Dynamical behaviour of BAM N.N. is described by the following set of differential equations:

$$\dot{u}_i(t) = -a_i u_i(t) + \sum_{j=1}^{m} w_{ji} \cdot f_j(z_j(t)) + I_i$$

$$\dot{z}_j(t) = -b_j \cdot z_j(t) + \sum_{i=1}^{n} v_{ij} \cdot f_i(u_i(t)) + J_j$$

n: number of neurons in the first layer

m: " " " " second "

$u_i(t)$: state of i.th neuron in the first layer

$z_j(t)$: " " j.th " " " "

W_{ji}, V_{ij}: synaptic connection weights

f_{ij}: activation functions

I_{ij}: inputs

Pure delayed BAM N.N.

$$\dot{u}_i(t) = -a_i \cdot u_i(t) + \sum_{j=1}^{m} w_{ji} \cdot f_j(z_j(t-\tau)) + I_i$$

τ, σ time delay

$$\dot{z}_j(t) = -b_j \cdot z_j(t) + \sum_{i=1}^{n} v_{ij} \cdot f_i(u_i(t-\sigma)) + J_j$$

Hybrid BAM NN

$$\dot{u}_i(t) = -a_i \cdot u_i(t) + \sum_{j=1}^{m} w_{ji} \cdot f_j(z_j(t)) + \sum_{j=1}^{m} w_{ji}^{\tau} \cdot f_j(z_j(t-\tau)) + I_i$$

$$\dot{z}_j(t) = -b_j \cdot z_j(t) + \sum_{i=1}^{n} v_{ij} \cdot f_i(V_i(t)) + \sum_{i=1}^{n} V_{ij}^{\tau} \cdot f_i(u_i(t-\sigma)) + J_j$$

Equilibrium Equation for Hybrid BAM NN

$$0 = -A \cdot U^* + W \cdot f(Z^*) + W^{\tau} \cdot f(Z^*) + I$$

$$0 = -B \cdot Z^* + V \cdot f(U^*) + V^{\tau} \cdot f(U^*) + J$$

U^*, Z^*: Eq. points

Shifting eq. points to origin:

$$x = U - U^* \qquad \dot{x} = \dot{U} \qquad \dot{x}(t) = -A \cdot (x(t) + U^*) + W \cdot f(y(t) + Z^*) + W^{\tau} \cdot f(y(t-\tau) + Z^*) + I$$

$$\Rightarrow$$

$$y = Z - Z^* \qquad \dot{y} = \dot{Z} \qquad \dot{y}(t) = -B \cdot (y(t) + Z^*) + V \cdot f(y(t) + U^*) + V^{\tau} \cdot f(x(t-\sigma)) + U^*) + J$$

$$\dot{x}(t) = -A \cdot x(t) - \cancel{A U^*} + W f(y(t) + Z^*) + W^{\tau} f(y(t-\tau) + Z^*) + \cancel{A U^*} - W f(Z^*) - W^{\tau} f(Z^*)$$

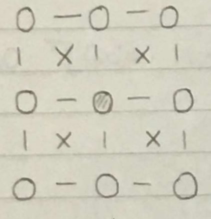
$$\dot{y}(t) = -B \cdot y(t) - \cancel{B Z^*} + V(f(x(x)) + U^*) + V^{\tau} f(x(t-\sigma) + U^*) + \cancel{B Z^*} - V f(U^*) - V^{\tau} f(U^*)$$

$$\dot{x}(t) = -A \cdot x(t) + W \cdot g(y(t)) + W^2 \cdot g(y(t-z))$$
$$\dot{y}(t) = -B \cdot y(t) + V \cdot g(x(t)) + V^2 \cdot g(x(t-G))$$

Equilibrum point of this system = origin

CELLULAR NEURAL NETWORKS

A cellular n.n. (CNN) is an array of cells with local connections only. The communication is allowed btwn neighbouring units.



r=1

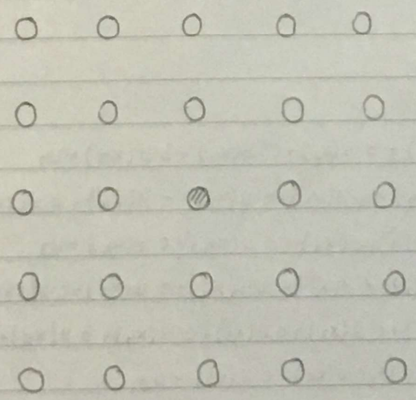
r: radius of neighborhood

Basic circuit unit of CNNs is called a "cell"

Each cell has an input, a state and an output.

