



Artificial Neural Network and Its Islamic Relevance

Saadi Ahmad Kamaruddin* and Ibrahim Shogar
Department of Theoretical and Computational Sciences
Kulliyah of Science, International Islamic University Malaysia (IIUM)

Abstract

This paper begins with an introduction to neural networks and presents some mathematical models and their applications on complex systems, especially in learning processes. The paper introduces simple mathematical models which relate aspects of artificial neural network ANN to human information processing. The role of these models on learning process and their relevance to the Islamic worldview are investigated. The complex workings and wonders of the human brain have become mysterious since time immemorial. Human brain is a thinking organ that learns and grows by interacting with the world through perception and action; and it is able to continually adapt and rewire itself. Only recently scientists have been able to learn how the neural network of the brain forms. (ANN) is a mathematical model or computational model that inspired by the structure and functional aspects of biological neural networks. As a final verdict, the complex structure of ANN which resembles the ordinary human brain mechanism may help for better understanding of the creative Power and lead to the enhancement of our faith in God as the Mighty Creator. The method used was analytical outlook to comprehend ANN in an Islamic approach.

Keywords: Complex systems, artificial neural network, brain mechanism, Islamic world view

Abstrak

Kerencaman dan ajaibnya otak manusia telah menjadi misteri sejak dulu lagi. Otak manusia ialah organ berfikir yang belajar dan berkembang secara berinteraksi dengan dunia melalui persepsi dan tindakan. Organ ini dapat terus mengadaptasi dan melakukan 'pendawaian' sendiri. Sejak akhir-akhir ini, saintis telah mengetahui bagaimana rangkaian neuron otak terbentuk. Rangkaian Neuron Tiruan (RNT) ialah model matematik atau perkomputeran yang diilhamkan daripada struktur dan aspek berfungsi rangkaian neuron biologi. Sebagai keputusan muktamad, struktur RNT yang kompleks dan menyerupai mekanisme otak manusia mungkin dapat membantu kita lebih memahami kuasa mencipta dan menguatkan keimanan kepada Tuhan yang Maha Pencipta. Objektif kertas ini adalah untuk menghubungkan-kaitkan RNT dengan pandangan hidup Islam dan relevannya dengan pembelajaran dan pendidikan. Kaedah yang digunakan ialah tinjauan analitikal untuk memahami RNT melalui pendekatan Islam.

Kata kunci: Sistem kompleks, rangkaian neuron tiruan, mekanisme otak, pandangan hidup Islam

Introduction

The study of complex systems in the natural phenomenon is generating tension of the scientists and engineers of modern world. Inspired by Divine

originated mechanisms in nature, and guided by biological dynamics of living organisms, the modern scientists have shown keen interest to investigate the complex systems in the created world. Nature has been an inspiring source to mankind at every age; nonetheless, God has revealed in the Scriptures that He has created the world in precise measures (Qur'an: 13:8, 25:2, 36:38, 54:49). The entire universe is functioning in accordance to fixed orders and specific systems. Life of plants and animals begins from a single cell of great complexity. Studies on systems

**Corresponding author: Saadi Ahmad Kamaruddin
Department of Theoretical and Computational Sciences,
Kulliyah of Science, International Islamic University
Malaysia (IIUM), Jalan Istana, Bandar Indera Mahkota,
Kuantan 25200, Pahang, Malaysia
E-mail: saadiahmad@iium.edu.my*

originated by Divine Power, such as human neural networks, structure of proteins, Ribonucleic acid (RNA) and Deoxyribonucleic acid (DNA), as well as other types of biological molecules have guided human intellect to develop new technologies and solve complex problems. Several branches of science, such as Genetic Engineering (GN) and Artificial Neural Networks (ANN), have been inspired by complex systems of the natural phenomenon. Various features of human information-processing, including the learning of associations, pattern recognition, creativity, and consciousness have been discussed within the context of neural network models. Even human civilizations have been investigated as complex phenomena by modern scientists (David, 2008).

