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ANN Implementation of Constructing Logic Gates Focusing On Ex-NOR

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Abstract

In this paper Construction of Logic Gates using Artificial Neural Network is discussed. The solution to the problem of Construction of Logic gates is discussed. The proof of the solution proposed is provided. The Artificial Neural Network utilized for providing the solution to the problem of construction of logic gates uses fixed set of weights to generate the output. The Artificial Neural Network model follows single layer network topology. Although there are two layers since computation it is performed only in one layer and one neuron it is single layer network. In this paper a new solution to the Ex-NOR problem is provided.

Keywords: Artificial Neural Network, Activation Function, Threshold Function, Neuron, Induced Local Field, Weights.

Introduction

Artificial Neural Network is the section of Computer Science that basically takes into consideration the construction of Programs on Computers which are having analogy with the working of Human brain. AnArtificial Neural Network(ANN) is a huge Parallel and Distributed processor which is made up of individual elements called neurons which are having natural capability of storing experiential knowledge and utilized the acquired knowledge. ANN resembles human brain in two aspects: (i) Knowledge is obtained by the artificial neural network from its environment through a learning process. (ii) Inter-neuron connection strength which are called synaptic weights are used to store the obtained knowledge.

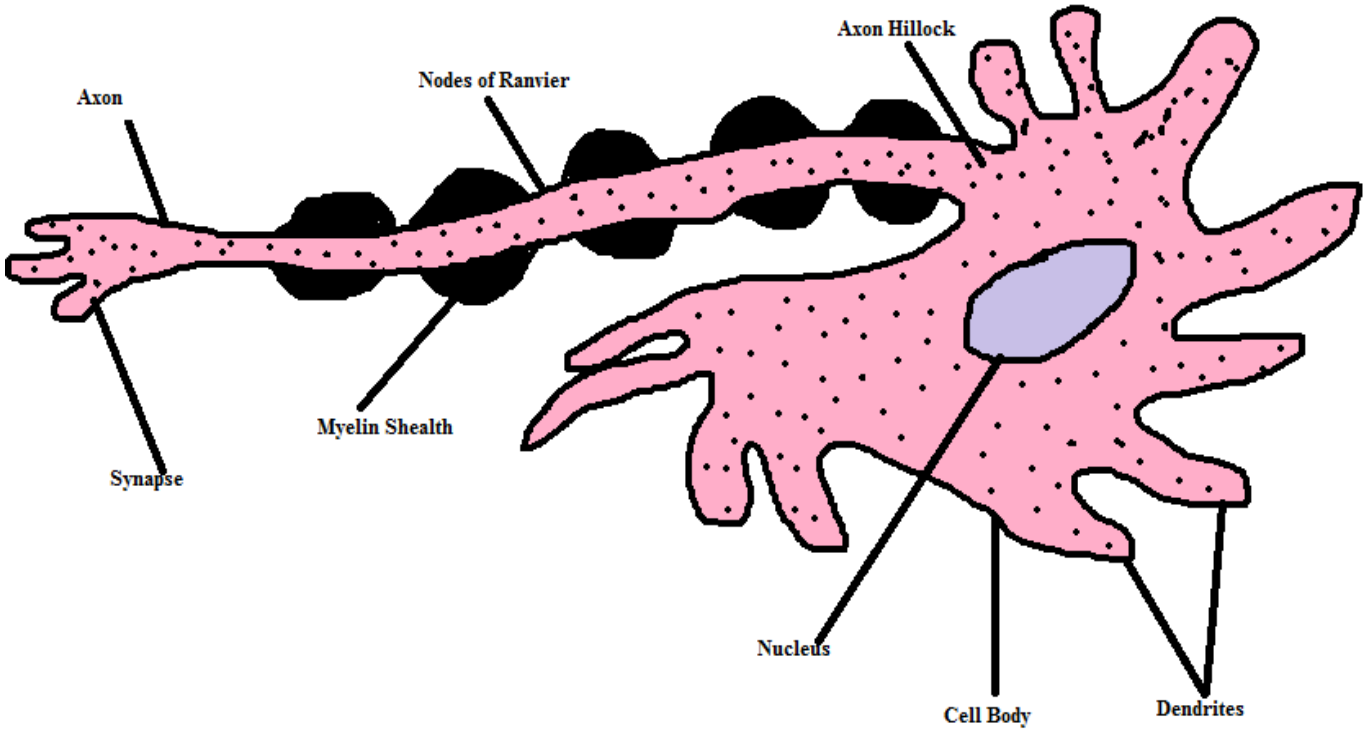

Figure-1
Major Structures of a Biological Neuron

Human Brain is a complex, non linear and parallel organization. Brain is basically an information processing system. Brain is having a unique structure that enables it to build its own set of axioms by the process what we call experience. The Nervous System present in the Humans are responsible for the production of all the responses that the Humans produce after having stimulus from the environment. Human being interact with the environment by means of the receptors (Five basic senses present externally in human body to experience stimulus from environment are sense of touch, sense of smell, sense of sight, sense of taste and sense of hearing). The receptors forward the information to the neural net present in the brain to perform responses for the obtained stimulus using the effectors present in the Human body.