Each cell interacts directly only with the cells within its radius of neighborhood.

Cells are multiple-input / single-output processors.



r=2

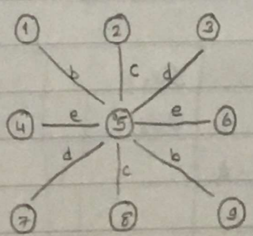
If r=1 → 3×3 neighborhood

r=2 → 5×5 "

⋮

r=n → (2n+1)×(2n+1) "

* In order to calculate the state of the cells, it is necessary to define the "template" of the network.



$$T: \begin{Bmatrix} b & c & d \\ e & a & e \\ d & c & b \end{Bmatrix} \quad \underbrace{(2r+1)\times(2r+1)}_{\text{Dimension of Template}}$$

T ↓ template (symmetric)

a: feedback of the central cell

c: " " " above and below neighbor cells

d: feedback of the left above and rightbelow neighbor cells

e: feedback of the right and left neighbor cells

- The CNN dynamics are described by a system of nonlinear differential equations.

$$\boxed{\dot{X} = -x + A \cdot y(x) + u} \Rightarrow \text{Sistemin}$$

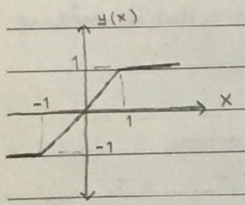
or

$$\boxed{\dot{X}_i = -X_i + \sum_{j=1}^{n} a_{ij} \cdot y(x_j) + u_i \quad , i = 1,2,\dots,n}$$

$x = [x_1 \; x_2 \; \dots \; x_n]^T$: State of cells $\qquad$ $A = \{a_{ij}\}$: Feedback matrix

$u = [u_1 \; u_2 \; \dots \; u_n]^T$. Input $\qquad$ $y(x) = [y(x_1) \; y(x_2) \dots y(x_n)]^T$: Output

$y(x_i) = \frac{1}{2} \cdot [|x_i + 1| - |x - 1|]$: Piece-wise linear function



$\boxed{r=1}$

1	2	3
4	5	6
7	8	9

$\dot{x}_1 = -x_1 + a \cdot y(x_1) + e \cdot y(x_2) + c \cdot y(x_4) + b \cdot y(x_5) + u_1$

$\dot{x}_2 = -x_2 + e \cdot y(x_1) + a \cdot y(x_2) + e \cdot y(x_3) + d \cdot y(x_4) + c \, y(x_5) + b \, y(x_6) + u_2$

$\dot{x}_3 = -x_3 + e \cdot y(x_2) + a \cdot y(x_3) + d \cdot y(x_5) + c \cdot y(x_6) + u_3$

$\dot{x}_4 = -x_4 + c \cdot y(x_1) + d \cdot y(x_2) + a \cdot y(x_4) + e \cdot y(x_5) + c \cdot y(x_7) + b \, y(x_8) + u_4$

$\dot{x}_5 = -x_5 + b \cdot y(x_1) + c \, y(x_2) + d \cdot y(x_3) + e \, y(x_4) + a \cdot y(x_5) + e \cdot y(x_6) +$
$\qquad d \cdot y(x_7) + c \, y(x_8) + b \cdot y(x_9) + u_5$

$\dot{x}_6 = -x_6 + b \cdot y(x_2) + c \cdot y(x_3) + e \, y(x_5) + a \cdot y(x_6) + d \, y(x_8) + c \cdot y(x_9) + u_6$

$\dot{x}_7 = -x_7 + c \, y(x_4) + d \, y(x_5) + a \cdot y(x_7) + e \cdot y(x_8) + u_7$

