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Neural Networks and their Applications in Industry

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ABSTRACT

The article looks at the necessity of artificial intelligence and more specifically neural computing systems in today's competitive business world. Some fundamentals of neural network architecture are discussed, followed by advantages of such networks. The domains of commercial applications of neural technology are highlighted. The various applications that neural networks have been put to and the potential possibilities that exist in a variety of civil and military sectors are tremendous. The national and international scenario and what neural technology holds for us in the future are also covered.

1. INTRODUCTION

Over the past few years, technology has become very dynamic. It is fuelling itself at an ever increasing rate. Computers are a prime component of this whole revolution. Computers that can help fight diseases by designing new drugs, computers that can design better computers, computers that simulate reality and what not! This is a very exciting time for technology as the traditional boundaries are now becoming blurred.

We often tend to think that computers can only decide on whether a statement is true or false. Such logical statements are then linked together to form a series of rules. To program a computer, all that is needed is to precisely define the problem, write a specification and use these rules. The program tells the computer, rule by rule, exactly what to do. But it is difficult to program a computer for more 'subjective' tasks, like predicting what the weather is going to be, or what the price of gold will be tomorrow. These tasks are in fact impossible to define accurately. Patterns need to be recognised that are complex and imperfect. Nature is chaotic and we need something to decode this chaos.

A different approach is needed to give computers more 'human-like' abilities, capability to make judgements, guesses and to change opinions. We humans learn by example and do not need to see every examples to make a guess, a judgement based upon what we have been taught.

With the growing emphasis on autonomy, intelligence and an increased amount of information required by businesses, traditional processing technology can only cope through faster hardware with more complex bespoke software. With this approach, some of the questions raised are:

- How long is it going to write this software?
- How many different versions for each variation are required?
- Having been written, how safe is it from bugs?

The problem growing throughout the 1990s and into the millennium is that engineers no longer have the luxury in development to calculate all the algorithms or identify all the rules in these complex systems. In fact, most of these systems are so chaotic that doing so would be futile and prone to failure.

Given the high stakes and intense competition within all areas of industry, intelligent business decisions are more important than ever. Even more important is the case for military applications. Data analysis plays an important role as a critical strategic weapon in business and operations of the armed forces (both peace-time and war-time). The inherent limitations of existing statistical technology makes normal data analysis a very tedious and often costly process–requiring assumptions, rigid rules, force fitting of data, as well as extensive trial and error experimentation and programming. Interpreted errors, biases and mistakes are introduced. Valuable competitive insights are lost. Technology based on artificial intelligence (AI) will soon become the only way to generate such systems economically.

2. WHY ARTIFICIAL INTELLIGENCE/NEURAL COMPUTING?

The rapid pace of change and a climate of competitiveness, in which the profoundly and speedily informed gain the advantage and demand a more incisive consideration and induction of emerging IT than has hitherto been the case.

There are a range of AI technologies available now—each with its own strengths and weaknesses. These are:

- Expert systems
- Fuzzy logic
- Case-based reasoning
- Neural networks
- Genetic algorithms

3. NEURAL NETWORKS

Neural computers are based on the biological processes of the brain (human neural systems). Terms like can learn brain-like, massively parallel, learning machines and revolutionary have been used to describe neural computing. And these are true! It is not surprising that most industries believe that taking a neural approach will require special, expensive neural integrated circuits, big parallel computers, or very high powered computers. This is not true!

Conventional computers concentrate on emulating human thought processes, rather than actually how they are achieved by the human brain. Neural computers, however, take an alternative approach in that they directly model the biological structure of the human brain and the way it processes information (although at a much simpler level). This necessitates a new kind of architecture, which, like the human brain, consists of a large number of heavily interconnected processing elements operating in parallel manner. Such an architecture is now both technically and commercially feasible to be deployed on a standard computer (from the laptop and desktop to the mainframe) and is certain to increase in general usage.