The modern era of neural network started in 1943 with the classical paper written by McCulloh and Pitts. McCulloh who was a psychiatrist and neuroanatomist was trying to explore the human behavior after getting different inputs. After making research on representation of an event in the nervous system he joined Pitts a mathematician and wrote the classical paper which was published and presented in the International Conference in University of Chicago. The paper written by McCulloh and Pitts described a logical calculus of neural networks that made the unification of the studies of neurophysiology and mathematical logic[1]. The paper written by McCulloh and Pitts influenced Von Neumann to use idealized switch delay elements to construct EDVAC which gave emergence to ENIAC the first digital computer. The Table-2 represents the difference between Human Brain and Artificial Neural Network.

An ANN is basically an implementation ofhardware or a software which aims to simulate the information processing abilities of its biological counterpart. ANNs are generally made up of a great number of interconnected elements. An Artificial neuron present in the ANN is simplified model of its biological counterpart. An Artificial Neural network is an engine that is portrayed to mimic the manner in which the human brain performs a particular operation or procedure of interest, the ANN described above is generallyimplemented by using components which are having electronic consideration or is simulated in the form of software on a Digital Computer. Neurons may be called nodes, units, Processing Element etc. Artificial Neural Networks are also known as Neuro Computers, Connectionist networks and Parallel Distributed Processors.

Table-1
Representing Difference between Computer and Biological Neural Network

Property	Computer	Biological Neural Networks (BNN)
Speed	The speed of Computer is in Nanoseconds	The speed of Biological Neural Network is in Milliseconds
Processing	Computer processing is sequential in nature in the Conventional Computers	Neural Networks are capable of carrying out a huge amount of parallel operations.
Size and Complexity	Less Complex	More complex. The number of neurons present in the human brain is approximately equal to 10^{11} and the total number of interconnection possible between the individual neuron is 10^4. Therefore the total number of possible interconnections is 10^{15}
Storage	In a computer information is stored in the memory in a form which is addressed by its location. If any new information in obtained for the same location, then the new information destroys the old information. The information in the computer is strictly replaceable.	Biological Neural Networks store information in the form of strength of interconnection between the neurons. In a Biological Neural Network for adding a new information in the network the strength of the interconnection is adjusted. The old information is not destroyed. The human brain having biological neural network is having the property of adapting the new stimulus without destroying the previous information.
Fault Tolerance	Computer Systems does not posses the property of fault tolerance. If any information got corrupted it is generally not possible to make a retrieval of the same.	Biological Neural Network having parallel and distributed architecture exhibit the property of fault tolerance. Since the information in the network is present in distributed form by means of interconnections between the elements present in the network. In BNN due to some unforeseen reason some of the units fail the BNN is still capable to deliver the work. The degradation in performance is not catastrophic it is graceful. The failed node burden is distributed to the network and there is no loss of information.
Control Mechanism	In a Computer there is a control unit which monitors all the activities of Computing. Also system software named operating system is present who is the supervisor of all computing activities.	There is no central controlling framework for processing in the Biological Neural Network.

Artificial Intelligence which is also a field of Computer Science is having association with Artificial Neural Network. Artificial Neural Network Technology can be used as a technique for implementation of computer program that mimics intelligence shown by human beings. The differences between the two fields are elaborated in Table-3.

Table-2
Representing Difference between Human Brain and Artificial Neural Network

Human Brain	Artificial Neural Networks
The structure of Brain is very complex.	The structure when compared with human brain is simple.
The processing time of human brain is in milliseconds. Thus the response time is slow compared to ANN.	Since it is simulated in computer which is having nanoseconds of speed the response time is fast.
Human brain can solve a variety of problems and is general in nature for solving problems.	It is generally designed for dedicated operations. In other words ANN are highly dedicated.
There are different sections in brain for performing various set of operations. The design is arbitrary and not regular.	The Design is regular and is in accordance to the basic topologies.
Generally the activities performed by Human brain are asynchronous.	Generally the activities are synchronous. Because it is simulated in Electronic system which is generally showing synchronous nature.

Table-3
Representing Difference between Artificial Intelligence and Artificial Neural Network

Artificial intelligence	Artificial neural networks
Artificial Intelligence is the module of Computer Science (CS) Department that makes consideration of the construction of Computer Programs which are analogous to the working of human reasoning process.	Artificial Neural Network is Stream of CS which carries out the construction of computer programs which are analogous to the working of Human brain.
Knowledge is represented by means of Knowledge representation techniques which are at a higher level. The represented knowledge is explicit in nature.	Knowledge acquired in Artificial Neural Network is represented by means of numeric values stored in free parameters called weights.
If an error is encountered in Artificial Intelligence, The branch is having the capability to correct it by remodifying the facts and pulses explicitly	If an error is obtained then in Artificial Neural Network the correction is by means of learning algorithm. Explicit correction is not generally made in ANN
The Intelligence obtained by the AI system depends upon the capability of the Designer (Constructor) of the system. The more efficient the design the more intelligent the system.	Intelligence obtained depends upon the training algorithm utilized for the Artificial Neural Network
Real time system require fast response, since processing is less compared to ANN less frequently used for construction of Real time systems	Since processing speed is fast due to the presence of Parallel and distributed architecture used for the construction of Artificial Neural Network.
Response time is consistent	Response time is consistent as it depends upon the training
Knowledge representation is symbolic. Also for inferring symbol processing is done	Numeric representation and processing is made
Sequential Processing is made in AI	Parallel and Distributed processing is made in ANN
It is not as good as ANN in exhibiting Fault tolerance	It is good in exhibiting Fault tolerance
The presence of Explaination subsystem enables AI system to give explaination of the responses obtained in AI	No explaination is provided by the system for the obtained output

Three basic entities which characterize ANN are first The network framework which specifies interconnection of neural units, second the characteristics exhibited by the individual units or artificial neurons and third The strategy for pattern learning or training. Learning in the context of neural network is the process by which free parameters of the Neural Network are adapted through a process of stimulation by the environment in which the network is embedded. Some types of learning in Neural network are Error Correction learning, Memory Based learning, Hebbian learning, Competitive learning and Boltzman learning. Some Applications of Artificial Neural Networks include Pattern Recognition, Image Processing, Control Systems, Forcasting, Optimization, Constraint Satisfaction, Marketing, Medical and Health care, Manufacturing, Science and Engineering, Food Industry, Transportation and Communication, Document and Form Processing and Business.

