The Essentials of Neural Networks and their Applications

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Abstract – *This article looks at the essentials for artificial intelligence and more specifically neural networking systems in today's competitive business world. Some core principles of neural network architecture are discussed, the advantages of such networks. The domain of commercial applications of neural technology has been highlighted. Neural networks have various applications and the potential that exists in various civil and military fields is tremendous.*

Key Words: **Artificial Neural Network (ANN), Neural Network (NN), Artificial Intelligence, Feedback Network, Neural Network Learning, Applications and drawbacks of ANN.**

1. INTRODUCTION

Technology has become very dynamic in the last few years. It is fuelling itself at an ever-increasing rate. Computers are a major component of this entire revolution. Computers that can help fight diseases by designing new drugs, computers that can design better computers, computers that simulate reality. This is a very exciting time for technology as traditional boundaries are now becoming blurred.

We often think that computers can only decide Boolean statements, whether that statement is true or false. Such logical statements are joined together to form a series of rules. To program a computer, all one has to do is define a problem properly, write a specification, and use these rules. The program tells the computer, from governance to governance, exactly what to do. But it is difficult to program a computer for more 'subjective' tasks, such as what is the weather forecast or what will the price of gold be tomorrow. These functions are impossible to define exactly. Complex and incomplete patterns must be uniquely identified. Nature is chaotic and we need something to understand this chaos.

Computers require a more 'human-like' ability, decision-making ability, a different approach to guessing and changing opinions. We humans learn by example and do not need to look at every example to make a guess, judging by what we have been taught.

As the emphasis is increasingly on autonomy, intelligence and an increasing amount of information required by businesses, traditional processing technology can only cope with faster hardware with more complex bespoke software. The growing problem in the 1990s and into the millennium is that engineers no longer have the luxury of computing all of those algorithms or identifying all the rules in these complex systems. In fact, these systems are so complex and chaotic and doing so would be a failure.

Given the high stakes and intense competition in all sectors of the industry, intelligent business decisions are more important than ever. There is an even more important case for military applications. Data analysis plays an important role in the trade and operations of the armed forces (both peace-time and war-time) as important factors. The inherent limitations of existing statistical technology make general data analysis a very tedious and often costly process - it requires assumptions, rigorous rules, data constraints as well as extensive trial and error experiments 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 create such a system economically.

2. NEURAL NETWORKS

Neural computers are based on the biological processes of the brain (human nervous system). Terms that can learn like the brain, have been widely used in parallel, learning machines and revolutionary to describe neural computing. It is not surprising that most industries believe that taking a neural approach would require specialized, expensive neural integrated circuits, large parallel computers, or high-level computers.

Traditional computers focus on emulating human thought processes, rather than how they are actually received by the human brain. However, neural computers adopt an alternative way of directly demonstrating the biological structure of the human brain and the way it processes information (albeit at a much simpler level). This requires a new type of architecture which, like the human brain, consists of a large number of heavily transferable processing elements. Operating in parallel manner. Such architecture is now technically and commercially possible to be deployed on a standard computer (from laptops and desktops to mainframes) and is certain to increase in general use.

2.1 Basic Theory

Neural computing is a relatively new but rapidly expanding branch of computing with its origins in the early 1940s. Although this has been seen by traditional computing since the 1960s, the field experienced fluctuations in popularity in the late 1980s as a result of new developments 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 that are connected by weighted pathways to form a network. Each element calculates its output as a non-linear function of its weighted inputs. When combined in a network, these processing elements may be applied arbitrarily. Complex non-linear tasks that can be used to solve classification, prediction, or optimization problems.

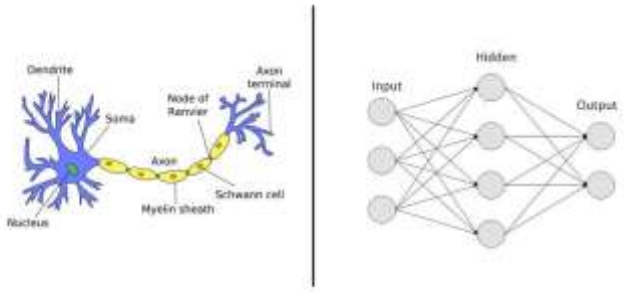

Fig 1: Human NN vs. Artificial NN

Neural networks can be taught to perform complex tasks and do not require programming as traditional computers. They are largely parallel, extremely fast and intrinsically fault-tolerant. They learn from experience, generalize from examples, and are able to extract essential features from noisy data. They require significantly shorter development time and may respond to unspecified conditions or may not be predicted earlier. They are ideally suited for real-world applications and may provide solutions to currently impossible or commercially impractical problems.