$\dot{x}_8 = -x_8 + b \cdot y(x_4) + c \cdot y(x_5) + d \, y(x_6) + e \cdot y(x_7) + a \, y(x_8) + e \, y(x_9) + u_8$

$\dot{x}_9 = -x_9 + b \cdot y(x_5) + c \cdot y(x_6) + e \cdot y(x_8) + a \cdot y(x_9) + u_9$

$$T = \begin{Bmatrix} b & c & d \\ e & a & e \\ d & c & b \end{Bmatrix}$$

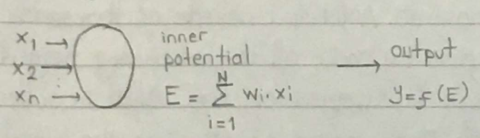
$$A = \begin{bmatrix} a & e & 0 & c & b & 0 & 0 & 0 & 0 \\ e & a & e & d & c & b & 0 & 0 & 0 \\ 0 & e & a & 0 & d & c & 0 & 0 & 0 \\ c & d & 0 & a & e & 0 & c & b & 0 \\ b & c & d & e & a & e & d & c & b \\ 0 & b & c & 0 & e & a & 0 & d & c \\ 0 & 0 & 0 & c & d & 0 & a & e & 0 \\ 0 & 0 & 0 & b & c & d & e & a & e \\ 0 & 0 & 0 & 0 & b & c & 0 & e & a \end{bmatrix}$$

$$\underbrace{\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \vdots \\ \vdots \\ \dot{x}_9 \end{bmatrix}}_{\dot{x}} = \underbrace{- \begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ \vdots \\ x_9 \end{bmatrix}}_{-x} + A \cdot \underbrace{\begin{bmatrix} y(x_1) \\ y(x_2) \\ \vdots \\ \vdots \\ y(x_9) \end{bmatrix}}_{y(x)} + \underbrace{\begin{bmatrix} u_1 \\ u_2 \\ \vdots \\ \vdots \\ u_9 \end{bmatrix}}_{u}$$

NEURAL NETWORKS

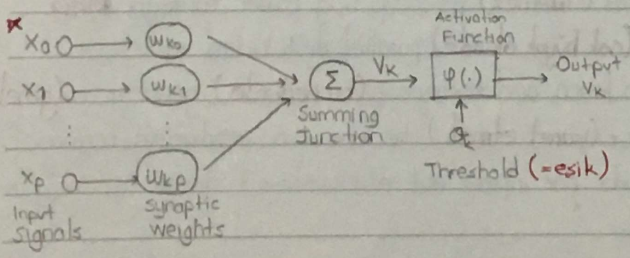
Artificial Neural Network (ANN) = is a mathematical model or computational (sayısal) model
(Neural Network) that is inspired (ilham verilmiş) by the structure and/or functional aspects (görünüş) of biological neural networks.

* In an ANN, simple artifical nodes (=düğüm), variously (=farklı olarak) called "neurons", are connected together to form a network of nodes mimicking (=andıran, taklit eden) the biological networks.

* 

A biological cell: consists of dendrites, a cell body (soma), and an axon. → (=hücre gövdesi)
The synapses (narrow gaps): transmit activations (=etkileşimler) btwn the dendrites and axon.
The dendrites: receive incoming signals from other nerve (=sinir) axons via synapse.
The axon: is an output mechanism for a neuron.

* Artificial neurons are the constitutive (=yapısal) units in an ann.
* The artifical neuron receives one or more inputs (representing the one or more dendrites)
* Sums them to produce an output (representing a biological neuron's axon)
* Usually the sums of each node are weighted, and the sum is passed through a non-linear function known as an activation function or transfer function.
* The transfer functions usually have a sigmoid shape, but they may also take the form of other non-linear functions, piecewise (=parçalı) linear functions, or step functions.