The insights gained from natural phenomenon have inspired human to develop new devices and new methods for resolving the complex problems. There are considerable efforts which demonstrate the interconnection between the biological brain and mathematical models of neural networks. Those efforts are essential to bridge the gap between the biological and mathematical models of neural networks. And for practical objectives, various fields are related to human information processing neural networks, such as mathematics, psychology, and cognitive education. ANN has assisted to ease many difficulties in the process of learning and attaining new knowledge. Brain-imaging technology has brought the field of neuroscience into the study of teaching and learning. Imaging technologies have allowed scientists to determine which areas of the brain are active when the mind is engaged in mathematics. This technology has given researchers and educators a new piece of the learning puzzle. It is now possible to compare learning theories in mathematics to neurological analyses of how the brain physically functions while it is doing mathematics¹.

This research paper focuses on Artificial Neural Networks (ANN), which is an information processing paradigm which inspired by the way biological nervous systems work. The key element of this paradigm is the structure of the information processing system (Yaneer, 2003). ANN is a mathematical model that motivated by the structure and functional aspects of biological neural networks of human brain. Neural Networks take a different approach to the problem solving than that of conventional computers. The later uses an algorithmic

approach, i.e. the conventional computer follows a set of instructions in order to solve a problem. Unless the specific steps that the computer needs to follow are known the computer cannot solve the problem. This method restricts the problem solving capability of conventional computers to problems that we already understand and know how to solve. But computers would be more useful if they could do things that we don't exactly know how to do it. Neural networks process information in a similar way the human brain works. The neural network is composed of a large number of highly interconnected processing elements known as neurons, working in parallel to solve specific problems. Neural networks learn by example; they cannot be programmed to perform a specific task therefore its operation can be unpredictable (Yaneer, 2003).

This paper begins with an introduction to neural networks and presents some mathematical models and their applications on various fields of complex systems, especially in learning processes. The paper introduces simple mathematical models which relate aspects of ANN to human information processing. The role of these models on learning process and their relevance to the Islamic worldview are investigated.

Overview of Neural Network in Biological Neurons

Work on artificial neural networks, commonly referred to as neural networks, has been motivated right from its inception by the recognition that the brain computes in an entirely different way from the conventional digital computer. The struggle to understand the brain owes much to the pioneering work of Ramón y Cajál (1911), who introduced the idea of neurons as structural constituents of the brain. A developing neuron is synonymous with a plastic brain: Plasticity permits the developing nervous system to adapt to its surrounding environment. In an adult brain, plasticity may be accounted for by two mechanisms: the creation of new synaptic connections between neurons, and the modification of existing synapses.

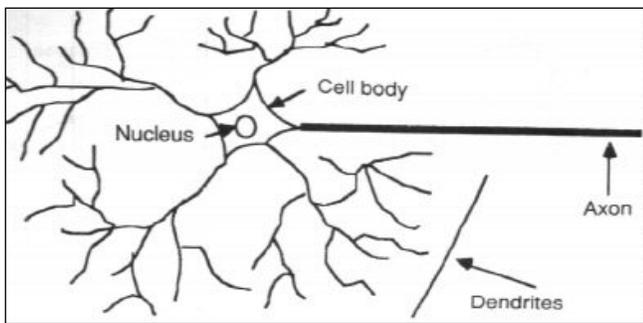


Figure 1.1: Biological neuron
(Source from <http://www.doc.ic.ac.uk>)

Axons act as transmission lines, and dendrites represent receptive zones. Neurons come in a wide variety of shapes and sizes in different parts of the brain. A pyramidal cell can receive 10,000 or more synaptic contacts and it can project onto thousands of target cells.

Just as plasticity appears to be essential to the functioning of neurons as information processing units in the human brain, so it is with neural networks made up of artificial neurons. In its most general form, a neural network 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 using electronic components or simulated in software on a digital computer. Our interest will be confined largely to neural networks that perform useful computations through a process of learning. To achieve good performance, neural networks employ a massive interconnection of simple computing cells referred to as neurons or processing units. We may thus offer the following definition of a neural network viewed as an adaptive machine.

Neural network resembles biological neurons

A neural network is a massively parallel distributed processor that has a natural propensity for storing experiential knowledge and making it available for use. It resembles the brain in two respects:

- i. Knowledge is acquired by the network through the learning process.
- ii. Interneuron connection strengths, known as synaptic weights, are used to store the knowledge.

The procedure used to perform the learning process is called a learning algorithm. Neural networks are also referred to as neurocomputers, connectionist

networks, and parallel distributed processors. To recap, the artificial neural network based techniques are an information processing model derived from functioning of human brain. This is a simple information processing device that accepts many inputs, combines them, and produces an output. The basic element of a neural network is a neuron. The output of one neuron becomes input to other neurons. A neural network is a structure of many such neurons connected in a systematic way.