Neural computing is a relatively new but rapidly expanding branch of computing whose origin dates back to the early 1940s. Though it has been largely overshadowed since the 1960s by conventional computing, it has experienced an upsurge in popularity in the late 1980s as a result of new developments in the field and general advances in computer hardware technology.

Neural networks are mathematical models, originally inspired by biological processes in the human brain. They are constructed from a number of simple processing elements interconnected by weighted pathways to form networks. Each element computes its output as a non-linear function of its weighted inputs. When combined into networks, these processing elements can implement arbitrarily complex non-linear functions which can be used to solve classification, prediction or optimisation problems.

3.1 Basic Theory

In this Section, neural networks are considered from an analytical viewpoint, so as to dispel any notions that neural networks are 'magical devices'. In fact, a neural network is little more than an example of fairly specialised parallel processing architecture. A point which should be noted is that neural computing is not to be viewed as a competitor to conventional computing, but rather as a complementary technique. The most successful neural computing applications to date have been those which operate in conjunction with other computing techniques. For example, using a neural network to perform a first pass over a set of incoming data, then passing the results over to a conventional system for subsequent processing.

3.2 What is a Neural Network?

Neural networks can be taught to perform complex tasks and do not require programming as conventional computers. They are massively parallel, extremely fast and intrinsically fault-tolerant. They learn from experience, generalise from examples, and are able to extract essential characteristics from noisy data. They require significantly less development time and can respond to situations unspecified or not previously envisaged. They are ideally suited to real-world applications and can provide solutions to a hos' of currently impossible or commercially impractical problems.

In simple terms, a neural network is made up of a number of processing elements called neurons, whose interconnections are called synapses. Each neuron accepts inputs from either the external world or from the outputs of other neurons. Output signals from all neurons eventually propagate their effect across the entire network to the final layer where the results can be output to the real world. The synapses have a processing value or weight, which is learnt during training of the network. The functionality and power of the network primarily depends on the number of neurons in the network, the interconnectivity patterns or topology, and the value of the weights assigned to each synapse.

3.3 Classification of Neural Networks

There are a number of artificial neural networks (ANNs). Just as there are many ways to connect circuits to perform a specific function with no single circuit topology applicable to all problems, the same is also true for neural networks. The easiest to understand and most used architecture is the globally connected feed-forward network—sometimes called multilayer perception (MLP), which is generally trained with the backpropagation of error algorithm, learning vector quantisation, radial basis function, Hopfield, and Kohonen, etc.

Global interconnectivity means that all the neuron outputs of one layer connect (through their weights) to every neuron input in the next layer and only to these neurons. The inputs to the neurons on the input layer are from the external world. Such networks perform classification and optimisation operations very well. The neuron output values can be expressed mathematically, but due to the built-in non-linear operators, these equations provide little in the way of an intuitive feel for how neural networks perform their tasks.

There are some additional features for this type of network which generally apply to all neural networks, regardless of architecture. Firstly, a neural network tends to be over-specified, meaning that there are many more unknowns than equations describing the system. Secondly, usually there are many weight sets (perhaps an infinite number) that will solve the same problem. Lastly, the weight sets are generated from training algorithms and are not programmed like conventional algorithms. This training process relieves the designer of developing an algorithmic solution for the problem at hand.

Some ANNs are classified as feed-forward while others are recurrent (i.e., implement feedback) depending on how data is processed through the network. Another way of classifying ANN types is by their method of learning (or training), as some ANNs employ supervised training while others are referred to as unsupervised or self-organising. Supervised training is analogous to a student guided by an instructor. Unsupervised algorithms essentially perform clustering of data into similar groups, based on the measured attributes or features serving as inputs to the algorithms. This is analogous to a student who derives lesson totally on his or her own. ANNs can be implemented in software or in specialised hardware.

