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Basic Study of Neural Networks

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Abstract: ***Human's central nervous system inspired the concept of neural networks. In an Artificial Neural Network, simple artificial nodes, known as "neurons", "neurodes", "processing elements" or "units", are connected together to form a network which are similar to a biological neural network. There is no single formal definition of what is an artificial neural network. Neural networks consist of sets of adaptive weights, i.e. numerical parameters that are tuned by a learning algorithm, and are capable of approximating non-linear functions of their inputs. In modern software implementations of artificial neural networks, the approach inspired by biology has been largely abandoned for a more practical approach based on statistics and signal processing. Here we also discuss about advantages, limitations and applications of neural networks.***

Keywords: Neuron, Nodes, Network, ANN, Adaptive.

1. Introduction

Neural networks are simplified model of the biological nervous system and therefore have drawn their motivation form the kind of computing performed by a human brain. The simplest definition of a neural network, more properly referred to as an 'artificial' neural network (ANN), is provided by the inventor of one of the first neuro computers, Dr. Robert Hecht-Nielsen. He defines a neural network as:

"...a computing system made up of a number of simple, highly interconnected processing elements, which process information by their dynamic state response to external inputs.

An artificial neural network, in general is highly interconnected network of large number of processing elements called neurons in an architecture inspired by a brain. An NN (Neural Network) can be massively parallel and therefore is said to exhibit Parallel Distributed processing (PDP).

1.1 Characteristics

The features of biological neural networks that make it superior to even most sophisticated AI computer systems are:

- **Flexibility**: Network automatically adjusts to a new environment without using an pre-programmed environment.
- **Robustness:** The decay of the nerve cells does not seem to affect the performance significance of the system.
- Fault tolerance
- **High speed**: As in a neural network there are many interconnected links and obvious speed of the neural network is very fast as compared to any other network.

Apart from this a neural network has capability to deal with a variety of data situations like Fuzzy, Noisy, Probalistic, Inconsistent type of data.

Some other properties of the neural network are:

- Mapping capabilities
- Pattern association
- Generalization

2. The Basics of Neural Networks

Neural networks are typically organized in layers. Layers are made up of a number of interconnected 'nodes' which contain an 'activation function'. Patterns are presented to the network via the 'input layer', which communicates to one or more 'hidden layers' where the actual processing is done via a system of weighted 'connections'. The hidden layers then link to an 'output layer' where the answer is output as shown in the graphic below.

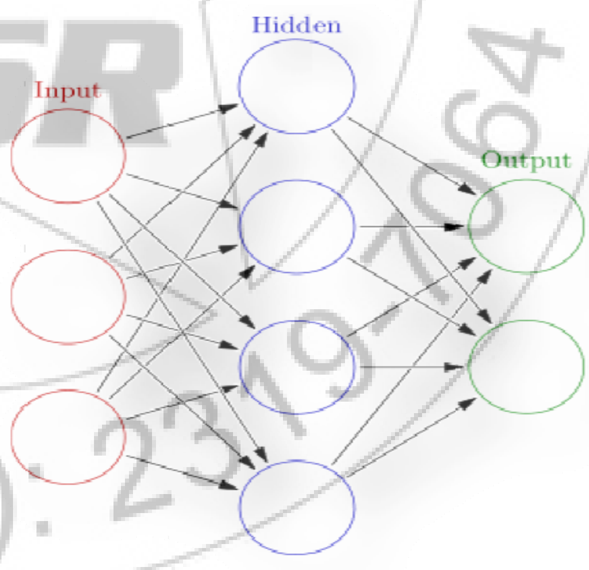

Figure: Neural network

Most ANNs contain some form of 'learning rule' which modifies the weights of the connections according to the input patterns that it is presented with. Although there are many different kinds of learning rules used by neural networks, this demonstration is concerned only with one; the delta rule. The delta rule is often utilized by the most common class of ANNs called 'back propagational neural networks' (BPNNs). Back propagation is an abbreviation for the backwards propagation of error.

With the delta rule, as with other types of back propagation, 'learning' is a supervised process that occurs with each cycle or 'epoch' (i.e. each time the network is presented with a new input pattern) through a forward activation flow of outputs, and the backwards error propagation of weight adjustments. More simply, when a neural network is initially presented with a pattern it makes a random 'guess' as to what it might be. It then sees how far its answer was from the actual one and makes an appropriate adjustment to its connection weights.

2.1 Artificial neural networks

One type of network sees the nodes as ‘artificial neurons’. These are called artificial neural networks (ANNs). An artificial neuron is a computational model inspired in the natural neurons. Natural neurons receive signals through *synapses* located on the dendrites or membrane of the neuron. When the signals received are strong enough (surpass a certain *threshold*), the neuron is *activated* and emits a signal though the *axon*. This signal might be sent to another synapse, and might activate other neurons.