* 

* w_{k1} : the effect of 1st neuron to kth neuron
* Σ (Summing Function): determines (=belirlemek) the total effect of input signals
* u_k : Net input of k. Neuron $\quad u_k = \sum_{i=1}^{n} w_{ki} \cdot x_i$
* $f(.)$: Activation Function
* $y_k = f(u_k)$: Output

Main elements of Neuron : 1. Synapses = determine the type and amount of energy
2. Adder = determines the net input of neuron
3. Activation Function = determines the behaviour of neuron
implies (=belirtmek) nonlinearity to the system.

Learning in Neural Networks

By adjusting (=ayarlayıcı) the weights of an artificial neuron we can obtain the output we want for specific inputs. But when we have an ANN of hundreds or thousands of neurons, it would be (=olurdu) quite complicated to find by hand all the necessary weights. But we can find algorithms which can adjust the weight of the ANN in order to (=için) obtain the desired output from the network. This process of adjusting the weights is called learning or training.

Various Neural Network Models : Hopfield N.N. - Cellular N.N. - Cohen-Grossberg N.N.
Neutral (=nötral) N.N - Bidirectional (=çift yönlü) Associative Memory N.N.

Applications of N.N. : Optimization Problems - Associative Memory (=İlişkisel Bellek)
Pattern Recognition (=Tanıma) i.e. recognizing handwritten characters
Image Processing - Noise Removal (=Gürültü Silme) - Signal Processing

Potential Dynamical Behaviors of NN's : Stability (=Kararlılık) - Chaos (Kargaşa) - Oscillations (Salınım, Titreşme)
Unstability - Limit Cycles - Periodic Solution

Benefits of N.N. : Neural Network derives (=türemek) its computing power through, ~~first~~
First, its massively (çok büyük ölçüde) parallel distributed structure.
Second, its ability to learn and therefore (bu nedenle) generalize (genelleştirme)
Generalization, refers (işaret etmek) to the n.n. producing reasonable
outputs for inputs not encountered during training (learning).

Benefits of N.N.: The use of neural networks offers the following useful properties and capabilities

1. Nonlinearity: An artifical neuron can be linear or nonlinear.

A neural network, made up interconnection (=ara bağlantı) of nonlinear neurons, is itself nonlinear.

Moreover, the nonlinearity is of a special kind in the sense that it is distributed throughout (=tamamıyla) the network.

Nonlinearity is a highly important property, particularly (=özellikle) if the underlying physical mechanism responsible (=sorumlu) for generation of the input signal is inherently (=kendiliğinden) nonlinear.

2. Input-Output Mapping (=Eşleme)**:** A popular paradigm (=örnek) of learning called supervised learning (=öğreticiyle öğrenme) involves (=contain) modification of the synaptic weights of a neural network by applying a set of labeled traning samples or task examples.

Each example consists of a unique input signal and a corresponding (=yerini tutan) desired response.

The network is presented with an example picked at random from the set, and the synaptic weights of the network are modified to minimize the difference btwn the desired response and the actual response of the network.

The training of the network is repeated for many examples in the set until the network reaches a steady state where there are no further (=başka) significiant changes in the synaptic weights.

Thus, the network learns from the examples by constructing an **input-output mapping** for the problem at hand (=el altında, hazır)

3. Adaptivity (=Uyarlanabilirlik)**:** Neural Networks have a builtin (=gömülü) capability to adapt (=adapte olmak) their synaptic weights to changes in the surrounding (=çevre) environmet.

In particular, a neural network trained to operate in a specific environment can be easily retrained (=yeniden eğitim) to deal with (=üstesinden gelmek) minor changes in the operating environment conditions.

Moreover, when it is operating in a nonstationary (=durgun olmayan) environment (i.e. one where statics change with time) a neural network can be designed to change its synaptic weights in real time.

4. Evidential Response (=Delilsel Karşıt): In the context of pattern classification, a neural network can be designed to provide information not only about which particular pattern to select, but also about the confidence in the decision made.
This latter (=end) information may be used to reject ambiguous (=belirsiz) patterns, and thereby (=dolayısıyla) improve the classification performance of the network.

