Artificial Neural Networks

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Abstract— **Although they are only one of the many types of statistical tools for modeling nonlinear relationships, neural networks seem to be surrounded by a great deal of mystique and, sometimes, misunderstanding. Because they have their roots in neurophysiology and the cognitive sciences, neural networks are often assumed to have brain-like qualities: learning capacity, problem-solving abilities, and ultimately, cognition and self-awareness. Alternatively, neural networks are often viewed as "black boxes" that can yield accurate predictions with little modeling effort. In this paper, some of the mystique and misunderstandings about neural networks by providing some simple examples of what they are, what they can and cannot do, and where neural nets might be profitably applied in financial contexts.**

***Index Terms*— synapse, animation**

I. Introduction

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.

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.

Neural Networks offer improved performance over conventional technologies in areas which includes: Machine Vision, Robust Pattern Detection, Signal Filtering, Virtual Reality, Data Segmentation, Data Compression, Data Mining, Text Mining, Artificial Life, Adaptive Control, Optimization and Scheduling, Complex Mapping and more.

An artificial neural network is a system based on the operation of biological neural networks, in other words, is an emulation of biological neural system. Why would be necessary the implementation of artificial neural networks? Although computing these days is truly advanced, there are certain tasks that a program made for a common microprocessor is unable to perform; even so a software implementation of a neural network can be made with their advantages and disadvantages.

Advantages:

- A neural network can perform tasks that a linear program cannot.
- When an element of the neural network fails, it can continue without any problem by their parallel nature.
- A neural network learns and does not need to be reprogrammed.
- It can be implemented in any application.
- It can be implemented without any problem.

Disadvantages:

- The neural network needs training to operate.
- The architecture of a neural network is different from the architecture of microprocessors therefore needs to be emulated.
- Requires high processing time for large neural networks.

Artificial neural networks are among the newest signal processing technologies nowadays. The field of work is very interdisciplinary, but the explanation I will give you here will be restricted to an engineering perspective.

An artificial neural network is developed with a systematic step-by-step procedure which optimizes a criterion commonly known as the learning rule. The input/output training data is fundamental for these networks as it conveys the information which is necessary to discover the optimal operating point. In addition, a non linear nature makes neural network processing elements a very flexible system.

Basically, an artificial neural network is a system. A system is a structure that receives an input, process

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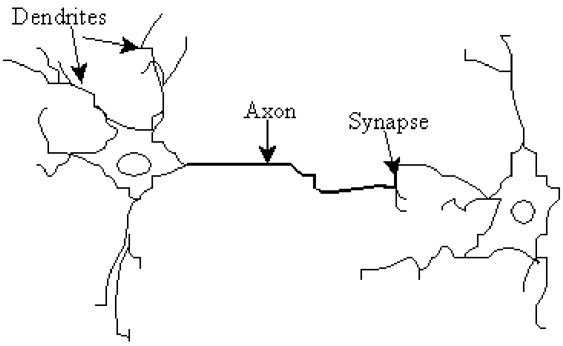
the data, and provides an output. Commonly, the input consists in a data array which can be anything such as data from an image file, a wave sound or any kind of data that can be represented in an array. Once an input is presented to the neural network, and a corresponding desired or target response is set at the output, an error is composed from the difference of the desired response and the real system output.

II The Biological Model

Artificial neural networks born after McCulloc and Pitts introduced a set of simplified neurons in 1943. These neurons were represented as models of biological networks into conceptual components for circuits that could perform computational tasks. The basic model of the artificial neuron is founded upon the functionality of the biological neuron. By definition, “Neurons are basic signaling units of the nervous system of a living being in which each neuron is a discrete cell whose several processes are from its cell body”

Figure 1. Natural neurons



The biological neuron has four main regions to its structure. The cell body, or soma, has two offshoots from it. The dendrites and the axon end in pre-synaptic terminals. The cell body is the heart of the cell. It contains the nucleolus and maintains protein synthesis. A neuron has many dendrites, which look like a tree structure, receives signals from other neurons.

A single neuron usually has one axon, which expands off from a part of the cell body. This I called the axon hillock. The axon main purpose is to conduct electrical signals generated at the axon hillock down its length. These signals are called action potentials.

The other end of the axon may split into several branches, which end in a pre-synaptic terminal. The electrical signals (action potential) that the neurons use to convey the information of the brain are all identical. The brain can determine which type of information is being received based on the path of the signal.

The brain analyzes all patterns of signals sent, and from that information it interprets the type of information received. The myelin is a fatty issue that insulates the axon. The non-insulated parts of the axon area are called Nodes of Rangier. At these nodes, the signal traveling down the axon is regenerated. This ensures that the signal travel down the axon to be fast and constant.