4. ADVANTAGES OF NEURAL NETWORKS

As seen already, neural computers have the ability to learn from experience, to improve their performance and to adapt their behaviour to new and changing environment. Unlike conventional rule-based systems, neural networks are not programmed to perform a particular task using rules. Instead, they are trained on historical data, using a learning algorithm. The learning algorithm changes the functionality of the network to suit the problem by modifying the values of the connection weights between processing elements. Once trained, the network interprets new data in a way that is consistent with the experience gathered during training.

Neural networks can provide highly accurate and robust solutions for complex non-linear tasks, such as fraud detection, business lapse/churn analysis, risk analysis and data-mining. One of their main benefits is that the method for performing a task need not be known in advance; instead it is automatically inferred from the data. Once learned, the method can be quickly and easily adjusted to track changes in the business environment.

A further advantage of neural networks over conventional rule-based systems and fuzzy systems is that, once trained, they are far more efficient in their storage requirements and operation; a single mathematical function can replace a large number of rules. An added benefit of this more compact mathematical representation is that it introduces a natural form of regularisation or generalisation. This makes neural systems extremely robust to noisy, imprecise or incomplete data.

The time needed to develop a neural application is often less than that in a conventional approach, since the interaction between the analyst and the expert is minimised—there are no algorithms or rules to define. The scope and accuracy of the finished application is improved since the neural computer can be exposed to many more examples than can be assimilated by a single human.

Early criticisms relating to the lack of explanatory information on how a neural network performs its task have now been largely overcome. Techniques such as sensitivity analysis can be used to identify which input variables have the largest effect on a particular decision or prediction. Furthermore, neural networks can now be structured to incorporate prior expert knowledge and present results in a form that is meaningful to human users.

5. APPLICATIONS OF NEURAL NETWORKS

Artificial neural networks have become an accepted information analysis technology in a variety of disciplines. This has resulted in a variety of commercial applications (in both products and services) of neural network technology (The applications that neural networks have been put to and the potential possibilities that exist in a variety of civil and military sectors are tremendous.)

Given below are domains of commercial applications of neural network technology.

★ **Business**
- Marketing
- Real Estate

★ **Document & Form Processing**
- Machine printed character recognition
- Graphics recognition
- Hand printed character recognition
- Cursive handwritten character recognition

★ **Finance Industry**
- Market trading
- Fraud detection
- Credit rating

★ **Food Industry**
- Odour/aroma analysis
- Product development

- Quality assurance

★ **Energy Industry**

- Electrical load forecasting
- Hydroelectric dam operation
- Natural gas

★ **Manufacturing**

- Process control
- Quality control

★ **Medical & Health Care Industry**

- Image analysis
- Drug development
- Resource allocation

★ **Science & Engineering**

- Chemical engineering
- Electrical engineering
- Weather forecasting

★ **Transportation & Communication**

Some applications of naural networks are:

5.1 Forecasting the Behaviour of Complex Systems

It is a broad application domain for neural networks. Specific examples include: electric load forecasting, economic forecasting, and forecasting natural and physical phenomena.

One of the recent applications being studied is the river-flow forecasting. It is an important application that can have significant economic impact. It can help in predicting agricultural water supply and potential flood damage, estimating loads on bridge, etc.

5.2 Signal Processing

Over the past decade or so, neural network approaches have been successfully combined with other signal processing techniques to produce a wide variety of applications. It can very well be argued that the commercial success of neural networks has been from its ready incorporation into other information processing approaches, such as pattern recognition and statistical inference, as well as symbolic processing.

5.3 Data Compression

A class of neural networks called the back-propagation network (BPN) is useful in addressing diverse problems requiring recognition of complex patterns and performing non-trivial mapping functions. Data compression is a common problem in today's world. Specifically, one would like to find a way to reduce the data needed to encode and reproduce accurately a moderately high resolution video image, so that these images may be transmitted over low-to-medium bandwidth communication equipment. Although there are many algorithmic approaches to perform data compression, most of these are designed to deal with static data, such as ASCII text, or with display images that are fairly consistent, such as computer graphics. Because video data rarely contains regular, well-defined forms (and even less frequently contain empty space), video data compression is a difficult problem from an algorithmic viewpoint. On the other hand, a neural network approach is ideal for a video data-reduction application, because BPN can be trained easily to map a set of patterns from an n-dimensional space to an m-dimensional space. Since any video image can be thought of as a matrix of picture elements (pixels), the image can be conceptualised as a vector in n-space. If we limit the video to be encoded to monochromatic, images can be represented as vectors of elements, each representing the gray scale value of a single pixel.