In simple terms, a neural network is made up of many processing elements called neurons, whose interrelations are called synapse. Each neuron accepts input from the outside world or from the output of other neurons. The output signals from all neurons eventually propagate their influence over the entire network to the last layer where the results can be output to the real world. Synapse has a processing value or weight, which is learned during the training of the network. The functionality and power of the network mainly depends on the number of neurons in the network, the interconnectivity pattern or topology, and the value of the load assigned for each synapse.

2.2 Classification of Neural Networks

There are many artificial neural networks (ANNs). Just as there are many ways to connect a circuit to perform a specific function with a single circuit topology applied to all problems, the same is true for the mural network. The easiest to understand and most commonly used architecture is a globally connected feed-forward network - sometimes called multilayer assumption (MLP), typically trained with backpropagation of error algorithms, From where vector learn quantification, radial base function, Hopfield and Cohen, etc.

Convolutional Neural Networks, or CNNs, were designed to map image data to an output variable. They have proven so effective that they are the go-to method for any type of prediction problem involving image data as an input. The benefit of using CNNs is their ability to develop an internal representation of a two-dimensional image. This allows the model to learn position and scale in variant structures in the data, which is important when working with images.

Global interconnectivity means that all neuron outputs (through their weight) of one layer are connected to the next layer and to every neuron input. The inputs of neurons at the input layer are from the outside world. Such networks perform classification and optimization operations very well. Neuron production values can be expressed mathematically, but due to the underlying non-linear operators, these equations provide intuitive insights into how neural networks perform their functions.

1. Single-layer feedforward neural network

In a layered neural network, the neurons are organized in the form of layers. The simplest structure is the single-layer feedforward network that consists of input nodes connected directly to the single layer of neurons. The node outputs are based on the activation function.

2. Multilayer feedforward neural network

The second class of a feedforward neural network distinguishes itself by the presence of one or more hidden layers, whose computation nodes are correspondingly called hidden neurons. By adding one or more hidden layers, the network is enabled to extract higher-order statistics from its input.

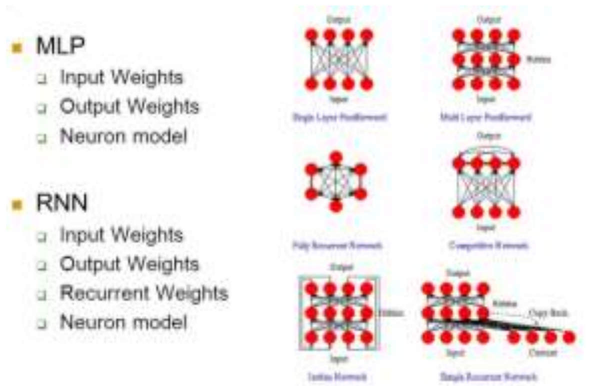

Fig 2: NN model parameters/networks

There are some additional features for this type of network that usually apply to all neural networks regardless of architecture. First, a neural network is over-specified, meaning that there are many more unknowns than the equations that describe the system. Secondly, there are usually several weight sets (perhaps an infinite number) that will solve the same problem. Finally, the weight set originates from training algorithms and is not programmed like traditional algorithms. This training process relieves the designer of developing an algorithm solution to the problem at hand.

Some ANNs are classified as feed-forward, while others are iterated (i.e., implement feedback) depending on how the data is processed through the network. Another way to classify ANN types is their learning method (or training), as some ANNs employ supervised training, while others are referred to as unprepared or self-organizing. Supervised training corresponds to a student-directed instructor. Clustering of data into similar clusters inevitably leads to an unheard-of algorithm, which is based on measurement characteristics or features serving as the input of the algorithm. ANNs can be implemented in software or specialized hardware.