5. Fault Tolerance (=Hata Toleransı): A neural network, implemented (=uygulamak) in hardware form, has the potential to be inherently fault tolerant, or capable of robust computation (= sağlam hesaplama)

6. VLSI Implementability: The massively parallel nature of a neural network makes it potentially fast for the computation of certain task.
This same feature makes a neural network well suited (=uygun) for implementation using very-large-scale-integrated (VLSI) technology.
One particular beneficial virtue (=meziyet) of VLSI is that it provides a means of capturing (=ele geçirmek) truly complex behavior in a highly hierarchical fashion.

7. Uniformity of Analysis and Design: (=Monotonluk)
Basically, neural networks enjoy universality (=evrensellik) as information processors.
We say this in the sense that the same notation (=gösterim) is used in all domains involving the app. of neural networks.
This feature manifests (=açıkça göstermek) itself in different ways:
- Neurons, in one form or another, represent an ingredient (=bileşen) common to all n.n.
- This commonality (=benzerlik) makes it possible to share theories and learning algorithms in different applications of n.n.
- Modular networks can be built through a seamless (=kusursuz) integration of modules.

8. Neurobiological Analogy:
The design of a.n.n. is motivated (=harekete geçirmek) by analogy w/ the brain, which is a living proof that fault tolerant parallel processing is not only physically possible but also fast and powerful.
Neurobiologists look to neural networks as a research tool for the interpretation (=yorum) of neurobiological phenomena.
On the other hand, engineers look to neurobiology for new ideas to solve problems more complex than those based on conventional (=geleneksel) hard-wired design techniques.
(=donanım)

Biological Neuron: A Biological Neuron contains: a cell body for signal processing
many dendrites to receive signals
an axon for outputting the result
a synapse btwn the oxon and each dendrite.

* Dendrites carry electrical signals in into the cell body (soma)
* The soma (cell body) integrates and thresholds the incoming signals
* The axon is a single long nerve fiber that carries the signal from the soma to other neurons.
* A synapse is the connection btwn dendrites and axons of two neurons.

A neuron works as follows
- Signals (impulses) come into the dendrites through the synapses.
- All signals from all dendrites are summed up in the cell body
- When the sum is larger than a threshold, the neuron fires, and sends out an impulse signal to other neurons through the axon.

* Incoming signals to a dendrite may be inhibitory (=engelleyici) or excitatory (= uyarıcı)
* The strength of any input signal is determined by the strength of its synaptic connection.
* A neuron sends an impulse down its axon if excitation (=uyarı) exceeds (=aşmak) inhibition by a critical amount (threshold/offset/bias) within a time window.
* Memories are formed by the modification of the synaptic strengths which can change during the entire life of the neural systems.

Human Brain: The human nervous system may be viewed as a three-stage system.

Stimulus (=Uyarıcı) → Receptors (=Alıcı) ⇄ Neural Net ⇄ Effectors (=Etkileyici) → Response

* Central to the system is the brain, represented by the neural net, which continually receives info., perceives (=algılamak) it, and makes appropriate decisions.
* The arrows pointing from left to right indicate (=belirtmek) the forward transmission of information-bearing signals through the system
* The arrows pointing from right to left signify (=anlamına gelmek) the presence (=mevcudiyet) of feedback in the system
* The receptors convert stimuli from the human body or the external environment into electrical impulses (=dürtü) that convey (=iletmek) info. to the brain (neural net)
* The effectors convert electrical impulses generated by the neural net into discernible (=farkedilebilir) responses as system output

How "large" is a human brain?

* A neuron is the basic element in a biological brain.
* There are approximately 100,000,000,000 neurons in a human brain.
* One neuron is connectedly with approximately 10,000 other neurons.
* The human brain is very large and very complex system.
* Although each neuron is slow, un-reliable, and non-intelligent, the whole brain can make decisions very quickly, in a relatively (=nispeten) reliable and intelligent way.