Model of Neuron

There are three techniques using which are utilized for the representation of Artificial Neural Network. The names of the techniques are Block Diagram Representation (BDR), Signal Flow Graph (SFG) and Architectural Graph (AG).

Block Diagram Representation: Anartificial neuron is an element capable of processing information, it is fundamental to the operation of anartificial neural network. There are three basic elements which are present in the basic neuronal model: (i) A set of synaptic weights or connecting links, each of which is characterized by a numeric value specifying strength of its own. (ii) A unit for summing the input signals usually called an adder,A linear Combiner used for the purpose generally. (iii) An activation function for squashing the produced activation value to produce the output.

The Activation function limits the amplitude of the output of anartificial neuron. The activation function is also known as a squashing function because of the reason that it squashes (limits) the permissible amplitude range of the output signal to some finite value.

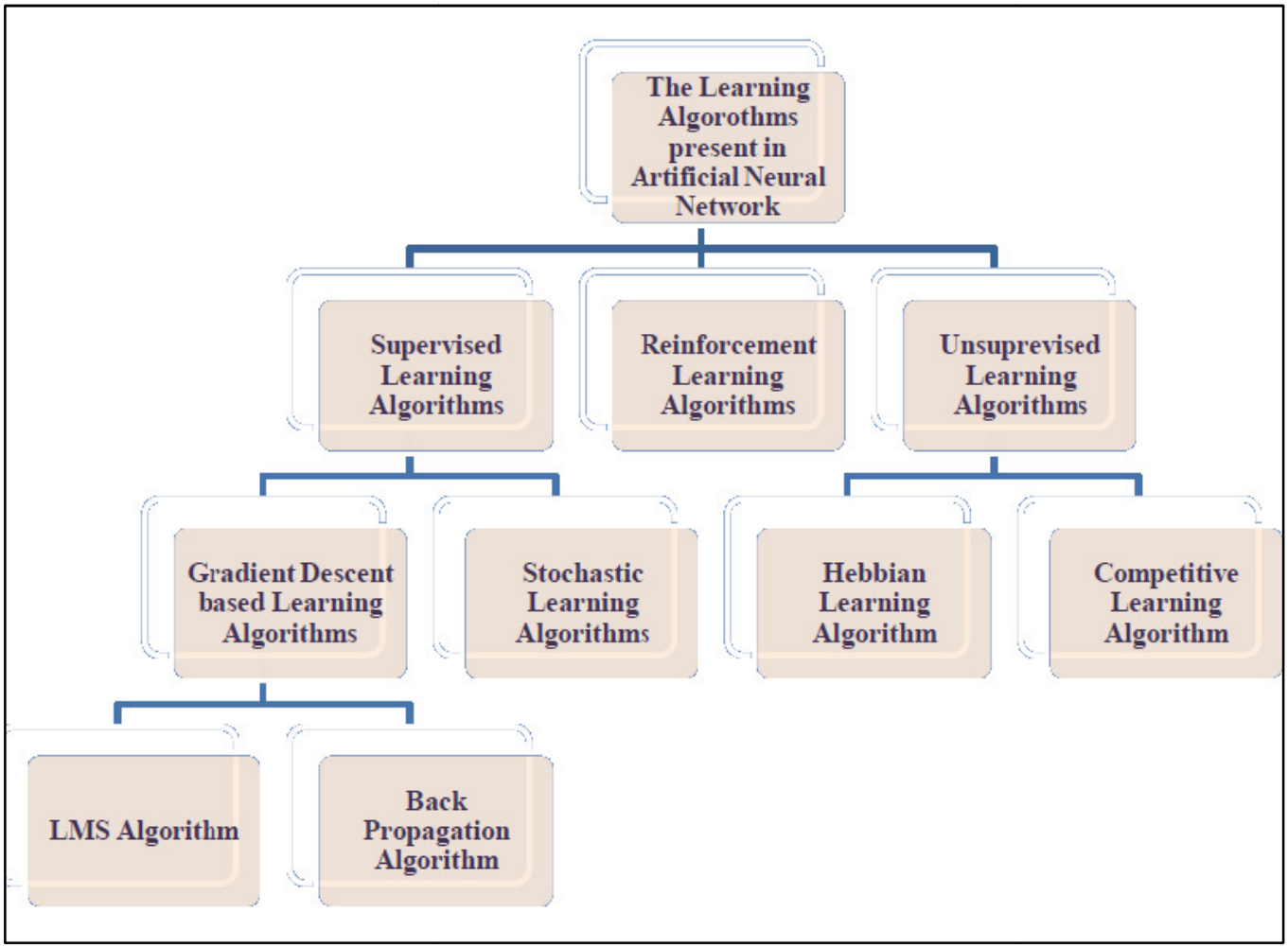

Figure-2
Classification Diagram of the Learning Algorithms used for ANN

Signal Flow Graph: The signal flow graph representing the block diagram representation of neuron was proposed by Mason along with some set of rules for linear networks. Since, the ANN exhibits non linear characteristics therefore the utility of signal flow graph in the representation of ANN has a limited scope. A signal flow graph is generally a network of directed links categorized into synaptic and activation (branches) that which are interconnected at certain points called nodes.

