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A Study Guide on Artificial Neural Network for NET/SET Computer Science Aspirants

Mr. Rajesh R Yadav
Assistant Professor
Department of Computer science,
V. K. Krishna Menon College,
Bhandup, Mumbai (India)
E-mail: rajeshy2808@gmail.com

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Abstract:

Artificial neural networks (ANNs) are computational networks that are biologically inspired. The paper will focus on components of ANN, topologies, various learning strategies, examples, elements, activation functions and its variants in simplified manner. The paper will also focus on perceptrons, its characteristics and its types. The paper covers the majority of important points useful for aspirants preparing for National Eligibility test and state level lectureship test. The main purpose to prepare this paper is to facilitate computer teachers, research scholars and aspirants preparing for competition with a simplified view on the concept of ANN which base a unit covering 6-10 marks in NET /SET exam.

Keywords: *NTA, NET-CSS , ANN ,Synapse, Perceptron, Neuron, Activation function.*

1. INTRODUCTION:

Artificial Neural Networks (ANN) / neural networks intended as computational algorithms simulate the behavior of biological systems composed of neurons.ANN are inspired by the human nervous system. It is an oriented graph. It consists of various nodes representing neurons connected by arcs that have correspondence to dendrites and synapses. Each of the arcs has weight associated with it at each node. Human brain and computer have a specific feature associated with them .The following table gives a clear view on Brain v/s Computer.

	Brain	Computer
Processing Elements	10^{10} neurons	10^{8} transistors
Element Size	10^{-6} m	10^{-6} m
Energy Use	30 W	30 W (CPU)
Processing Speed	10^{2} Hz	10^{12} Hz
Style Of Computation	Parallel, Distributed	Serial, Centralized
Energetic Efficiency	10^{-16} joules/opn/sec	10^{-6} joules/opn/sec
Fault Tolerant	Yes	No
Learns	Yes	A little

As sayings from one of movie -

2. NEURON:

Simple Definition of Neuron:-*A neuron is the fundamental/basic unit of any living organism's Central Nervous System.*

2.1 BIOLOGICAL NEURON:

For the normal functioning of cells in the body all the neurons perform three basic functions:

- To Receive signals (or information) from outside.
- To Process the incoming signals and determine whether or not the information should be passed along.
- To communicate signals to target cells which might be other neurons or muscles or glands.
- Biological neuron consist of 4 basic components

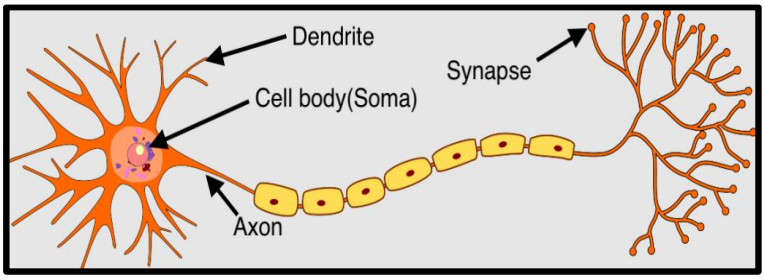

Fig.1. Structure of Neuron

Components of Biological Neuron:

- **Dendrite (Receiver):** They are responsible for receiving incoming signals from outside.
- **Soma / Cell body (Processor):** These are responsible for the processing of input signals and deciding whether a neuron should fire an output signal.
- **Axon (Catalyst):** They are responsible for transmitting processed signals from neuron to relevant cells.
- **Synapse (Transmitter):** They are the connection between an axon and other neuron dendrites.

3. ARTIFICIAL NEURON

An artificial neuron receives n input x1,x2,x3,….,xn and weights w1,w2,w3,…,.wn attached to the input link. The weight sum ∑xiwi is computed to be passed on non-filter function Ø called activation function to release output.

Threshold logic unit (TLU): It is designed to simulate the functionality of a simple neuron. Each of its components is analogous to a biological component.

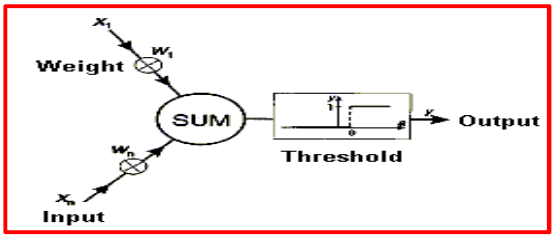

Fig.2. Structure of artificial neuron

Each of the input signals is multiplied by a weight associated in order to supply a weighted signal to the summation unit, where the values are summed to supply the input activation to the threshold logic unit.

