *i*

- The weight vector

$$w_i = [w_{i1} \quad w_{i2} \quad \dots \quad w_{in}]^T$$

- The learning signal

$$r = f(w_i, x)$$

- The increment of the weight vector $w_i$, ($\Delta w_i$) produced by the learning step at time t according to the general rule is:

$$\Delta w_i(t) = c.\, r[w_i(t), x(t)].\, x(t)$$

- The learning rate $c > 0$.
- The adapted weight vector

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# LEARNING RULES

- PERCEPTRON (PERCEPTION) LEARNING RULE *(supervised)*
- DELTA LEARNING RULE *(supervised)*
- WIDROW-HOFF LEARNING RULE *(supervised)*
- CORRELATION LEARNING RULE *(supervised)*
- HEBBIAN LEARNING RULE *(unsupervised)*