Architectural Graph: In Architectural graph in the structure the neurons are represented by circles and the lines joining the circles represent the corresponding synaptic weights.

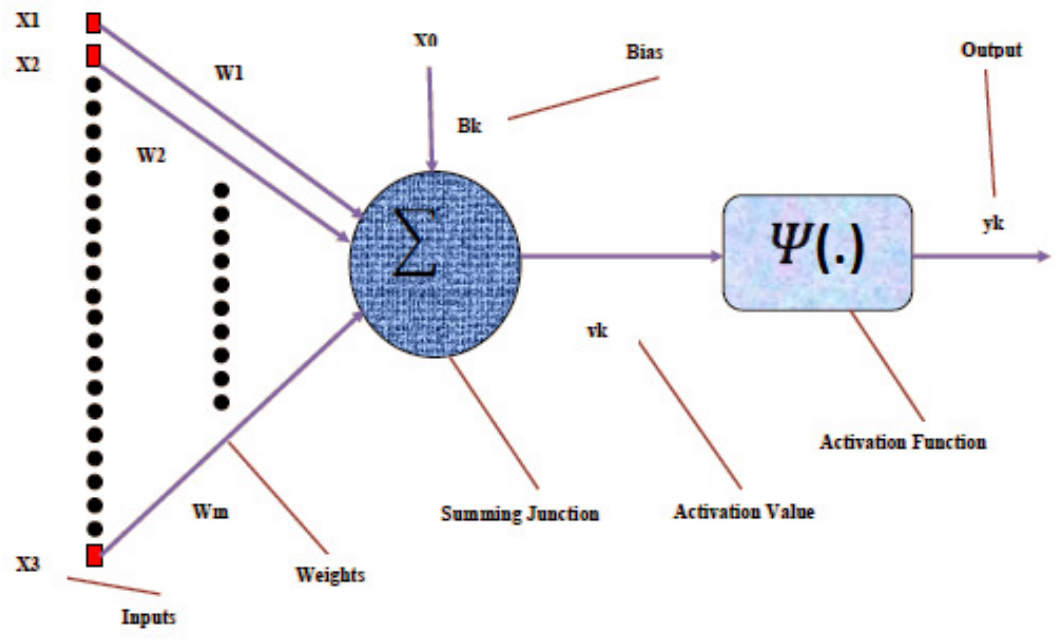

Figure-3
Block Diagram Representation of Artificial Neuron in Artificial Neural Network.

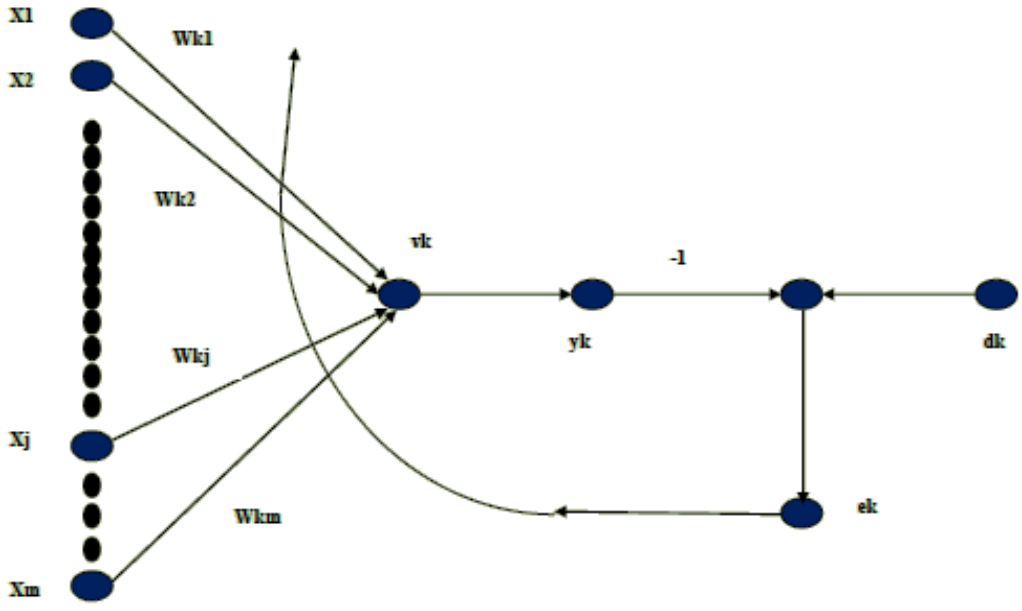

Figure-4
Signal Flow Graph Diagram Representation of Artificial Neuron in Artificial Neural Network.