Neural Networks

* Neural Networks (ANN) has been motivated right from its inception by the recognition (=tanıma) that the human brain computes in an entirely different way from the conventional (=geleneksel) digital computer.
* The brain is highly complex, nonlinear, and parallel computer (information-processing system).
* It has the capability to organise its structural constituents (=bileşen), known as neurons, so as to perform (=yapmak) certain computations (e.g. pattern recognition, perception, and motor control) many times faster than the fastest digital computer in existence (=varolan) today.
* Neural Networks are made up of (artificial) neurons.
* A n.n. is a machine that is designed to model the way in which the brain performs a particular task or function of interest.
* The network is usually implemented (=uygulamak) by using electronic components or is simulated in software on a digital computer.
* To achieve good performance, n.n. employ (=çalıştırmak) a massive interconnection of simple computing cells referred to as "neurons" or "processing units".

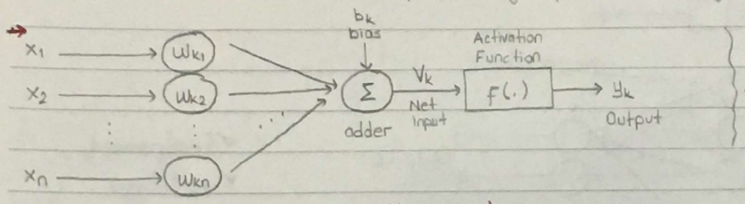
Artificial Neuron: A neuron is an information-processing unit that is fundamental to the operation of a n.n.

Three basic elements of the neural model:

1. A set of synapses, each of which is characterized by a weight or strength of its own.
Specifically, a signal x_j at the input of synapse j connected to neuron k is multiplied by the synaptic weight w_{kj}.
It is important to make a note of the manner (=tavır) in which the subscripts (=alt simge) of the synaptic weight w_{kj} are written.
The first subscript refers to the neuron in question and the second subscript refers to the input end of the synapse to which the weight refers.
The synaptic weight of an artificial neuron may lie in a range that includes negative as well as positive values.

2. An adder for summing the input signals, weighted by the respective (=ilgili) synapses of the neuron; the operations described here constitute (=bileşen) a linear combiner (=birleştirici)

3. An activation function for limiting the amplitude (=genlik) of the output of a neuron.
The activation function is also referred to as a squashing (=ezmek) function in that it squashes (limits) the permissible (=izin verilebilir) amplitude range of the output signal to some finite value.



=> Nonlinear model of k. Neuron in ANN.

Inputs   Weight Coefficients (=Ağırlık Katsayısı)

The model of a neuron also includes an externally applied bias, denoted by b_k.
The bias has the effect of increasing or lowering the net input of the activation function, depending on whether it is possitive or negative, respectively.
In mathematical terms, we may describe a neuron k by writing the following equations:

$$u_k = \sum_{j=1}^{n} w_{kj} \cdot x_j$$

$$y_k = f(u_k + b_k)$$

$$v_k = u_k + b_k$$

Types of Activation Function

tanh => $f(x) = \frac{e^x - e^{-x}}{e^x + e^{-x}}$

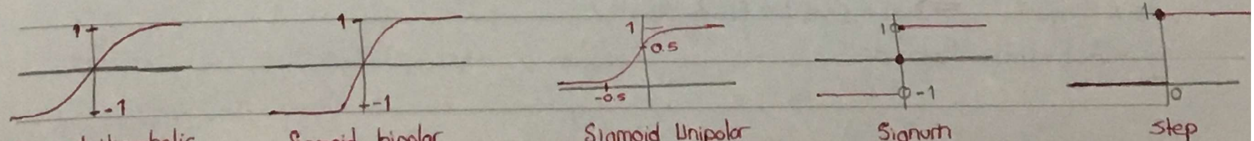
Sigmoid (bipolar) (=Çift Kutuplu) => $f(x) = \frac{1-e^{-x}}{1+e^{-x}}$

Sigmoid (unipolar) (=Tek Kutuplu) => $f(x) = \frac{1}{1+e^{-x}}$

✓ Bounded (=Sınırlı)
✓ Continuous

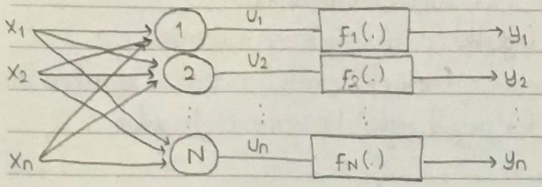
Sgn (.) => $f(x) = \begin{cases} 1 & \text{if } x > 0 \\ 0 & \text{if } x = 0 \\ -1 & \text{if } x < 0 \end{cases}$

