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IMPLEMENTATION OF ARTIFICIAL NEURAL NETWORK

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Abstract: - This paper presents an emergence of an Artificial Neural Network (ANN) as a tool for analysis of different parameters of a system. An Artificial Neural Network (ANN) is an information-processing paradigm that is inspired by the way biological nervous systems such as brain, process information. ANN consists of multiple layers of simple processing elements called as neurons. The neuron performs two functions, namely, collection of inputs & generation of an output. Use of ANN provides overview of the theory, learning rules, and applications of the most important neural network models, definitions and style of Computation. The mathematical model of network throws the light on the concept of inputs, weights, summing function, activation function & outputs. Then ANN helps to decide the type of learning for adjustment of weights with change in parameters. Finally the analysis of a system is completed by ANN implementation & ANN training & prediction quality.

Keywords: Biological Inspiration, ANN Methodology, ANN Implementation and Prediction.

I. INTRODUCTION

Many tasks involving intelligence or pattern recognition are extremely difficult to automate, but appear to be performed very easily by humans. For instance, humans recognize various objects and make sense out of the large amount of visual information in their surroundings, apparently requiring very little effort. It stands to reason that computing systems that attempt similar tasks will profit enormously from understanding how humans perform these tasks, and simulating these processes to the extent allowed by physical limitations. This necessitates the study and simulation of Neural Networks. The neural network of an human is part of its nervous system, containing a large number of interconnected neurons (nerve cells). “Neural” is an adjective for neuron, and “Network” denotes a graph like structure. Artificial Neural Network refers to computing systems whose central theme is borrowed from the analogy of biological neural networks. Artificial Neural Networks are also referred to as “Neural Nets”, artificial neural systems “parallel distributed processing systems” and “connectionist systems”. For a computing system to be called by these pretty names, it is necessary for the system to have a labeled directed graph structure

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where nodes perform some simple computations. From elementary graph theory we recall that a "Directed Graph" consists of a set of "Nodes" (vertices) and a set of "Connections" (edges/links/arcs) connecting pairs of nodes. In a neural network, each node performs some simple computations, and each connection conveys a signal from one node to another, labeled by a number called the "Connection Strength" or "Weight" indicating the extent to which a signal is amplified or diminished by connection. This system is the alternative for human expertise and knowledge. Artificial Neural Networks are modeled closely following the brain and therefore a great deal of terminology is borrowed from neuroscience.

II. LITERATURE REVIEW

A.O. Kurban investigated an artificial neural network are non-linear mapping systems with a structure loosely based on principles observed in the biological nervous systems. In greatly simplified terms from, a typical real neuron has a branching dentritic tree that collects signals from many other neurons in a limited area; a cell body that integrates collected signals and generates a response signal (as well as manages metabolic functions); and along branching axon that distributes the response through contacts with dentritic trees of many other neurons. The response of each neuron is a relatively simple non-linear function of its inputs and is largely determined by the strengths of the connections from its inputs. In spite of the relative simplicity of the individual units, systems containing many neurons can generate complex and intersecting behaviors. In general terms, a NN consists of large number of simple processors linked by weighted connections. By analogy, the processing nodes may be called "neurons". Each node output depends only on the information that is locally available at the node, either stored internally or arriving via the weighted connections. Each unit receives inputs from many other nodes and transmits its output to other nodes. By itself, a single processing element is not very powerful; it generates a scalar output with a single numerical value, which is a simple non-linear function of its inputs. The power of the system emerges from the combination of many units in an appropriate way. A network is utilized different function by varying the connection topology and the values of the connecting weights. Complex functions can be implemented by connecting the units together with appropriate weights. It has been shown that a sufficiently large network with an appropriate structure and property chosen weights can approximate with arbitrary accuracy any function satisfying certain broad constraints. [1] This model is a drastically simplified approximation of real nervous systems. The intent is to capture the major characteristics important in the information processing functions of real networks without varying too much about the physical constraints imposed by biology. Artificial NN are made up of simple, highly interconnected processing units called neurons, each of which performs two functions, namely, aggregation of its inputs from other neurons