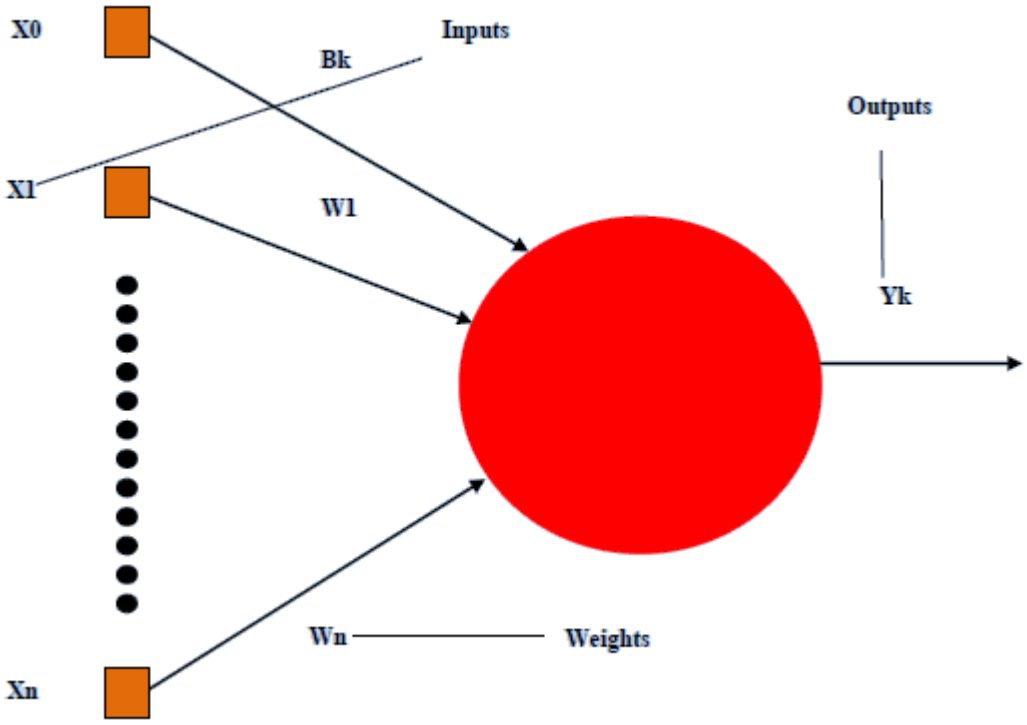

Figure-5
Architectural Graph Diagram Representation of Artificial Neuron in Artificial Neural Network

Literature Survey

In 2007 Havatiet. al. made a study about Artificial Neural Network based on MLP where it was trained and tested using ten years meteorological data[2]. In 1976 Grossberg and in 2005 Bevilacquaproposed systems which help meteorologist to predict the future weather easily and accurately[3,4]. In the year2009 Radhika and Shashi proposed an application of Support Vector Machines (SVMs) for weather prediction is presented. Time series data of daily maximum temperature at a location is studied to predict the maximum temperature of the next day at that location based on the daily maximum temperatures for a span of previous n days referred to as order of the input. Performance of the system is observed for various spans of 2 to 10 days by using optimal values of the Kernal[5]. In the year 2008 the authors Gowriet. al. presented that each propagation is followed immediately by a weight update in online learning[6]. In the book Artificial Neural Network written by B. Yegna Narayana several models of Neuron are shown[7]. In the Book Neural Networks : A Comprehensive Foundation Simon Haykin gave brief introduction to several Learning methodologies and XOR problem solution using Multilayer perceptron is given[8]. In the year 2012 Das and Sreedhar gave a discussion on network architectures namely Single Layer and Multilayer[9]. In the book Artificial Intelligence written by Rich and Knight Hopfield Network is described utilizing which Travelling Salesman problem can be solved[10]. The solution is given in brief in the book written by Yegna Narayana[8]. The Author Vaibhav Kant Singh made use of concepts of Neural Networks presented in the books written by Yegna Narayana, Rich and Knight and Haykin in the compilation of the current work[7,8,10]. During the couple of years i.e. 2015 and 2016 the author Vaibhav Kant Singh the author of the current paper proposed solution to the XOR problem using MLP[11-14]. In Feb. 2016 the author Vaibhav Kant Singh proposed a novel solution for Ex-NOR problem[15].

Mathematical Solution to Logic Gates using ANN

In this section we will see converged values of weights. The free parameter values prescribed will satisfy all possible inputs for the respective GATE. In Figure-6 W1 and W2 represents synaptic weights, Bk represent Bias weight, vk represents activation value, yk represents output, A and B represent input and symbol φ(.) represent activation function. In the figure xi represents ith input. Here there are two values for x i.e. A and B. From the Artificial Neural Network framework of Figure- 6 we are able to analyze that there are four parameters which are required for generating output yk i.e. A, B, W1 and W2.

$$vk=(\sum xi.wi+Bk)=uk+Bk \quad (1)$$

Where, $uk=\sum xi.wi$

AND GATE Construction using ANN: From Table-4 and Figure-6 taking the values of W1=W2=1 and Bk=0. Also taking threshold function as activation function where the threshold value is set at a value of 2. We will see the ANN that is going to mimic the AND GATE. The mathematical proof is shown in this section. We know that for threshold function.

$$yk = \begin{cases} 1 \; if \; vk \geq threshold \\ 0 \; if \; vk < threshold \end{cases} \quad (2)$$