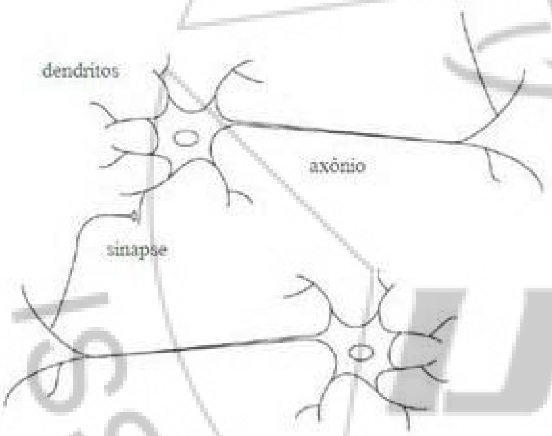

Figure : Natural neurons.

The complexity of real neurons is highly abstracted when modeling artificial neurons. These basically consist of *inputs* (like synapses), which are multiplied by *weights* (strength of the respective signals), and then computed by a mathematical function which determines the *activation* of the neuron. Another function (which may be the identity) computes the *output* of the artificial neuron (sometimes in dependence of a certain *threshold*). ANNs combine artificial neurons in order to process information.

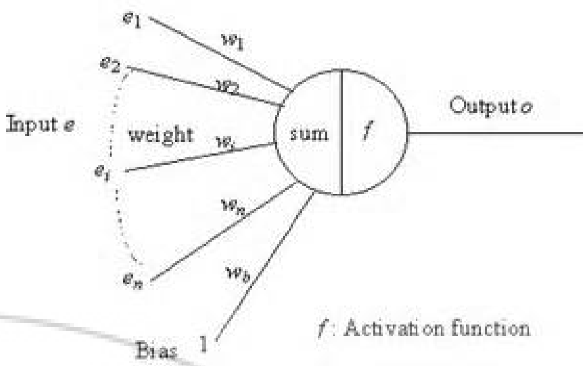

Figure: An artificial neuron.

The higher a weight of an artificial neuron is, the stronger the input which is multiplied by it will be. Weights can also be negative, so we can say that the signal is *inhibited* by the negative weight. Depending on the weights, the computation of the neuron will be different. By adjusting the weights of an artificial neuron we can obtain the output we want for specific inputs. But when we have an ANN of hundreds or thousands of neurons, it would be quite complicated to find by hand all the necessary weights. But we can find algorithms which can adjust the weights of the ANN in order to obtain the desired output from the network. This process of adjusting the weights is called *learning* or *training*.

2.2 Applications of NN

Neural networks are universal approximators, and they work best if the system you are using them to model has a high tolerance to error. However they work very well for:

- Capturing associations or discovering regularities within a set of patterns;
- Where the volume, number of variables or diversity of the data is very great;
- The relationships between variables are vaguely understood; or,
- The relationships are difficult to describe adequately with conventional approaches.

2.3 Limitations of NN

In reference to back propagational networks however, there are some specific issues potential users should be aware of.

- Backpropagational neural networks (and many other types of networks) are in a sense the ultimate 'black boxes'. Apart from defining the general architecture of a network and perhaps initially seeding it with a random numbers, the user has no other role than to feed it input and watch it train and await the output. In fact, it has been said that with backpropagation, "you almost don't know what you're doing". Some software freely available software packages (NevProp, bp, Mactivation) do allow the user to sample the networks 'progress' at regular time intervals, but the learning itself progresses on its own. The final product of this activity is a trained network that provides no equations or coefficients defining a relationship (as in regression) beyond its own internal mathematics. The network 'IS' the final equation of the relationship.

- Backpropagational networks also tend to be slower to train than other types of networks and sometimes require thousands of epochs. If run on a truly parallel computer system this issue is not really a problem, but if the BPNN is being simulated on standard serial machine (i.e. a single SPARC, Mac or PC) training can take some time. This is because the machines CPU must compute the function of each node and connection separately, which can be problematic in very large networks with a large amount of data. However, the speed of most current machines is such that this is typically not much of an issue.

2.4 Advantages over Conventional Techniques

Depending on the nature of the application and the strength of the internal data patterns one can generally expect a network to train quite well. This applies to problems where the relationships may be quite dynamic or non-linear. ANNs provide an analytical alternative to conventional techniques which are often limited by strict assumptions of normality, linearity, variable independence etc. Because an ANN can capture many kinds of relationships it allows the user to quickly and relatively easily model phenomena which otherwise may have been very difficult or impossible to explain otherwise.

3. Future Scope of ANN

In future all current NN technologies will most likely be vastly improved. Everything from handwriting and speech recognition to stock market prediction will become more sophisticated after development of better training methods and network architectures.

In future NN allow:

Robots that can see, feel, and predict the world around them, common usage of self-driving cars, composition of music, handwritten documents to be automatically transformed into formatted word processing documents, trends found in the human genome to aid in the understanding of the data compiled by the Human Genome Project, self-diagnosis of medical problems using neural networks and much more!

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