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or the external environment and generation of an output from the aggregated inputs. Through this simple structure, neural networks have been shown to be able to approximate most continuous functions to any degree of accuracy, by choice of an appropriatenumber of neuron units (Kurban and Yildirim, 2003; Yildirim and Uzmay, 2003). [2]

III. BIOLOGICAL INSPIRATION

Human brain is made up of a network of neurons that are coupled with receptors and effectors. Receptors are called “dendrites” and effectors are called “axons”.[3] Fig. 1 shows that the dendrites collects the signals from many other neurons in a limited area; a cell body or soma that integrates collected signals & generates a response signal & along branching axon that distributes the response through contacts with dendrite trees of many other neurons. [4]

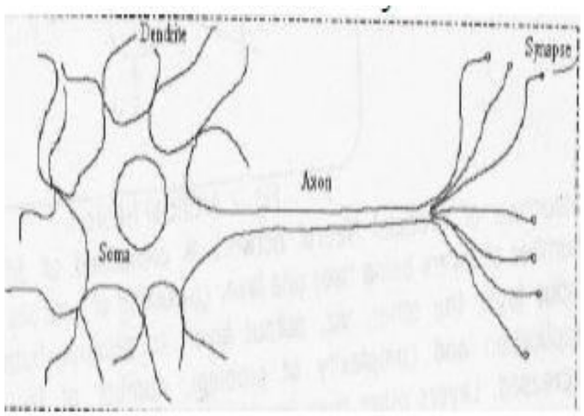

Fig. 1 Biological Neuron

IV. ANN METHODOLOGY

ANNs are basically massive parallel computational models that imitate the function of human brain. An ANN consists of large number of simple processors linked by weighted connections. By analogy, the processing nodes may be called “neurons”. Each node output depends only on the information that is locally available at the node, either stored internally or arriving via the weighted connections. Each unit receives inputs from many other nodes transmits its output to yet another nodes. By itself, a single processing element is not very powerful; it generates a scalar output with single numerical value, which is a simple non-linear function of its inputs. The power of the system emerges from the combination of many units in an appropriate way. [1] The ANN does not really solve the problem in a strictly mathematical sense, but it demonstrates information processing characteristics that give an approximate solution to a given problem. The ANNs have been widely used in complex non linear function mapping, image processing, pattern recognition & classification & so on. Feed-forward networks are common type of neural networks. A feed forward network comprises an input layer, where the inputs of the problem are received, hidden layers, where the relationship between the inputs & outputs are determined & represented by synaptic weights, & an output layer which emits the outputs of the problem. The neural feed forward network is modeled with three basic elements: a) A set of synapses characterized by synaptic weights, b) An adder or linear combiner for summing the input signals. c) An activation function for limiting the amplitude of the output of neuron to some finite value. The input of the activation function can be increased by using a bias term. Here, we have made use of a certain ANN architecture known as the multi-layer-feed-forward neural network or Multi Layer Perceptron (MLP)[5] .

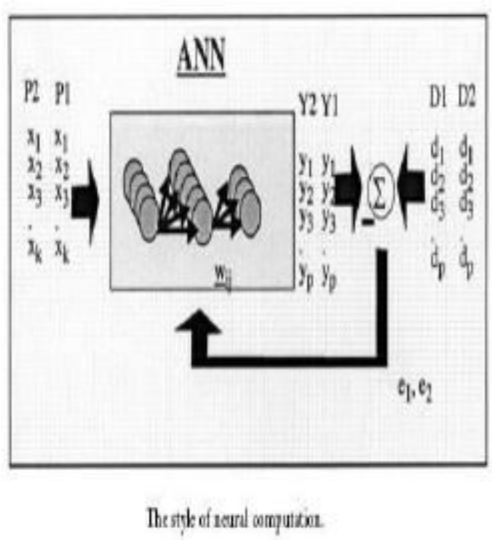

Fig.2 Style of Neural Computation

artificial neural networks, the designer chooses the network topology, the performance function, the learning rule, and the criterion to stop the training phase, but the system automatically adjusts the parameters. So, it is difficult to bring a priori information into the design, and when the system does not work properly it is also hard to incrementally refine the solution. But ANN-based solutions are extremely efficient in terms of development time and resources, and in many difficult problems artificial neural networks provide performance that is difficult to match with other technologies. Denker 10 years ago said that "artificial neural networks are the second best way to implement a solution" motivated by the simplicity of their design and because of their universality, only shadowed by the traditional design obtained by studying the physics of the problem. At present, artificial neural networks are emerging as the technology of choice for many applications, such as pattern recognition, prediction, system identification, and control.[6]