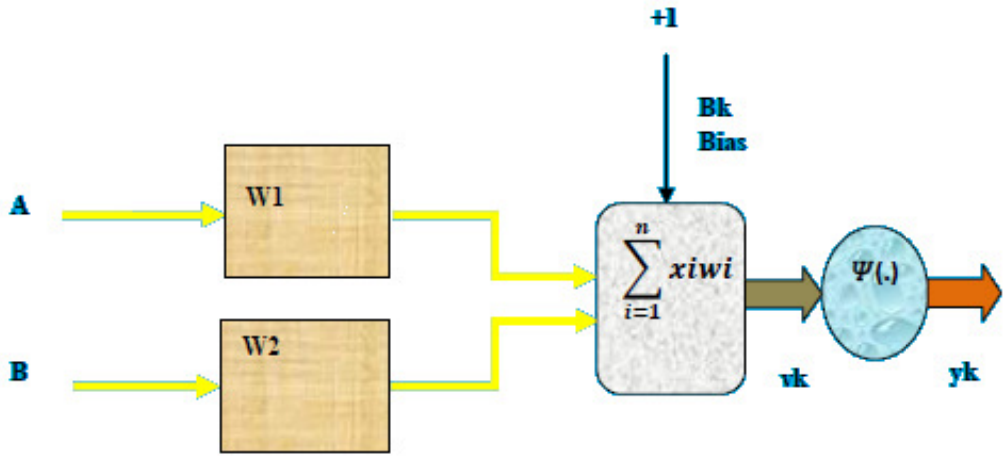

Figure-6
Block Diagram Representation of Artificial Neuron in Artificial Neural Network for Solution of AND, OR, NAND and NOR LOGIC Gates

Table-4
Representing Output for the Applicable Inputs on the basis of Logic for the various LOGIC GATES

Input		**Output for the Logic GATE**			
A	B	AND $y = A.B$	OR $y = A + B$	NAND $y = \overline{A.B}$	NOR $y = \overline{A + B}$
0	0	0	0	1	0
1	0	0	1	1	0
0	1	0	1	1	0
1	1	1	1	0	1

Table-5
Representing proof of construction of ann behaving like an and gate. Equation (AA) and equation (TT) are refereed while making evaluation

CASE:1 When , A=0, B=0, W1=1, W2=1 Since vk=∑xi.wi=AW1+BW2 =0X1+0X1=0, Since 0<2 therefore Ψ(vk)=yk=0. Therefore, yk=0	**CASE:2** When , A=0, B=1, W1=1, W2=1 Since vk=∑xi.wi=AW1+BW2 =0X1+1X1=1. Since 1<2 therefore Ψ(vk)=yk=0. Therefore, yk=0
CASE:3 When , A=1, B=0, W1=1, W2=1 Since vk=∑xi.wi=AW1+BW2 =1X1+0X1=1. Since 1<2 Therefore Ψ(vk)=yk=0	**CASE:4** When , A=1, B=1, W1=1, W2=1 Since vk=∑xi.wi=AW1+BW2 =1X1+1X1=2, Since 2=2 therefore Ψ(vk)=yk=1

The outputs obtained in the four cases of above Table-5 satisfies the Logic of AND GATE of Table 4.

OR GATE Construction using ANN: From Table-4 and Figure-6 taking the values of W1=W2=1 and Bk=0. Also taking threshold function as activation function where the threshold value is set at a value of 1. We will see the ANN that is going to mimic the AND GATE. The mathematical proof is shown in this section. We know that for threshold function.

The outputs obtained in the four cases of above Table-6 satisfies the Logic of OR GATE of Table-4.

NAND GATE Construction using ANN: From Table-4 and Figure-6 taking the values of W1=W2= -1 and Bk=0. Also taking threshold function as activation function where the threshold value is set at a value of -1. We will see the ANN that is going to mimic the AND GATE. The mathematical proof is shown in this section. We know that for threshold function.

The outputs obtained in the four cases of above Table-7 satisfies the Logic of NAND GATE of Table-4.

NOR GATE Construction using ANN: From Table-4 and Figure-6 taking the values of W1=W2= -1 and Bk=0. Also taking threshold function as activation function where the threshold value is set at a value of 0. We will see the ANN that is going to mimic the AND GATE. The mathematical proof is shown in this section. We know that for threshold function.

Table- 6
Representing proof of construction of ann behaving like an or gate. Equation (1) and equation (2) are refereed while making evaluation

CASE:1 When , A=0, B=0, W1=1, W2=1 Since vk=∑xi.wi=AW1+BW2 =0X1+0X1=0, Since 0<1 therefore Ψ(vk)=yk=0. Therefore, yk=0	**CASE:2** When , A=0, B=1, W1=1, W2=1 Since vk=∑xi.wi=AW1+BW2 =0X1+1X1=1. Since 1=1 therefore Ψ(vk)=yk=1. Therefore, yk=1
CASE:3 When , A=1, B=0, W1=1, W2=1 Since vk=∑xi.wi=AW1+BW2 =1X1+0X1=1. Since 1=1 Therefore Ψ(vk)=yk=1	**CASE:4** When , A=1, B=1, W1=1, W2=1 Since vk=∑xi.wi=AW1+BW2 =1X1+1X1=2, Since 2>1 therefore Ψ(vk)=yk=1

Table-7
Representing proof of construction of ann behaving like an nand gate. Equation (1) and equation (2) are refereed while making evaluation