Application of Neural Network Method in Various Fields

Neural network have been utilized in various fields, due to its flexible characteristics and broad adaptability. The list of neural network applications, the money that has been invested in neural network software and hardware, and the depth and breadth of interest in these devices have been growing rapidly (Demuth and Beale, 2001). Widrow *et. al*(1994) argue that ANN has contributed tremendously in the statistical field. Most ANN applications fall into the following three categories:

- i. Pattern classification,
- ii. Prediction and financial analysis, and
- iii. Control and Optimization.

Neural network applications had been widely used on business, aerospace, automotive, banking, credit card activity checking, defense, electronics, entertainment, financial, industrial, insurance, manufacturing, medical, robotics, speech, securities, telecommunications and transportation systems (Demuth and Beale, 2001).

Telecommunication

One of the most profound uses of neural network is in the field of signal processing, particularly in noise suppression over the telephone line. The neural net commonly employed in such application as a form of adaptive linear neuron (ADALINE). The need for adaptive echo cancellers has become more pressing with the development of transcontinental satellite links for long distance telephone circuits Fausett(1994). The noise suppression or noise cancellation idea is simple. At the end of the telecommunication line, the incoming signal is transmitted through both the telephone system component, called the hybrid, and the adaptive filter (the ADALINE neural net). The difference between the two received signals is the error, and is used to minimize the output's noise. Through continuous application, the ADALINE can be trained to remove

the noise (echo) from the hybrid's output signal effectively (Nguyen & Windrow, 1989).

Transportation

Another use of the neural network which is gaining attention is backing up a trailer, usually to accomplish tasks such as loading and unloading goods and entering a loading bay. For example, a neural network can be trained to provide automatic steering control to a truck attempting to back up into a loading dock (Nguyen and Windrow, 1989; Miller, 1990). Several general information such as the location of the loading dock, position of the cab, position of the truck, position of the rear face of the truck and the angles of coincidence between the truck and the dock. With these information, the neural network is able to learn how to steer the truck into accurate position for docking, in any situation where a solution is possible. The neural controller, with practice, is able to learn and improves its accuracy in providing steering signals which direct the truck to the dock, regardless of its initial position (Demuth and Beale, 2001).

Recognition System

Another field which had previous application using neural network is in recognition system, particularly in the automatic recognition of handwritten characters (alphanumeric characters). The large variation in variables such as font sizes, positions, character styles, and handwriting consistency make this certain application a difficult problem for traditional techniques. General-purpose multilayer neural nets, such as the backpropagation net (a multilayer net trained by backpropagation) have been used for recognizing handwritten zip codes (LeCun *et al.*, 1990). According to LeCun *et al.* (1990), even though the application was made based on a strict coding arrangements, it is possible to customize the arrangements itself to improve the application's accuracy and performance. The backpropagation net consists of several hidden layers, but the pattern of connections from one layer to another is quite localized.

Medicine

One of many examples of the application of neural networks to medicine was developed by Anderson in the mid-1980s (Anderson *et al.*, 1988; Anderson *et al.*, 1988). The main application of the neural network is basically to provide a disease recognition and suggestion database based on the symptoms and

diagnosis made. The idea behind this application is to train an autoassociative memory neural network to store a large number of medical records, each of which includes information on symptoms, diagnosis, and treatment for a particular case. After training, the net can be presented with input consisting of a set of symptoms; it will then find the full stored pattern that represents the 'best' diagnosis and treatment. This particular application improves with repeated use.

Finance

In the past few years, many researchers have used Artificial Neural Networks (ANNs) to analyze traditional classification and prediction problems in accounting and finance. Sotiris *et al.* (2006) explored the efficacy of ANNs in detecting firms with fraudulent financial statements (FFS) and in predicting corporate bankruptcy. Until today, two experiments have been done using representative ANNs algorithms. For the first experiment, the algorithms were trained by using a set 164 fraud and non-fraud data of selected Greek based financial firms in the period of 2001-2002. As for the second experiment, ANNs algorithms were trained using a set of 150 failed and solvent Greek firms from the period of 2003 to 2004. The two experiments reported that the ANNs is able to predict bankruptcies and documents forgery with satisfying accuracy. Kramer (1997) concluded that ANNs can be successfully utilized in insurance field to determine financial aspects of the company.