Table 1. Terminology of Neuron

Biological Terminology	ANN Terminology
Neuron	Node/Unit/Cell/Neurode
Synapse	Connection/Edge/Link
Synaptic Efficiency	Connection Strength/Weight
Firing Frequency	Node Output

A. Mathematical Model When creating a functional model of the biological neuron, there are three basic components of importance. First, the synapses of the neuron are modeled as weights. The strength of the connection between an input and a neuron is noted by the value of the weight. Negative weight values reflect inhibitory connections, while positive values designate excitatory connections [Haykin]. The next two components model the actual activity within the neuron cell. An adder sums up all the inputs modified by their respective weights. This activity is referred to as linear combination. Finally, an activation function controls the amplitude of the output of the neuron. An acceptable range of output is usually between 0 and 1, or -1 and 1. Mathematically, this process is described in the figure,

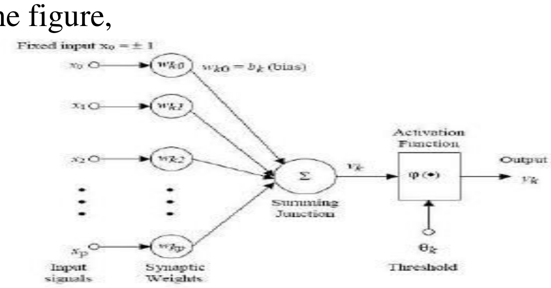

Fig. 3 Mathematical Model

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From this model the interval activity of the neuron can be shown to be,

$$v_k = \sum_{j=1}^{p} w_{kj} x_j \tag{1}$$

The output of the neuron, Yk, would therefore be the outcome of some activation function on the value of Vk. [7] ***B. Feed Forward Networks***

This is a subclass of acrylic networks in which a connection is allowed from a node in layer i only to nodes in layer i+1 as shown in Fig.4. These networks are succinctly described by a sequence of numbers indicating the number of nodes in each layer. For instance, the network shown in Fig. 4 is a 3-2-3-2 feed forward network; it contains three nodes in the input layer (layer 0), two nodes in the first hidden layer (layer 1), three nodes in the second hidden layer (layer 2), and two nodes in the output layer (layer 3). These networks, generally with no more than four such layers, are among the most common neural nets in use, so much so that some users identify the phrase "neural networks" to mean only feed forward networks. Conceptually, nodes in successively higher layers abstract successively higher level features from preceding layers. In the literature on neural networks, the term "feed forward" has been used sometimes to refer to layered or acrylic networks. [8]

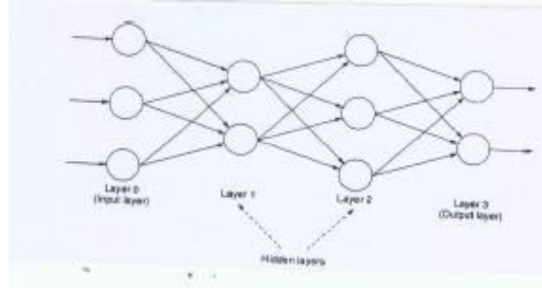

Fig. 4 Feed Forward Networks

C. Neural Learning

It is reasonable to conjecture that neurons in an animal's brain are "hard wired." It is equally obvious that animals, especially the higher order animals, learn as they grow. How does this learning occur? What are possible mathematical models of learning? In this section, we summarize some of the basic theories of biological learning and their adaptations for artificial neural networks. In artificial neural networks, learning refers to the method of modifying the weights of connections between the nodes of a specified network. Learning is the process by which the random-valued parameters (Weights and bias) of a neural network are adapted through a continuous process of simulation by the environment in which network is embedded. Learning rate is defined as the rate at which network gets adapted. Type of learning is determined by the manner in which parameter change takes place. Learning may be categorized as supervised learning, unsupervised learning and reinforced learning. In Supervised learning, a teacher is available to indicate whether a system is performing correctly, or to indicate a desired response, or to validate the acceptability of a system's responses, or