CASE:1 When , A=0, B=0, W1=1, W2=1 Since vk=∑xi.wi=AW1+BW2 =0X1+0X1=0, Since 0>-1 therefore Ψ(vk)=yk=1. Therefore, yk=1	**CASE:2** When , A=0, B=1, W1=1, W2=1 Since vk=∑xi.wi=AW1+BW2 =0X-1+1X-1=-1. Since -1=-1 therefore Ψ(vk)=yk=1. Therefore, yk=1
CASE:3 When , A=1, B=0, W1=1, W2=1 Since vk=∑xi.wi=AW1+BW2 =1X-1+0X-1=1. Since -1=-1 Therefore Ψ(vk)=yk=1	**CASE:4** When , A=1, B=1, W1=1, W2=1 Since vk=∑xi.wi=AW1+BW2 =1X-1+1X-1=-2, Since -2<-1therefore Ψ(vk)=yk=0

Table-8
Representing proof of construction of ann behaving like an nor gate. Equation (1) and equation (2) are refereed while making evaluation

CASE:1 When , A=0, B=0, W1=1, W2=1 Since vk=∑xi.wi=AW1+BW2 =0X1+0X1=0, Since 0=0 therefore Ψ(vk)=yk=1. Therefore, yk=1	**CASE:2** When , A=0, B=1, W1=1, W2=1 Since vk=∑xi.wi=AW1+BW2 =0X-1+1X-1=-1. Since -1<0 therefore Ψ(vk)=yk=0. Therefore, yk=0
CASE:3 When , A=1, B=0, W1=1, W2=1 Since vk=∑xi.wi=AW1+BW2 =1X-1+0X-1=-1. Since -1<0 Therefore Ψ(vk)=yk=0	**CASE:4** When , A=1, B=1, W1=1, W2=1 Since vk=∑xi.wi=AW1+BW2 =1X-1+1X-1=-2, Since -2<0therefore Ψ(vk)=yk=0

The outputs obtained in the four cases of above Table-8 satisfies the Logic of NOR GATE of Table-4.

NOT GATE Construction using ANN: From Figure-7 and Table-9 it is clear that there is one Input i.e. A. One synaptic weight is present i.e. W1 and Bias weight Bk is present, yk represents the output and φ represents the activation function. For the ANN prescribed in Figure-6 when the value of W1 is taken as -1 and activation function φ is taken as threshold function where threshold is taken as 0. The following Table-10 represents the solution for NOT GATE. The two cases prescribed in Table-10 mimic the working of NOT GATE simulated by means of ANN framework.

The outputs obtained in the two cases of above Table-10 satisfies the Logic of NOT GATE of Table-9

Proposed Solution to Ex-Nor Problem

In the proposed solution a MLFFN is proposed which comprises of three layers. The First layer comprises of two neurons. The second layer comprises of one neuron. The third layer comprises of one neuron. All the three layers comprises of Linear Threshold Units. The naming of the network could be (2-2-1-1). The solution proposed specifies the final values for weights acquired after training the network. After attaining the values prescribed in the solution the proposed ANN gives the desired values for output for the applicable input to the Ex-NOR logic GATE. In this section we will see the mathematical proof of the provided solution. Figure-8 represents the proposed Architectural Graph for the problem, whereas the Figure-9 represents the Signal Flow Graph giving the detail of the weights and other parameters involved in the ANN. In the Architectural graph all the neurons represent LTU (Linear threshold Unit).

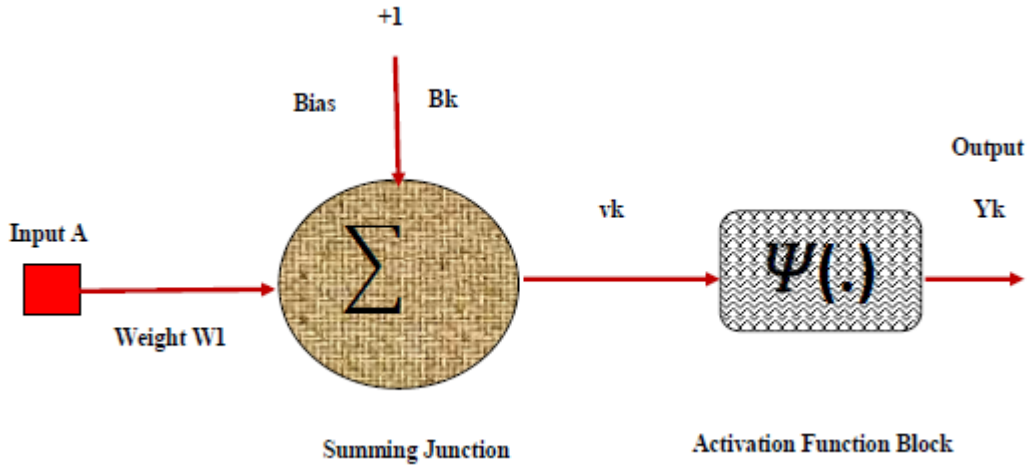

Figure-7
Block Diagram Representation of Artificial Neuron in Artificial Neural Network for Solution of NOT LOGIC GATE

Table-9
Representing Output for the Applicable Inputs on the basis of Logic for the NOT LOGIC GATES

Truth Table for Not Gate	
A	$y = \bar{A}$
0	1
1	0

Table-10
Representing proof of construction of ann behaving like an not gate. Equation (1) and equation (2) are refereed while making evaluation

CASE 1:	**CASE 2:**
When , A=0, W1=-1 Since vk=∑xi.wi=AXW1=0X-1=0 Since 0=0 therefore Ψ(vk)=yk=1 Therefore, yk=1 when A=0	When , A=1,W1=-1 Since vk=∑xi.wi=AXW1=1X-1=-1 Since -1<0 therefore Ψ(vk)=yk=0 Therefore, yk=0 when A=1