Business

Neural network are being applied in a number of business settings (Harston, 1990). For instance, neural network have been used in mortgage assessment work by Nestor, Inc. (Collins *et al.*, 1988a ; Collins *et al.*, 1988b). There is also credit card fraud detection reportedly being used by Eurocard Nederland, Mellon Bank, and First USA Bank (Bylinsky, 1993). Commercial artificial neural network applications also can be clearly seen in Foreign exchange trading systems: Citibank London (Penrose, 1993; Colin, 1991; Colin, 1992).

Military and Defense Systems

Detection of bombs in suitcases using a neural network approach called Thermal Neutron Analysis (TNA) developed by Science Applications International Corporation (SAIC) has been reported by (Nelson *et al.*, 1991; Johnson, 1989; Doherty, 1989;

Schwartz,1989). Recently, Saadi (2011) has developed a systematic firearm identification system using backpropagation neural network based whole firing pin impression image. He found that a two-layer 6-7-5 connections backpropagation neural network (BPNN) of sigmoid/linear transfer functions with ‘trainlm’ algorithm was found to yield the best classification result using cross-validation, where 96% of the images were correctly classified according to the pistols used, under very small mean-square error (MSE=0.01) of the trained network.

Basic Structure of a Neural Network

There are usually many inputs. These inputs are commonly called input neurons. There are only hypothetical neurons that produce an output equal to their supposed input. No processing is required by an input neuron. Similar to inputs, there are also one or more output neurons, typically very few. The basic structure of a NN can be understood clearly through the example as depicted in Figure 2.

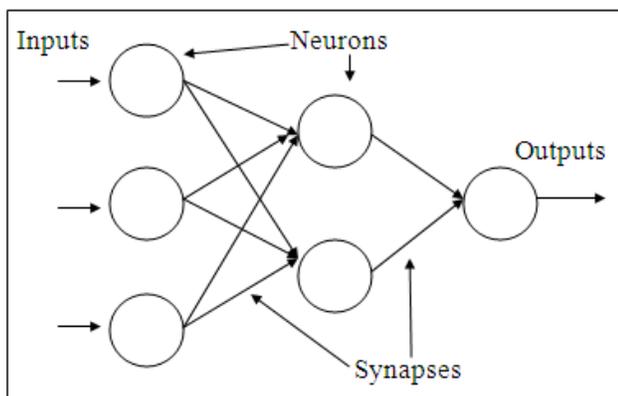


Figure 2: Basic structure of a neural network

Multi-Layer Perceptrons Network

Multi-layer perceptrons (MLP) are feedforward networks with one or more hidden layers. The neural network employed in this study possessed a three-layer learning (Figure 3). Detailed information about MLPs can be found in the literature(Eberhart & Dobbins,1990).

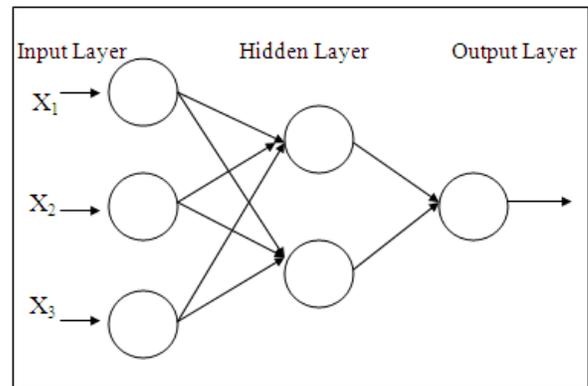


Figure 3: The structure of the artificial neural networks

Given a training set of input–output data, the most common learning rule for multilayer perceptrons is the backpropagation algorithm (BPA). Backpropagation involves two phases: a feedforward phase in which the external input information at the input nodes is propagated forward to compute the output information signal at the output unit, and a backward phase in which modifications to the connection strengths are made based on the differences between the computed and observed information signals at the output units(Eberhart and Dobbins,1990).