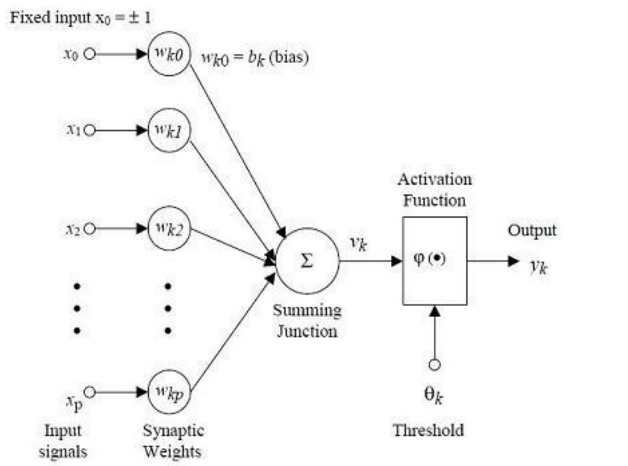
The synapse is the area of contact between two neurons. They do not physically touch because they are separated by a cleft. The electric signals are sent through chemical interaction. The neuron sending the signal is called pre-synaptic cell and the neuron receiving the electrical signal is called postsynaptic cell.

The electrical signals are generated by the membrane potential which is based on differences in concentration of sodium and potassium ions and outside the cell membrane.

When biological neurons are classified by function they fall into three categories. The first group is sensory neurons. These neurons provide all information for perception and motor coordination. The second group provides information to muscles, and glands. There are called motor neurons. The last group, the interneuron, contains all other neurons and has two subclasses. One group called relay or protection interneurons. They are usually found in the brain and connect different parts of it. The other group called local interneuron’s are only used in local circuits.

III The Mathematical Model

Once modeling an artificial functional model from the biological neuron, we must take into account three basic components. First off, the synapses of the biological neuron are modeled as weights. Let’s remember that the synapse of the biological neuron is the one which interconnects the neural network and gives the strength of the connection. For an artificial neuron, the weight is a number, and represents the synapse. A negative weight reflects an inhibitory connection, while positive values designate excitatory connections. The following components of the model represent the actual activity of the neuron cell. All inputs are summed altogether and modified by the weights. This activity is referred as a linear combination. Finally, an activation function controls the amplitude of the output. For example, an acceptable range of output is usually between 0 and 1, or it could be -1 and 1. Mathematically, this process is described in the figure



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

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

The output of the neuron, yk, would therefore be the outcome of some activation function on the value of vk.

Activation functions

As mentioned previously, the activation function acts as a squashing function, such that the output of a neuron in a neural network is between certain values (usually 0 and 1, or -1 and 1). In general, there are three types of activation functions, denoted by Φ (.). First, there is the Threshold Function which takes on a value of 0 if the summed input is less than a certain threshold value (v), and the value 1 if the summed input is greater than or equal to the threshold value.

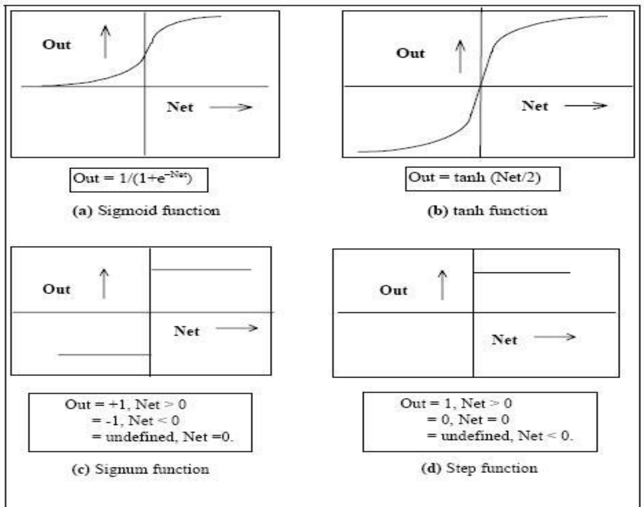
$$\varphi(v) = \begin{cases} 1 & \text{if } v \geq 0 \\ 0 & \text{if } v < 0 \end{cases}$$

Secondly, there is the Piecewise-Linear function. This function again can take on the values of 0 or 1, but can also take on values between that depending on the amplification factor in a certain region of linear operation.

$$\varphi(v) = \begin{cases} 1 & v \geq \frac{1}{2} \\ v & -\frac{1}{2} > v > \frac{1}{2} \\ 0 & v \leq -\frac{1}{2} \end{cases}$$

Thirdly, there is the sigmoid function. This function can range between 0 and 1, but it is also sometimes useful to use the -1 to 1 range. An example of the sigmoid function is the hyperbolic tangent function.

$$\varphi(v) = \tanh\left(\frac{v}{2}\right) = \frac{1-\exp(-v)}{1+\exp(-v)}$$



Common non-linear functions used for synaptic inhibition. Soft non-linearity: (a) Sigmoid and (b) tanh; Hard non-linearity: (c) Signum and (d) Step.