5.4 Paint Quality Inspection

Visual inspection of painted surfaces, such as automobile body panels, is currently a very time consuming and labour-intensive process. To reduce the amount of time required to perform this inspection, one of the major US automobile manufacturers reflects a laser beam off the painted panel and on to a projection screen. Since the light source is a coherent beam, the amount of scatter observed in the reflected image of the laser provides an indication of the quality of the paint finish on the car. In the past, inspection of scatter-pattern would have been performed primarily by humans, because conventional computer programming techniques that could be used to automate the observation and scoring process suffered from a lack of flexibility, and were not particularly robust.

By using a backpropagation type of neural network to perform the quality-scoring operation, a system can be constructed that captures the expertise of human inspectors, and is relatively easy to maintain and update. To improve the performance of the system, algorithmic techniques can be coupled with the above approach to simplify the problem.

5.5 DNA Sequence Analysis

In the 45 years since the discovery of DNA's helical structure, scientist have made great strides in exploring human DNA's structure and locating human genes. As a part of this effort, advanced recombinant DNA and gene-mapping techniques, developed over the last two decades, have led to an unprecedented effort to map and sequence the entire human genome–the collection of 1,00,000 human genes.

The huge amount of data the human genome project (presently going on in the US with scientists all over the world participating) produced will require high performance computing and more intelligent computer algorithm for analysis and inference. Recently, the neural network model has been recognised as a promising AI technique because such approaches might well embody important aspects of intelligence not captured by symbolic and statistical methods.

These knowledge-based neural networks, called expert networks in some cases, perform as well as human experts (and often exhibit characteristics of a traditional symbolic expert system).

6. WORLD SCENARIO

Many organisations are carrying out commendable work in the area. The Neural Network Group at the Austrian Research Institute for Artificial Intelligence, for example, has always aimed at turning their research results into practical applications, be they industrial, medical or otherwise. A similar approach needs to be adopted in India also. A list of major real-world applications for which neural network solutions have been developed by the Institute are:

- Prediction of rainfall based on radar images.
- Prediction of traffic flow on highways.
- Contributions to the control of rotary blood pumps.
- Identification of coronary artery disease from stress ECG.
- Recognition of hand-written characters.
- Alarm detection in cardiotocograms (CTG) for foetal monitoring.

International Business Machines (IBM) has integrated neural network and AI technology into software applications, such as data mining packages. Such techniques enable business users to sift through vast quantities of raw data to spot hidden trends or anomalies which might otherwise be missed. IBM's business intelligence and data mining software can mimic human thought when processing information called the verification model–or go beyond human logic to discover correlations and similarities between seemingly disparate data–called the discovery model.

Before neural networks and artificial intelligence were used in business intelligence applications, companies lacked the ability to leverage information they were collecting in data warehouses. They were unable to connect consumer buying patterns, customise promotions to target a range of customers with different needs, or identify potentially fraudulent insurance claims based on past behaviour.

Cadbury's saw its market share of the chocolate market slip from 33 per cent to 28 per cent, but a business intelligence solution helped the company focus attention on those product lines that appealed to customers, and as a result Cadbury's market share is now much more.

Neural computing and AI techniques also lie behind many of the sophisticated search engines and intelligent agents found on the

Internet and corporate intranets. Who can deny the fact that in business today, the ability to access the right information at the right time is absolutely critical! They are used in case-based reasoning tools such as those developed by Inference (California, USA) for intelligent problem solving in the help desk, customer support and other computer telephony integration packages.