MLP models have their statistical equivalent models which are the followings:

- i. A MLP with one output is a simple nonlinear regression(Sarle,1994).
- ii. A MLP with a moderate number of hidden neurons is essentially the same as a projection pursuit regression, except that an MLP uses a predetermined transfer function while the projection pursuit regression model uses a flexible nonlinear smoother or transfer function(Sarle,1994).
- iii. A MLP becomes a nonparametric sieve if the number of hidden neurons is allowed to increase with the sample size(White,1989). This makes it a useful alternative to methods such as kernel regression(Hardle,1990) and smoothing splines.

Feed forward Neural Network

The most common neural network is the feedforward neural network, where information processing moves only in forward direction as shown in Figure 4.

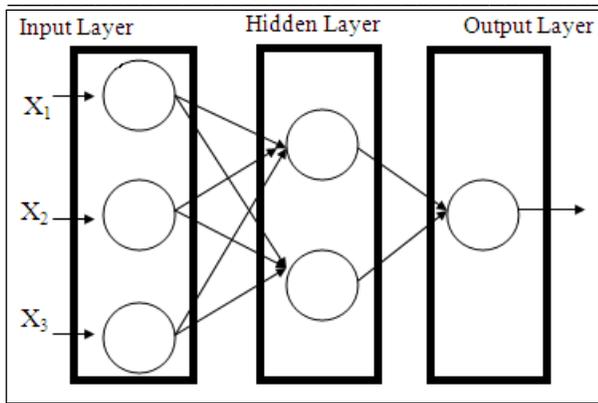


Figure 4: Feedforward neural network

The neurons in the network are arranged in layers. Typically, there is one layer for input neurons (the input layer), one or more layers of internal processing units (the hidden layers), and one layer for output neurons (the output layer). Each layer is either partly or fully interconnected to the preceding layer and the following layer. The connections between neurons have weights associated with them, which determine the strength of influence of a neuron to other neurons. Information flows from the input layer through the hidden processing layer(s) to the final output layer to generate predictions. The connection weights are determined by a training process, wherein known input and known output data is fed to the network. The network adjusts connected weights so that a relationship between inputs and outputs can be established with certain degree of accuracy.

Inputs

The input layer of an ANN typically functions as a buffer for the inputs, transferring the data to the next layer. Preprocessing the inputs may be required as ANNs deal only with numeric data. This may involve scaling the input data and converting or encoding the input data to a numerical form that can be used by the ANN. For example, in an ANN real estate price simulator application described in a paper by Haynes and Tan(1993), some qualitative data pertaining to the availability of certain features of a residential property used a binary representation. For example, features like the availability of a swimming pool, a granny flat and a waterfront location, were represented with a binary value of ‘1’, indicating the availability of the feature, or ‘0’ if it was not. Similarly, a character or an image to be presented to

an ANN can be converted into binary values of zeroes and ones.

The input layer to the neural network is the medium through which the inputs are presented to the neural network. When a set of input is presented to the input layer of the neural network, the inputs are processed and resultant information is passed to the subsequent layer(s). Every input neuron should represent some known variable that has an influence over the output of the neural network. As final output will depend on inputs introduced to the network, the quality and relevance inputs are very important.

Outputs

The output layer of an ANN functions in a similar fashion to the input layer except that it transfers the information from the network to the outside world. Post-processing of the output data is often required to convert the information to a comprehensible and usable form outside the network. The post-processing may be as simple as just a scaling of the outputs ranging to more elaborate processing as in hybrid systems. The output of the network can be determined as;

$$Y_k = F \sum_{i=1}^n Z_i W_{ik} \quad (1)$$

Where F is the output function, Z_i is the output of hidden layer and W_{ik} is the connection strength between neurons of hidden and output layer. For hidden layer’s processing unit output;

$$Z_i = F \sum_{j=1}^n V_{ij} X_j \quad (2)$$

Where X_j is the output of input layer and V_{ij} is the weight between input and hidden layer.

Transfer (Activation) Functions

The transfer or activation function is a function that determines the output from a summation of the weighted inputs of a neuron. The transfer functions for neurons in the hidden layer are often nonlinear and they provide the nonlinearities for the network. Graphically, the transfer function is as in Figure 5.