Step => $f(x) = \begin{cases} 1 & \text{if } x \geq 0 \\ 0 & \text{if } x < 0 \end{cases}$



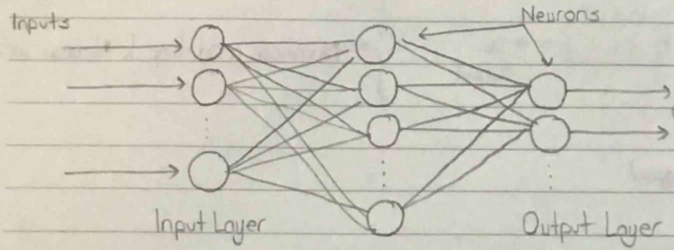
Tangent Hiperbolic   Sigmoid bipolar   Sigmoid Unipolar   Signum   Step

Artificial Neural Network

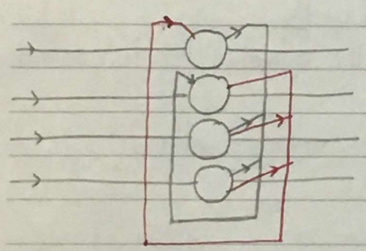


$$\boxed{y = f(u) = f(Wx)}$$

✓ Feedforward (=İleribeslene)
✓ Single layer



✓ Feedforward
✓ Multilayer



$$\boxed{y_{n+1} = f(y_n, u)}$$

(=Yinelenen)
✓ Recurrent (at least one feedback loop)
✓ Single layer

The Architecture of ANN

- Number of inputs and outputs of the network
- Number of layers
- How the layers are connected to each other
- The activation function of each layer
- Number of neurons in each layer

Notations for j. Neuron in an ANN

n = Number of neurons in ANN

x_i = Input signal $\Rightarrow x_i = [x_1\, x_2 \dots x_n]^T$

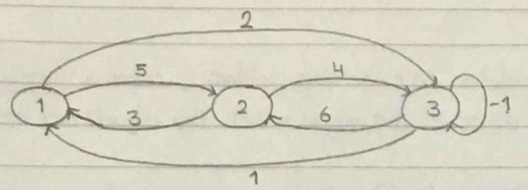
W_{ji} = Weight coefficients (from i.neuron to j.neuron)

u_j = Net input $\Rightarrow u_j = \sum_{i=1}^{n} w_{ji} \cdot x_i$

y_j = Output $\Rightarrow y_i = f(u_j) = f\left(\sum_{i=1}^{n} w_{ji} \cdot x_i\right)$

f = Activation Function

Ex:



$W = \{w_{ji}\}$: Weight Matrix

$n = 3$

$u_j = \sum_{i=1}^{n} w_{ji} \cdot x_i$ $\qquad x_1 = 0.1 \qquad x_2 = 0.5 \qquad x_3 = -0.2$

For neuron (1) $j=1$ $\qquad u_1 = W_{11} \cdot x_1 + W_{12} \cdot x_2 + W_{13} \cdot x_3 = 0 \cdot x_1 + 3 \cdot x_2 + 1 \cdot x_3 = 1.3$

For neuron (2) $j=2$ $\qquad u_2 = W_{21} \cdot x_1 + W_{22} \cdot x_2 + W_{23} \cdot x_3 = 5 \cdot x_1 + 0 \cdot x_2 + 6 \cdot x_3 = -0.7$

For neuron (3) $j=3$ $\qquad u_3 = W_{31} \cdot x_1 + W_{32} \cdot x_2 + W_{33} \cdot x_3 = 2 \cdot x_1 + 4 \cdot x_2 + (-1) \cdot x_3 = 2.4$

$$W = \begin{bmatrix} u_{11} & u_{12} & u_{13} \\ u_{21} & u_{22} & u_{23} \\ u_{31} & u_{32} & u_{33} \end{bmatrix} = \begin{bmatrix} 0 & 3 & 1 \\ 5 & 0 & 6 \\ 2 & 4 & -1 \end{bmatrix} \qquad U = W.X \qquad \begin{bmatrix} u_1 \\ u_2 \\ u_3 \end{bmatrix} = \begin{bmatrix} \\ W \\ \\ \end{bmatrix} \cdot \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} \qquad \begin{matrix} y_1 = f(u_1) \\ y_2 = f(u_2) \\ y_3 = f(u_3) \end{matrix}$$