Other AI and neural intelligence systems are used for credit scoring and to help pinpoint and prevent fraud in areas as diverse as equity trading and cellular telephony networks.

7. NEURAL NETWORKS– INDIAN SCENARIO

Lot of opportunities exist in the country for AI technologies, especially neural computing applications. Though most of the work is being done around robotics and expert systems, there are also people and organisations capable of developing neural system products. The potential sectors of application range from manufacturing, banking and finance, defence, telecommunications, pharmaceuticals to holiday industry.

Substantial amount of work is being done at the Centre for Artificial Intelligence and Robotics (CAIR, Bangalore) and the Institute for Robotics and Intelligent Systems (IRIS, Bangalore). They have developed a neural network for optical character recognition. The project is complete and awaits commercialisation. IRIS is working on functional electrical simulation using neural networks to simulate the muscles of a handicapped person and allow him to walk.

Scientists at the Indian Statistical Institute (Machine Intelligence Unit), Calcutta, have figured out computer simulated models, more advanced than human brain, for creating artificial entities more intelligent than present day systems in performing cognitive tasks. This project will have far reaching implications on medical research and robotics.

8. COMPETITIVE EDGE

The progress of neural computing industry worldwide is limited by a general lack of awareness. Commercial companies and their customers are unaware of the technology. With any new technology, there is a danger of false expectations being raised, especially by breakthroughs in research. When these expectations are not met, the technology may become discredited. It can take a long time to undo this kind of damage. Recovery and industrial/commercial take up will be longer than would otherwise have been the case. Clearly, this is a scenario that must be avoided.

Managers have, for some time, been subjected to a confusing technological clamour; OOPS, 4GLs, CASE, OLAP, genetic algorithms, KBS, virtual reality, etc, all have high current visibility. The claimed benefits of these technologies sometimes overlap—the technologies themselves sometimes overlap.

The general market for neural computing products is still in its infancy. Worldwide sales of neural computing-based systems were estimated to be of the order of $1000 m in 1997. The growth in UK alone has been confirmed by UK DTI findings that 8 out of 10 times about 100 companies are either investigating neural technology or developing neural applications.

Pure research does not remain pure indefinitely. Sooner, it turns up as applied research, and finally as technology. Theory becomes industrial practice, knowledge becomes competitive power. Television, computer technology and biotechnology have undergone a metamorphosis and emerged as an industry-changing force.

The neural computing industry now has the impetus of an expanding market. It is the right time to encourage it by identifying new applications and promoting them. There is a danger, however, that the rate at which the technology is taken up will be constrained by inappropriate neural computing technology. This danger needs to be guarded against by ensuring that neural computing research is undertaken in collaboration with business. It will only be through the implementation of such research that industry can benefit from the technology and become world-leaders.

9. CONCLUSION

Neural computers perform very favourably in business and military applications. They do not require explicit programming by an expert and are robust to noisy, imprecise or incomplete data. Furthermore, knowledge is encapsulated in a compact, efficient way that can easily be adapted to changes in business environment.

As with all technologies, there is a window of opportunity for exploitation–and that window is here today. You cannot afford to ignore the fact that your competitors are already investigating the opportunities and realising the significant business benefits that neural technology brings to a range of applications.

The reason one should use neural computing technology is the competition!

REFERENCES

1. Freeman, James A. & David, M. Neural networks: Algorithms, applications, and programming techniques. Skapura Addison-Wesley Longman, Inc.
2. Yuhas, Ben P.; Goldstein, Moise, H.; Sejnowski, Terrence J & Jenkins, Robert E. Neural network models of sensory integration for improved vowel recognition. (Proc. *IEEE*, October 1990).
3. Widrow, Bernard & Lehr, Michael, A. Thirty Years of adaptive neural networks: Perceptron, madaline and backpropagation. (Proc. *IEEE*, September 1990).
4. Amari, Shun-ichi. Mathematical foundations of neurocomputing; (Proc. *IEEE*, September 1990).

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