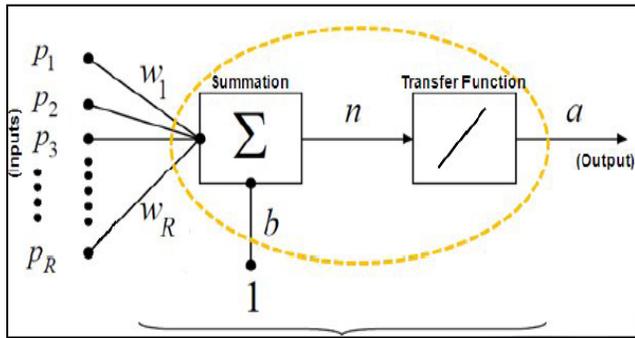


Figure 5: Transfer Function
Source from Masters, T. (1993)

A transfer function maps any real numbers into a domain normally bounded by 0 to 1 or -1 to 1. Bounded activation functions are often called squashing functions(Haynes & Tan,1993). The most common transfer functions used in current ANN models are the sigmoid (S-shaped) and linear (purelin) functions as in Figure 6 and 7 respectively. However, the most versatile transfer functions used in

current ANN models are the tangent sigmoidal functions as in Figure 8. Masters(1993) loosely defined a sigmoid function as a ‘continuous, real-valued function whose domain is the reals, whose derivative is always positive, and whose range is bounded’.

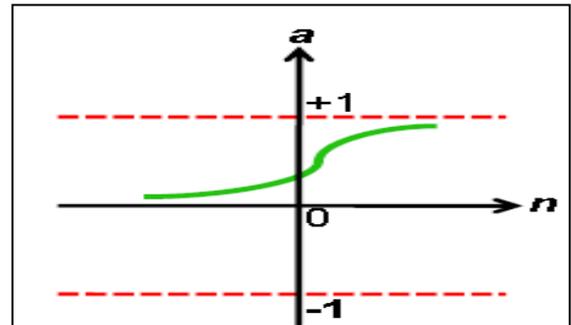


Figure 6: Log-Sigmoid

$$\log sig(n) = \frac{1}{1 + e^{-n}} \quad (3)$$

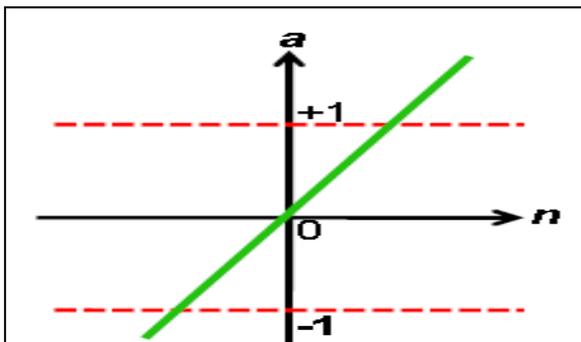


Figure 7: Linear
 $purelin(n) = n \quad (4)$

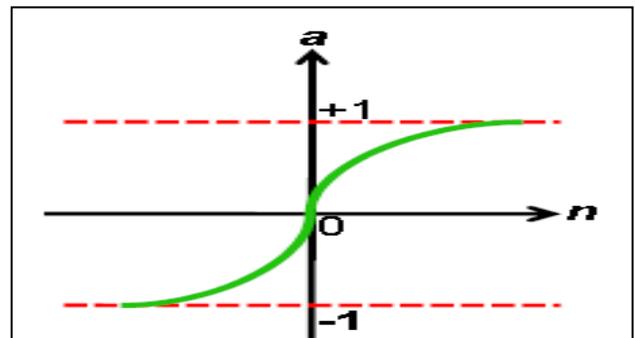


Figure 8: Tangent-Sigmoid
 $\tan sig(n) = \frac{2}{(1 + e^{-2n}) - 1} \quad (5)$

Supervised and Unsupervised Training Models

In this study, the data of interest were devoted to supervised training models. In this context, the sample selected from the training class is called as training set. Supervised training model is more preferable by the users since the number of sample, input and output are already known before the learning process start. From a theoretical point of

view, supervised and unsupervised learning differ only in the causal structure of the model. In supervised learning, the model defines the effect one set of observations, called inputs, has on another set of observations, called outputs. In other words, the inputs are assumed to be at the beginning and outputs at the end of the causal chain. The models can include mediating variables between the inputs and outputs.

Furthermore, supervised or associative learning was the main concern in this paper, in which the network was trained by providing it with input and matching output patterns (Figure 9). These input-output pairs can be provided by an external teacher, or by the system which contains the neural network (self-supervised). Tasks that fall within the paradigm of supervised learning include pattern recognition (classification) and regression (function approximation).