Learning in Neural Networks

- The property (=özellik) that is of primary significance (=önem) for a neural network is the ability of the network to learn from its environment.
- Learning involves (=contain) adjustments (=ayarlar) to the synaptic connections that exist btwn the neurons.
- Ideally the network becomes more knowledgable (=bilgili) about its environment after each iteration of the learning process.

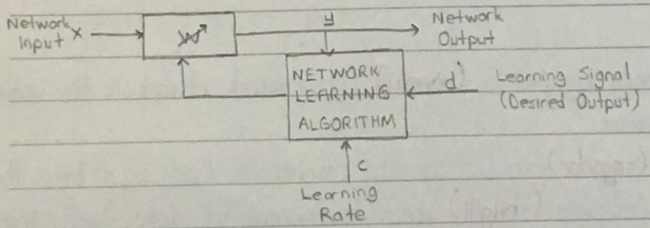
- Definition of learning in the context of neural networks:
  Learning is process by which the free parameters of a neural network are adapted through a process of stimulation (=dürtü) by the environment in which the network is embedded.
  The type of learning is determined (=belirlemek) by the manner (=tavır) in which the parameter changes take place.

- Definition of learning process implies (=belirtmek) the following sequence of events:
  1. The neural network is stimulated by an environment. "Dışarıdan yeni bir girdi verilmesi"
  2. The n.n. undergoes changes (=değişim göstermek) in its free parameters (=serbest değişkenler) as a result of this stimulation.
  3. The n.n. 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 (=dikkate almak) is the manner in which a neural network relates (=bağlı olmak) 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. "Ağ eğitiminde kullanılır"

- Two fundamental learning paradigm: 1. Learning with a teacher (SUPERVISED LEARNING)
"Desired output is given to the network"
2. Learning without teacher (UNSUPERVISED LEARNING)
"There is NO desired output"

1. SUPERVISED LEARNING



The learning rule is provided with a set of training set of proper network behaviour: $\{x_1,d_1\},\{x_2,d_2\}...\{x_n,d_n\}$
As the inputs are applied to the network, the network outputs are compared with the desired outputs.

x_n = Input to the network
d_n = Corresponding correct desired output

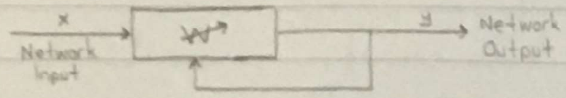
GENERAL RULES FOR NEURON i

- 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. (ΔW_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 Discreate-Time Form: $W_i^{k+1} = W_i^k + \Delta W^k$

$$W_i^{k+1} = W_i^k + c.r.[W_i^k, x^k, d_i^k].x^k$$

2. UNSUPERVISED LEARNING



- Learning signal is not available

- $W_i = [W_{i1} \ W_{i2} \cdots W_{in}]^T$
- $r = f(W_i, x)$
- $\Delta W_i(t) = c \cdot r \cdot [W_i(t), x(t)] \cdot x(t)$
- $c > 0$
- $W_i(t+1) = W_i(t) + \Delta W_i(t)$

General Discrete-Time Form: $W_i^{k+1} = W_i^k + \Delta W^k$

$$W_i^{k+1} = W_i^k + c \cdot r \cdot [W_i^k, x^k] \cdot x^k$$

LEARNING RULES

- PERCEPTRON (PERCEPTION) LEARNING RULE
- DELTA LEARNING RULE
- WIDROW-HOFF LEARNING RULE
- CORRELATION LEARNING RULE

$\}$ ⇒ SUPERVISED

- HEBBIAN LEARNING RULE

$\}$ → UNSUPERVISED