The threshold logic unit compares the input activation to a threshold value. *"The weighted sum is less than the threshold value, if this is the condition the output is considered as 0 otherwise 1."*

- An artificial neuron receives n input x1,x2,x3,….,xn and weights w1,w2,w3,…,.wn and bias (b) attached to the input link.
- The weight sum ∑xiwi is computed to be passed on non-filter function Ø called activation function to release output.
- The formula to calculate total input to neuron is given by f (b+∑xiwi)
- An "activation function" are mathematical equations used to standardize the output from the neuron. Standardization refers to the transformation of data to have mean 0 and standard deviation 1. Each neuron has its activation function. It is difficult to understand without mathematical reasoning. It also helps to normalize the output in a range between 0 to 1 or -1 to 1. An activation function is also known as the transfer function

Example: *A neuron with three input has a weight vector [0.2 -0.1 0.1] and bias =0 .If the input vector is X=[0.2 0.4 0.2] then total input to neuron using above formula* is

f (b+∑xiwi)=0 + [0.2*0.2+ (-.0.1)*0.4 + 0.1*0.2]

=0.04-0.04+0.02

=0.02

4. ARTIFICIAL NEURAL NETWORK:

A Neural Network or ANN consists of layers of interconnected “artificial neurons”. Neural networks learn by examples.

Researches on ANN:

1911: Ramon Y Cajal introduced the idea of neurons as structural constituents of Brain.

1943: McCulloch and Pitts apply boolean algebra to nerve net behavior.

1948: Donald hebb postulates a qualitative mechanism for learning at cellular level in brain.

1957: Rosenblatt developed "Perceptron" neuro computer.

1960 to 1980's: No Research in ANN.

Middle 1980's: John Hopfield revives ANN.

Today ANN is most active current areas of research.

4.1) Elements of Neural Network:

1) Input Layer: It provides information from the outside world to network. No computation is done in this layer. It simply passed on information to hidden layers.
2) Hidden layer: It does all computation on features entered through the input layer .This layer is not exposed to the outside world.
3) Output layer: It brings up information learned from the network to the outside world.

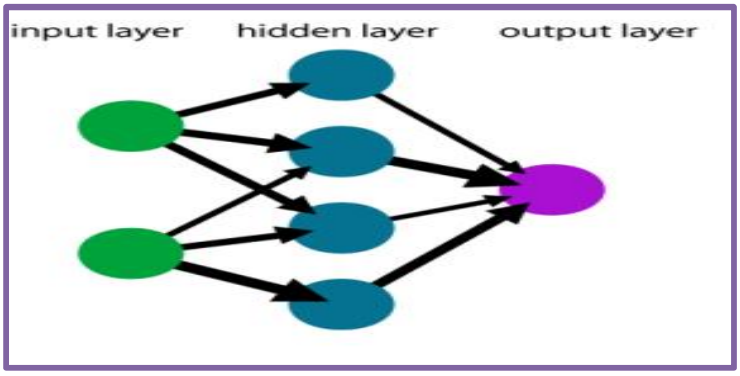

Fig.3. Schematic diagram of a standard neural network design. Signals pass from the input units through a hidden layer to an output unit.

5. TERMINOLOGY COMPARISON OF ARTIFICIAL NEURON NETWORK AND BIOLOGICAL NEURON:

Biological terminology	Artificial neural network terminology
Neuron	Unit
Synapse	Connection
Synaptic strength	Weight
Firing frequency	Unit output

Table 1 : Corresponding terms from biological and artificial neural networks. Adapted from Mehrotra, Mohan, & Ranka.

From the above table it is clear that Biological neurons and ANN have the same function, just the differences are in names.

6. ARTIFICIAL NEURAL NETWORK TOPOLOGIES:

a) **FEED FORWARD ANN**: In feed forward ANN, information flow is unidirectional. Here there is no presence of feedback loops. Example : Data mining

b) **FEEDBACK ANN:** In feedback ANN, information flow is bidirectional. Here there is the presence of feedback loops. Example : Recurrent Neural Network

7. ANN LEARNING STRATEGIES:

1) **Supervised Learning**: In Supervised learning, manual labels of inputs are used. Instructive information on desired responses are explicitly specified by supervisor/trainer/teacher.

2) **Unsupervised Learning:** In Unsupervised learning manual labels of inputs are not used. There is no instructive information about desired responses.

3) **Reinforcement Learning:** In Reinforcement learning, the decision system receives rewards at the end of the sequence of steps for its action. There is partial information about desired responses or only right or wrong evaluative information is available.

8. ACTIVATION FUNCTION

This topic usually comes as application based.