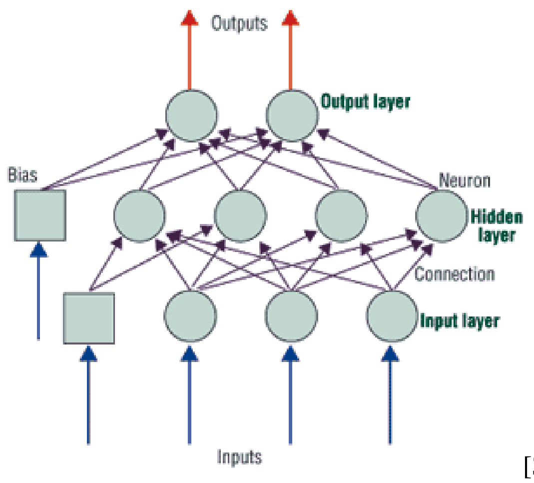
The artificial neural networks which we describe are all variations on the parallel distributed processing (PDP) idea. The architecture of each neural network is based on very similar building blocks which perform the processing. In this chapter we first discuss these processing units and discuss different neural network topologies. Learning strategies as a basis for an adaptive system. [4]

Processing units

Each unit performs a relatively simple job: receive input from neighbors or external sources and use this to compute an output signal which is propagated to other units. Apart from this processing, a second task is the adjustment of the weights. The system is inherently parallel in the sense that many units can carry out their computations at the same time. Within neural systems it is useful to distinguish three types of units: input units (indicated by an index i) which receive data from outside the neural network, output units (indicated by an index o) which send data out of the neural network, and hidden units (indicated by an index h) whose input and output signals remain within the neural network. During operation, units can be updated either synchronously or asynchronously. With synchronous updating, all units update their activation simultaneously; with asynchronous updating, each unit has a (usually fixed) probability of updating its activation at a time t, and usually only one unit will be able to do this at a time. In some cases the latter model has some advantages.

This section focuses on the pattern of connections between the units and the propagation of data. As for this pattern of connections, the main distinction we can make is between:

Feed-forward neural networks, where the data from input to output units is strictly feed forward. The data processing can extend over multiple (layers of) units, but no feedback connections are present, that is, connections extending from outputs of units to inputs of units in the same layer or previous layers.



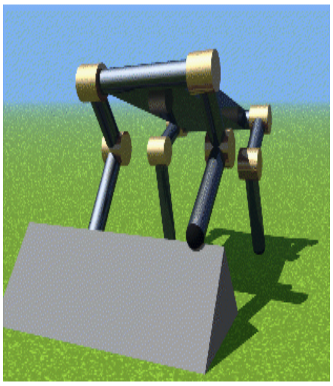
[3]

Recurrent neural networks that do contain feedback connections. Contrary to feed-forward networks, the dynamical properties of the network are important. In some cases, the activation values of the units undergo a relaxation process such that the neural network will evolve to a stable state in which these activations do not change anymore. In other applications, the changes of the activation values of the output neurons are significant, such that the dynamical behavior constitutes the output of the neural network (Pearl mutter, 1990).

IV Applications

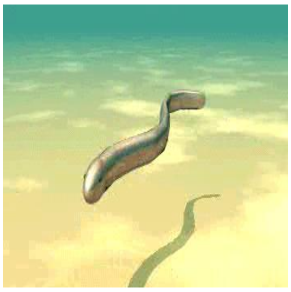
Autonomous Walker & Swimming Eel

(A) The research in this area involves combining biology, mechanical engg. and information technology in order to develop the techniques necessary to build a dynamically stable legged vehicle controlled by a neural network. This would incorporate command signals, sensory feedback and reflex circuitry in order to produce the desired movement.



(B) Simulation of the swimming lamprey (eel-like sea creature), driven by a neural network.

Swimming Lamprey



One emerging application which exploits the correlation between audio and video is speech-driven facial animation. The goal of speech-driven facial animation is to synthesize realistic video sequences from acoustic speech. Much of the previous research has implemented this audio-to-visual conversion strategy with existing techniques and neural networks. Here, they examine how this conversion process can be accomplished with hidden Markov models (HMM).