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to indicate the amount of error in system performance. This is in contrast with unsupervised learning, where no teacher is available and learning must rely on guidance obtained heuristically by the system examining different sample data or the environment. Learning is similar to training i.e. one has to learn something which is analogous to one has to be trained. A neural network has to be configured such that the application of a set of inputs produces (either 'direct' or via a relaxation process) the desired set of outputs. Various methods to set the strengths of the connections exist. One way is to set the weights explicitly, using a priori knowledge. Another way is to 'train' the neural network by feeding it teaching patterns and letting it change its weights according to some learning rule. We can categorize the learning situations in two distinct sorts. These are

1. Supervised Learning Supervised learning or Associative learning in which the network is trained by providing it with input and matching output patterns. These input-output pairs can be provided by an external teacher, or by the system which contains the neural network (self-supervised). Example: An archaeologist discovers a human skeleton and has to determine whether it belonged to man or woman. In doing this, the archaeologist is guided by many past examples of male and female skeletons. Examination of these past examples (called the training set) allows the archaeologist to learn about the distinctions between male and female skeletons. This learning process is an example of supervised learning, and the result of learning process can be applied to determine whether the newly discovered skeleton belongs to man or woman.

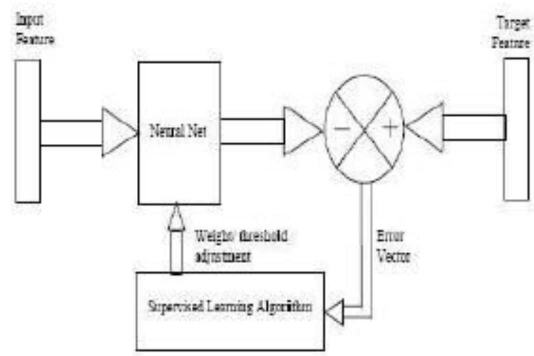

Fig. 5 Supervised Learning

2 .Unsupervised Learning Unsupervised learning or Self-organization in which an (output) unit is trained to respond to clusters of pattern within the input. In this paradigm the system is supposed to discover statistically salient features of the input population. Unlike the supervised learning paradigm, there is no a priori set of categories into which the patterns are to be classified; rather the system must develop its own representation of the input stimuli. Example: In a different situation, the archaeologist has to determine whether a set of skeleton fragments belong to the same dinosaur species or need to be differentiated into different species. For this task, no previous data may be available to clearly identify the species for each skeleton fragment. The archaeologist has to determine whether the skeletons (that can be reconstructed from the fragments) are sufficiently similar to belong to the same species, or if the differences between these skeletons are large enough to warrant grouping them into different species. This is an unsupervised learning process, which involves estimating the magnitudes of differences between the skeletons. One archaeologist may believe the skeletons belong to different species, while another may disagree, and there is no absolute criterion to determine who is correct.

3 .Reinforced Learning Reinforcement Learning is type of learning may be considered as an intermediate form of the above two types of learning. Here the learning machine does some action on the environment and gets a feedback response from the environment. The learning system grades its action good (rewarding) or bad (punishable) based on the environmental response and accordingly adjusts its parameters. Generally, parameter adjustment is continued until an equilibrium state occurs, following which there will be no more changes in its parameters. The self organizing neural learning may be categorized under this type of learning. [7]