Definition: It is a function that decides whether neuron should be activated or not by the calculation of weighted sum (∑xiwi) and adding bias (b) to it i.e. b+∑xiwi

8.1. VARIANTS OF ACTIVATION FUNCTION:

a) **Linear Function**: It is used at one place i.e. output layer. The range of this function is - ∞ to ∞.The equation of linear function is y=ax.

b) **Sigmoid function**: This function is plotted as S Shaped Graph. It is used in output layer of binary classification. The range of this function is 0 to 1.The equation of linear function is $A=1 / 1+e^{-x}$.

c) **Tanh function:** The Acronym is Tangent Hyperbolic function. It is used in hidden layers. The range of this function is -1 to 1.The nature is non-linear. It is a shifted version of the sigmoid function. It is better than the sigmoid function. The equation of tanh function is $1-e^{-2x}/1+e^{-2x}$.

d) Relu function: Acronym for Rectified linear unit It is implemented in the hidden layer of neural network. The range of this function is 0 to ∞. The nature is non linear. It is much faster than tanh and sigmoid function The equation of Relu function is A(x) =max(o,x).
If X is positive then output is x otherwise 0.

Note:

- If no activation function is mentioned, Relu is the best choice.

- For binary classification, sigmoid function is the best choice.

9. **PERCEPTRON:**

Perceptron is a computational model of a single neuron invented by Frank Rosenblatt in the year 1958 at the Cornell lab. It is an algorithm used for Supervised learning of binary classifiers. It is the simplest neural network possible. It is a methodology for Supervised learning. They are single-layer feed-forward networks. It consists of an input layer, a hidden layer, and an output layer. The input layer is connected to the hidden layer through weights which may be inhibitory or excitery or zero (-1, +1 or 0). The activation function used is a binary step function for the input layer and the hidden layer.

The output is Y= f (y)

The activation function is:

F (y) =

1 if y >= threshold
0 if – (threshold) <= y <= threshold
-1 if y < - (threshold)

9.1) Characteristics of perceptron:

- It is error- based.
- It uses Hebb's rule of learning.
- It is a single layer feed forward network.
- It is a finite state learning algorithm.
- Perceptron can learn AND operation.
- The most famous example of the inability of Perceptron to solve a problem with a linearly non-separable case is XOR Problem.

9.2) Unit of Perceptron:

1) **Sensory unit**: It is an input layer. It is connected to an associative unit with fixed weight (1,-1,0).
2) **Associative unit**: It is a hidden layer. It is an intermediate layer between sensory and response unit. All intermediate operations are performed by this unit.
3) **Response unit:** It is an output layer. It has an activation value (1 0 -1).The output of the response unit is in the form of a binary signal.

9.3) TYPES OF PERCEPTRON:

1) Single layer perceptron: It is a feed forward neural network that is based on threshold transfer function. It can classify linearly separable cases. It has only input and output layer. In single layer Perceptron, updation rule of weight vector is w(n+1)=w(n)+n[d(n)-y(n)]*x(n).

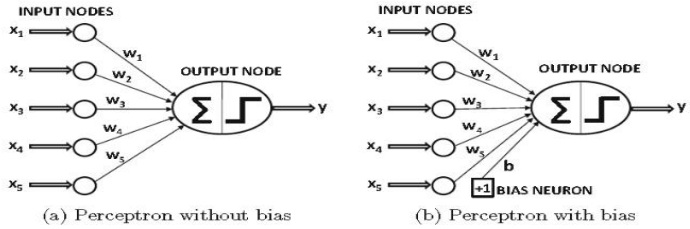

Fig.4. Basic architecture of single layer Perceptron

The perceptron architecture is shown in Figure 4 , where a single input layer transmits the respective features to the output node. The weight on edges from the input to the output i.e. w1 . . . w5 are multiplied with the features. An additional bias can be integrated and added at the output node. Then, an activation function is applied to convert the aggregated/summated value into a class-label. Apparently the single layer perceptrons could capture only linear classifiers, and not capture nonlinear regularities.

2) Multilayer Perceptron: It is a feed forward neural network with one or more hidden layer. It uses a back propagation algorithm. It can solve XOR problem.

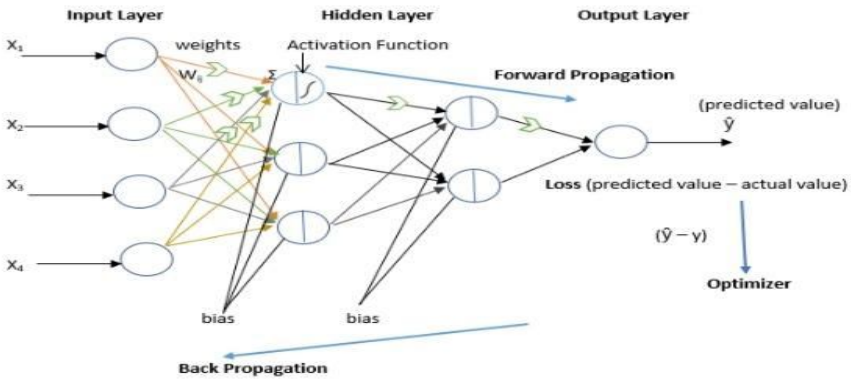

Fig.5. Architectural view of Multilayer Perceptron

Components in Multilayer Perceptron

1) **Input layer**: It simply receives and transmits the information. No sort of computation is performed in this layer.
2) **Hidden layers**: They are the intermediate layers between input and output layer.
3) **Output layer**: It generates the results for given inputs. Number of output neurons can be single or multiple.