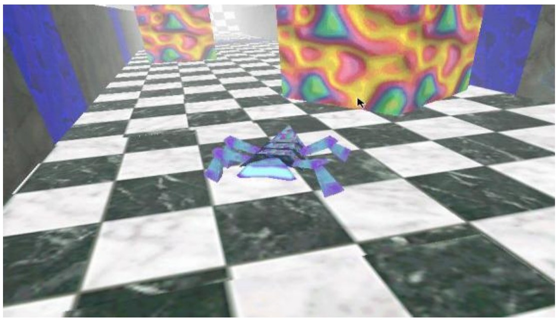
Real-time Target Identification for Security Applications

Audio-to-Visual Conversion

(A) Tracking Demo: The parabolic contour is fit to each frame of the video sequence using a modified deformable template algorithm. The height between the two contours and the width between the corners of the mouth can be extracted from the templates to form our visual parameter sets.

(B) Morphing Demo: Another important piece of the speech -driven facial animation system is a visual synthesis module. Here we are attempting to synthesize the word "wow" from a single image. Each frame in the video sequence is morphed from the first frame shown below. The parameters used to morph these images were obtained by hand.

Galapagos is a fantastic and dangerous place where up and down have no meaning, where rivers of iridescent acid and high-energy laser mines are beautiful but deadly artifacts of some other time. Through spatially twisted puzzles and bewildering cyber-landscapes, the artificial creature called Mendel struggles to survive, and you must help him. Mendel is a synthetic organism that can sense infrared radiation and tactile stimulus. His mind is an advanced adaptive controller featuring Non-stationary Entropic Reduction Mapping -- a new form of artificial life technology. He can learn like your dog, he can adapt to hostile environments like a cockroach, but he can't solve the puzzles that prevent his escape from Galapagos.



Galapagos features rich, 3D texture-mapped worlds, with continuous-motion graphics and 6 degrees of freedom. Dramatic camera movement and incredible lighting effects make your passage through Galapagos breathtaking. Explosions and other chilling effects will make you fear for your synthetic friend. Active panning 3D stereo sound will draw you into the exotic worlds of Galapagos.

Faces are tracked robustly by integrating motion and model-based tracking.

The system localizes and tracks peoples' faces as they move through a scene. It integrates the following techniques:

- Motion detection
- Tracking people based upon motion
- Tracking faces using an appearance model

(A) Tracking in low resolution and poor lighting conditions

(B)Tracking two people simultaneously: lock is maintained on the faces despite unreliable motion based body tracking

Facial Animation

Facial animations created as the underlying surface representation. Neural networks could be use for learning of each variation in the face expressions for animated sequences.

The (mask) model was created in Soft Image, and is an early prototype for the character "Mouse" in the YTV/ABC television's series "Rebooting" (They do not use hierarchical splines for Reboot!). The original standard bicubic B-spline was imported to the "Dragon" editor and a hierarchy automatically constructed. The surface was attached to a jaw to allow it to open and close the mouth. Groups of control vertices were then moved around to create various facial expressions. Three of these expressions were chosen as key shapes, the spline surface was exported back to Soft Image, and the key shapes were interpolated to create the final animation.

V Conclusion

The computing world has a lot to gain from neural networks. Their ability to learn by example makes them very flexible and powerful. Furthermore there is no need to devise an algorithm in order to perform a specific task; i.e. there is no need to understand the internal mechanisms of that task. They are also very well suited for real time systems because of their fast response and computational times which are due to their parallel architecture.

Neural networks also contribute to other areas of research such as neurology and psychology. They are regularly used to model parts of living organisms and to investigate the internal mechanisms of the brain.

In addition to the applications featured here, other application areas include:

- Financial Analysis -- stock predictions.
- Signature Analysis -- the banks in America have taken to NNs to compare signatures with what is stored.
- Process Control Oversight -- NNs are used to advise aircraft pilots of engine problems.
- Direct Marketing -- NNs can monitor results from a test mailing and determine the most successful areas.
- Pen PC's.

Significant progress has been made in the field of neural networks-enough to attract a great deal of attention and fund further research. Advancement beyond current commercial applications appears to be possible, and research is advancing the field on many fronts. Neural based chips are emerging and applications to complex problems developing. Clearly, today is a period of transition for neural network technology.

VI The Future

The future of Neural Networks is wide open, and may lead to many answers and/or questions. Is it possible to create a conscious machine? What rights do these computers have? How does the human mind work? What does it mean to be human?

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Saumya BajpaiBE(IT)/MTech(IT)/MBA(Operations), 2 publications, research work done in Botnet in MTech(IT),ISTE, Worked as Convener in many conferences & workshops, worked as department head for 1 year.
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