Neural Networks and Its Islamic Relevance

The holy Qur'an declares that, everything in this world is created in precise measure and in a perfect manner. The Qur'an states;

“He Who has created everything in the best possible manner; then He commenced the creation of mankind from clay; then He produced human progeny from an extract fluid of water; then He perfected him and breathed His Spirit into him; then He provide you the faculties of hearing, sight, and intellects (hearts), so that you can appreciate your Lord; but only few can do so”

[The Qur'an. 32:7-9]

These Qur'anic verses are constructing the epistemological foundations of the Islamic worldview.

The exploration in the created world, nature and human self, is a crucial method for developing and enhancing of faith in God. Study of complex systems in the natural phenomena, such as human neural network, is no doubt a major approach to the discovery and appreciation of creative power of Divinity. The faculty of knowledge, or '*Fuad*' in Qur'anic terminology, plays a crucial role in the process of learning (Qur'an.16:78, 23:78, 32:9, 67:23). It is only by reason and intellect mankind can recognize the Creator and make distinction between the Creative Power and His creatures. The holy Qur'an clearly distinguishes between human brain as a complex system and human intellect as faculty of knowledge used for thinking and learning. It is the later type which gives humans their distinguishing character and makes them capable for morality and responsibility (Qur'an. 2:31). The holy Qur'an considers using of intellect, assisted by the sensory

perceptions, is a basic form of religious practice '*Ibadah*'. In other words, thinking and learning are the crucial objectives of human life in relation to the Creator and creatures. Therefore, it might be asserted that, study of neural networks is part of this general scheme of Divine plan that aims to appreciate the Creator through the study of complex system in His created world. In this context, all mathematical models of neural networks presented above are seen essential to address the technical part of the process of learning and appreciation of God that assigned by the Divine plan.

The focus point of Qur'anic view on human brain as a faculty of knowledge is that it must be fully utilized for thinking and learning process. To perform the task of *Khilafah*, human must use his learning capabilities to investigate in the created world to increase his awareness on the Creator and appreciate His bounties. The Qur'an asserts that the most fearful among the creatures of God are those who have knowledge (Qur'an. 35:28). About those who willingly reject to attain knowledge by neglecting to use their faculties of knowledge the Qur'an says:

“Certainly, We have created for Hell many of the Jinn and mankind; those who have faculties of knowledge (Qulub) but they never use it for learning, and they have sights but they never use it to see, and they have faculties of hearing but they never use it to hear; those people are just like livestock, rather, they are worse”

[The Qur'an.7:179]

The human brain, according to the modern science, is considered as responsible for sensory processing, motor control, language, common sense, logic, creativity, planning, and self-awareness. The major elements which believed to be responsible for brain function are the nerve cells, or neurons, and their interactions². Among the objectives of the study of neural networks is to develop the basis for understanding the sensory processing, motor control, memory and higher information-processing functions of the brain. Mapping of brain function has identified sensory, or motor related aspects of the brain: visual processing centers, auditory processing centers, the motor cortex, as well as aspects of language processing that may be counted among

the higher information-processing functions(Christos, & Dimitrios, 1996). The

following Figure 9 shows the process of learning and appreciation resembles to NN