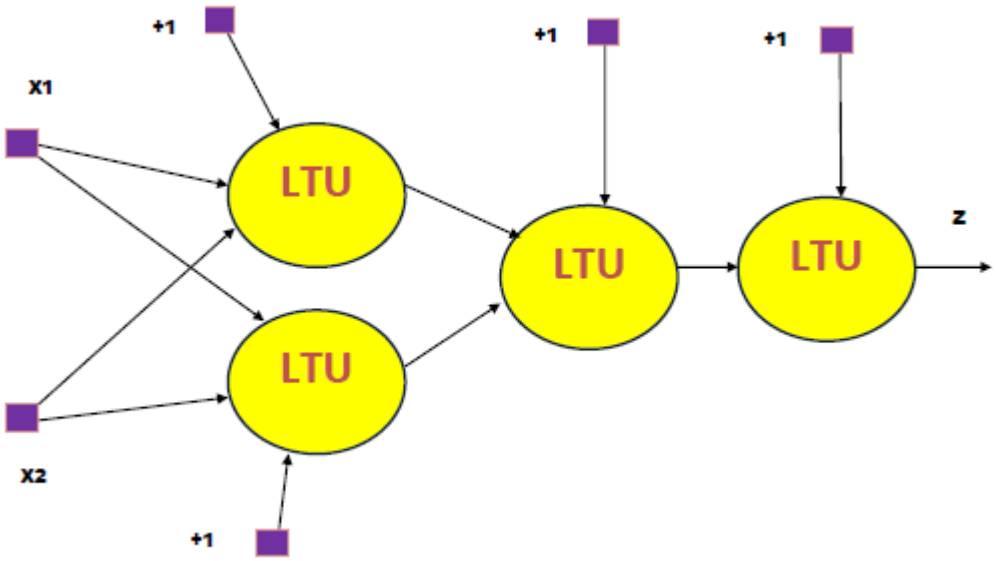

Figure-8
Architectural Graph Representation of Artificial Neural Network for Solution of Ex-NOR LOGIC GATE

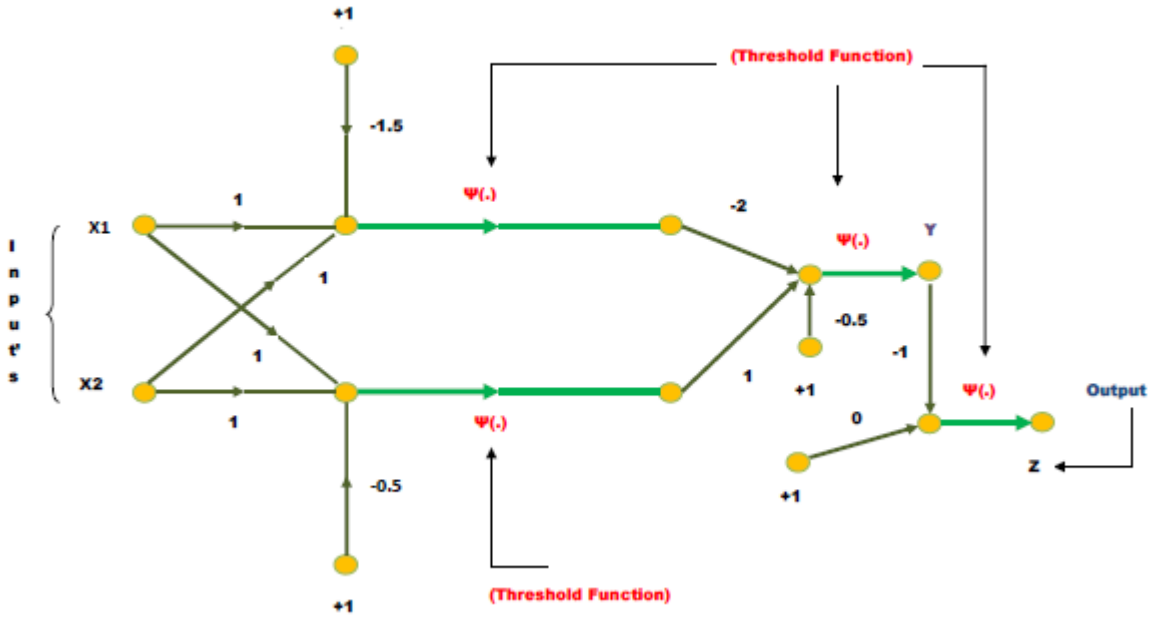

Figure-9
Signal Flow Graph Representation of Artificial Neural Network for Solution of Ex-NOR LOGIC GATE

Taking the value of threshold as "0" in the Function definition of Threshold function of Equation (2). The Signal flow graph of Figure-9 provides the desired solution for the Ex-NOR problem. An Extension of the solution proposed in this section is also given by the author Vaibhav Kant Singh in his paper[15].

Limitations: The major limitation of the above proposed system is the lack of learning algorithm. The proposed model uses the basic ANN framework to solve the problem of construction of Logic Gates using ANN. The model uses fixed values to cope up with the problem.

Conclusion

The paper concludes that it is possible to construct AND, OR, NAND, NOR and NOT GATES using the basic Artificial

Neural Network model. The proposed model work well for all the possible values on Input depending upon the GATE. Also the proposed solution of Figure-9 satisfies the solution to the Ex-NOR problem using LTU in multiple layer.

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