D. Back Propagation Network The back propagation algorithm (Rumelhart and McClelland, 1986) is used in layered feed-forward ANNs. This means that the artificial neurons are organized in layers, and send their signals "forward", and then the errors are propagated backwards. The network receives inputs by neurons in the *input layer*, and the output of the network is given by the neurons on an *output layer*. There may be one or more intermediate *hidden layers*. The back propagation algorithm uses supervised learning, which means that we provide the algorithm with examples of the inputs and outputs we want the network to compute, and then the error (difference between actual and expected results) is calculated. The idea of the back propagation algorithm is to reduce this error, until the ANN *learns* the training data. The training begins with random weights, and the goal is to adjust them so that the error will be minimal. [9] Back propagation network has gained importance due to the shortcomings of other available networks. The network is a multi layer network (multi layer perception) that contains at least one hidden layer in addition to input and output layers. Number of hidden layers & numbers of neurons in each hidden layer is to be fixed based on application, the complexity of the problem and the number of inputs and outputs. Use of non-linear log-sigmoid transfer function enables the network to simulate non-linearity in practical systems. Due to this numerous advantages, back propagation network is chosen for present work. [3] Implementation of back propagation model consists of two phases. First phase is known as training while the second phase is called Testing. Training, in back propagation is based on gradient decent rule that tends to adjust weights and reduce system error in the network. Input layer has neurons equal in number to that of the inputs. Similarly, output layer neurons are same in the number as number of outputs. Number of hidden layer neurons is deciding by trial and error method using the experimental data. [10]

E.ANN Development & Implementation In this work, both ANN implementation & training is developed, using the neural network toolbox of Mat Lab. Different ANNs are build rather than using one large ANN including all the output variables. This strategy allowed for better adjustment of the ANN for each specific problem, including the optimization of the architecture for each output.

F. ANN Training & Prediction quality One of the most relevant aspects of a neural network is its ability to generalize, that is, to predict cases that are not included in the training set. One of the problems that occur during neural network training is called over fitting. The error on the training set is driven to a very small value, but when new data is presented to the network, the error is large. The network has memorized the training examples, but it has not learned to generalize to new situations. One method for improving network generalization is to use a network that is just large enough to provide an adequate fit. The larger network you use the more complex functions the network can create. There are two other methods for improving generalization that are implemented in Mat Lab Neural Network Toolbox software: regularization & early stopping. The typical performance function used for training feed forward neural networks is the mean sum of squares of the network errors,

$$mse = \frac{1}{N}\sum_{i=1}^{N}(e_i)^2 = \frac{1}{N}\sum_{i=1}^{N}\left(X_{real}(i) - X_{predicted}(i)\right)^2 \quad (2)$$

It is possible to improve generalization, if you modify the performance function by adding a term that consists of the mean of the sum of the squares of the network weights & biases,

$$msereg = \lambda mse + (1-\lambda) msw, \quad (3)$$

Where λ is the performance ratio, &

$$msw = \frac{1}{N}\sum_{j=1}^{N} w_j^2 . \quad (4)$$

Using this performance function causes the network to have smaller weights & biases, & this force the network response to be smoother & less likely to over fit. Once the different stages of the training process & the ANN structure had been determined, & before the optimization procedure is developed, it is important to estimate the ANN prediction qualities. There is excellent agreement of predicted values & expected values. This close agreement shows that the ANN can be used in the data analysis, of theoretical work to generate the missing data in the theoretical program. The results of model ANN are compared with the hydrodynamic simulation data. [6]

V. ANN FOR HYDRODYNAMIC JOURNAL BEARING

The Artificial Neural Network can be used for prediction of pressure distribution in hydrodynamic journal bearing which can be further used for stability analysis of hydrodynamic journal bearing. [11].

VI. CONCLUSION

As the ANN is an emerging technology it can be used for data analysis in applications such as pattern recognition, prediction, system identification & control. From above theories it can be seen that ANN is a radial basis function back propagation network. The network is capable of predicting the parameters by experimental system. The network has parallel structure and fast learning capacity. The collected experimental data such as speed, load, & values of pressure distribution etc. are also employed as training and testing data for an artificial neural network. The neural network is a feed forward three layered network. Quick propagation algorithm is used to update the weight of the network during the training. The ANN has a superior performance to follow the desired results of the system and is employed to analyze such systems parameters in practical applications.

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