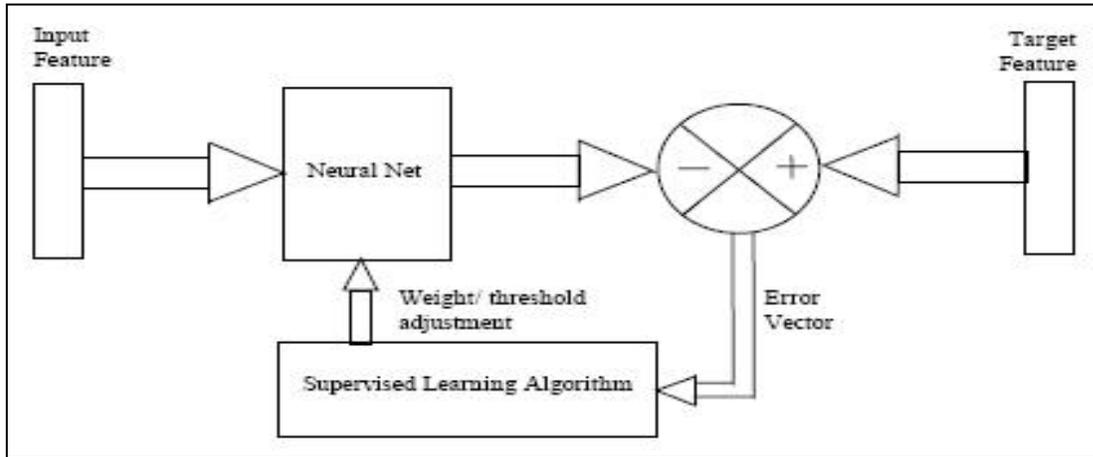


Figure 9: Flowchart of firing input to output process prior to supervised learning
 Source from <http://www.learnartificialneuralnetworks.com/>

The Process of learning and appreciation of the Creator

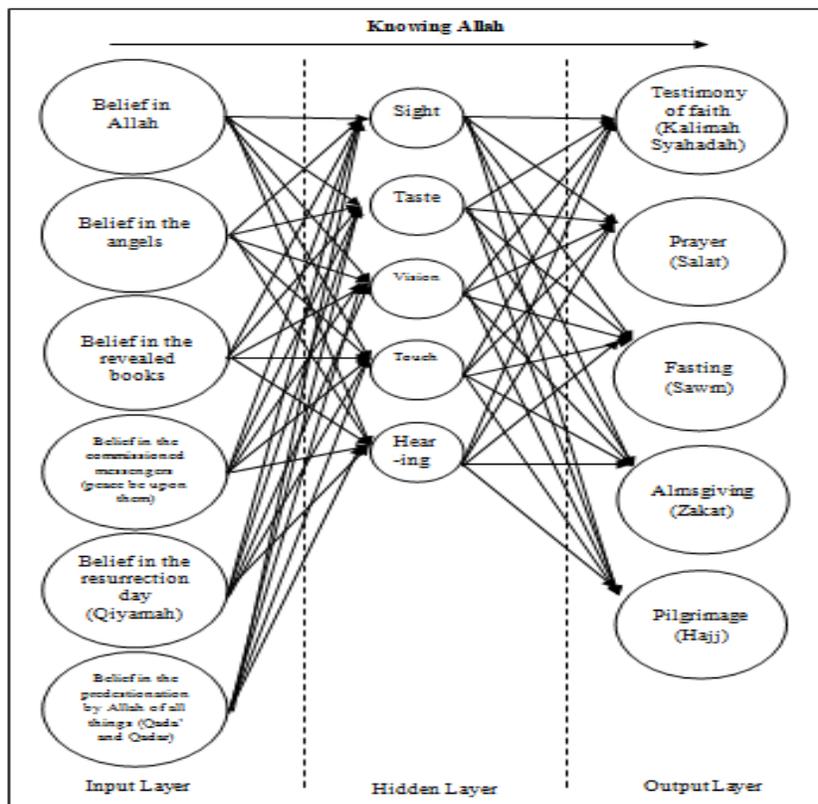


Figure 10: shows the process of learning and appreciation resembles to NN

Conclusion

The general conclusion is that, artificial neural network analysis as a form of modeling can assist to resolve many difficulties in the process of learning and provides better solutions into our complex problems. The basic advantage of ANN is its capability to be used as mechanism for learning an observed data. ANN can perform complex tasks which too hard to be noticed by either humans or other computer techniques³. The effective role of ANN models on learning process and their relevance to the Islamic worldview is obvious. The remarkable ability of ANN to derive meaning from complicated and imprecise data can be used to extract patterns and detect trends to promote knowledge of both; the Creator and the created world. Christos and Dimitrios, have summed up the advantages of ANN modeling as follows:

1. Adaptive learning: An ability to learn how to do tasks based on the data given for training or initial experience.
2. Self-Organization: An ANN can create its own organization or representation of the information it receives during learning time.
3. Real Time Operation: ANN computations may be carried out in parallel, and special hardware devices are being designed and manufactured which take advantage of this capability.
4. Fault Tolerance via Redundant Information Coding: Partial destruction of a network leads to the corresponding degradation of performance. However, some network capabilities may be retained even with major network damage[37].

The process of thinking and learning, according to the Islamic worldview, has no limits. It is a continuous task from the cradle to the grave.

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Article history

Received: 07/11/2011

Accepted: 28/12/2011