Other components in Multilayer Perceptron:

Bias and Weights are the learn-able parameters.

1) Weight:

- An important role in propagation of signal in the network is played by weights.
- A weight decides how much influence the input will have on the output.

2) **Bias:**

- Bias helps in controlling the value at which activation function will trigger.
- The bias value allows the activation function to be shifted to the left or right, to better fit the data.

3) **Activation function :**

- To introduce non-linearity and normalize the data to the neuron output.

4) Loss function:

It depicts the efficiency of the model performance with respect to the expected outcome.

5) **Optimizer**: The purpose of optimizer is to reduce/decrease the loss function (or to achieve the global minima) by updating the weights and bias during backpropagation.

Theoretical aspect on training a Neural Network along with Backpropagation:

The backpropagation algorithm has two main phases- forward and backward phase.

A) **Forward Propagation:** In this phase, the input layer of Neuron receives signals. They simply transmit the information to the hidden layer without performing any computation. The hidden layer neural net input is calculated as summation of each output of the input layer then multiplied by weights and then an additional bias can be added. An activation function is then applied in order to do the calculation of the hidden layer neuron output. This phase continues with activation level calculations propagating /forwarding to the hidden layer(s) output. Every successive layer, each neuron aggregates its inputs and applies a transfer-function in order to compute its output. The network's output layer then generates the final response, i.e., the estimated target value.

B) **Backward Propagation:** Backward propagation is a learning that adjusts weight in a neural network by propagating weight changes backward from source to sink. In this phase error between actual values and requested nominal value in an output layer is propagated backward in order to modify weight and bias value.

Solved Examples on Perceptron:

1) A perceptron has weight w1=-3.9 and w2=1.1 with the threshold value=0.3.What output does it give for input x1=1.3 and x2=2.2 ?

Solution : Weighted sum=$\sum xiwi$

$= x1.w1 + x2.w2$

$= -3.9 \times 1.3 + 2.2 \times 1.1$

$= -2.65$

Now Threshold value =0.3

Since -2.65 < 0.3 ,output =0 (REFER TO TOPIC 9:PERCEPTRON)

Advantages of ANN:

1) It has a parallel/equal multiprocessing ability. It has the mathematical strength to perform more than one assignment simultaneously.

2) Failure of one component of the network doesn't influence the performance of the entire framework.

3) A neural network gains from the experience and doesn't require reconstructing or reprogramming.

Disadvantages of ANN:

1) The black box nature is the most noticeable disadvantage of ANN. The neural network doesn't give the appropriate clarification of deciding the yield. It diminishes trust in the network.

2) The term of the advancement of the network is obscure.

3) There is no confirmation of appropriate network structure. There could be no legitimate principle to decide the design.

Applications of Artificial Neural Network:

1) **Text classification and categorization:** It is a fundamental piece of numerous applications like web looking, data separation, and language recognition..

2) **Medical:** We can utilize it in recognizing cancerous cells and breaking down the X-ray pictures to give itemized or detailed results.

3) **Summarize detection:** Question setting framework needs to decide if two sentences have a similar meaning or not. Artificial neural networks are exceptionally useful in summarizing discovery.

4) **Forecast:** We can utilize it in each field of business choices or forecasting like in finance and the securities exchange, in financial and money related measures.

5) **Image processing:** We can process images using satellites for agricultural and defense use.

6) **Aerospace:** ANN are used for aircraft fault detection.

7) **Military:** We use ANN in the military for Weapon orientation and steering, target tracking.

8) **Electronics:** We use ANN in electronics for code sequence prediction, IC chip layout, and chip failure analysis.

9) **Medical:** Since medicine has too many machines. They are used in cancer cell analysis, EEG and ECG analysis and many more health related problem.

10) **Speech:** An ANN is used for speech recognition and speech classification.

11) **Telecommunications:** An Artificial neural network is used for mage and data compression, automated information services.

12) **Transportation:** An Artificial neural network in transportation for truck Brake system diagnosis and vehicle scheduling, routing systems.

13) **Software:** An ANN is used in pattern Recognition, facial recognition, optical character recognition, etc.

14) **Time Series Prediction:** An Artificial neural network is used to predict time, make predictions on stocks and natural calamities.

Conclusion:

Artificial neural networks are powerful models to solve the problems. Mostly, neural network methods exceed other methods. The above details clearly states that artificial neural network is one of broad concepts in Current trends scenario. I have tried to cover major point that will be helpful to teachers, students and other aspirants.

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