2.3Neural Network Training

The process of calibrating the values of weights and biases of the network is called training of neural network to perform the desired function correctly.

1. **Supervised Learning**

The basic aim is to approximate the mapping functionso well that when there is a new input data (x) then the corresponding output variable can be predicted. It is called supervised learning because the process of an learning can be thought of as a teacher who is supervising the entire learning process. Thus, the "learning algorithm" iteratively makes predictions on the training data and is corrected by the "teacher", and the learning stops when the algorithm achieves an acceptable level of performance (or the desired accuracy). In supervised learning, the data will be presented in a form of couples (input, desired output), and then the learning algorithm will adapt the weights and biases depending on the error signal between the real output of network and the desired output.

2. **Unsupervised Learning**

The main aim of Unsupervised learning is to model the distribution in the data in order to learn more about the data. It is called so, because there is no correct answer and there is no such teacher. Algorithms are left to their own devises to discover and present the interesting structure in the data. In supervised learning, the data will be presented in a form of couples (input, desired output), and then the learning algorithm will adapt the weights and biases depending on the error signal between the real output of network and the desired output.

3. **Reinforcement Learning**

In reinforcement learning, an appropriate action is taken to maximize the reward in a particular situation. It is employed by various software and machines so that it can detect possible behavior or path in a specific situation. Reinforcement learning differs from supervised learning in a way that supervised learning holds the answer key to training data so the model is trained with the correct answer whereas in reinforcement learning, there is no answer but the reinforcement agent decides that what to do in order to complete the given task. In the absence of a training dataset, it is bound to learn from its experience.

2.4 Advantages of Neural Networks

- Neural networks have the ability to self-learn and produce that is not limited to the input provided to them.
- Input is stored in its network instead of database; Therefore, data loss does not affect its function.
- These networks can learn from examples and implement them when a similar event occurs, allowing them to work through real-time events.
- Even if a neuron is not responding or a piece of information is missing, the network can detect a fault and still produce an output.
- They are versatile and can perform multiple tasks in parallel without affecting the system performance.

2.5 Limitations of Neural Networks

- NN needs training to operate.
- The architecture of NN is different from the architecture of microprocessors therefore need to be emulated.
- Requires high processing time for large neural network.
- NNs do not provide explanations for their decisions.
- NN decisions are not supported by significant tests, hence low validity.
- High cost & complex network is another drawback of NN.

4. APPLICATIONS OF NEURAL NETWORK

The Artificial Neural Network has been in existence since 1943, when it was initially designed, but has recently come to light under Artificial Intelligence, due to applications that make it much better. Artificial neural networks have become an accepted information analysis technique in a wide variety of disciplines. This has resulted in a wide variety of commercial applications (both in product and service) of neural network technology. Given below are the domains of commercial applications of neural network technology:

1. Business

- Sales Forecasting
- Customer Research
- Digital Marketing
- Data Validation
- Real Estate
- Risk Management

2. Document & Form Processing

- Pre-processing
- Layout analysis
- Machine printed character recognition
- Character segmentation
- Graphics recognition
- Hand printed character recognition
- Signature verification

3. Finance Industry

- Market trading
- Fraud detection
- Credit rating

4. Food Industry

- Odour/aroma analysis
- Product development
- Quality assurance

5. Manufacturing Industry

- Process monitoring and control
- Quality control
- Identification
- Planning & scheduling

6. Science & Engineering

- Electrical engineering
- Agricultural Control System Engineering
- Civil engineering

7. Medical & Health Care Industry

- Image analysis
- Biochemical analysis
- Drug design
- Diagnostic system

8. Education

- OMR technology
- Estimating student retention and degree completion time
- Data mining

9. Transportation & Communication

- Self-driving cars
- Automatic navigation system
- Indoor optical wireless communication

3. CONCLUSION

As we know that neural network is such a vast subject that it is not possible to cover completely in just a few pages, yet we try to give a glimpse of artificial neural network through this paper. Here, we understood the fundamentals of neural networks and their applications in various industries. It is clear that the usage of neural network is going to increase in the future in terms of both the number and type of their applications. The future of neural networks is bright and current research leads in the right direction towards the ultimate goal of all artificial intelligence, namely, the development of a humanoid robot that can work and think like a human. However, we need to develop more algorithms and programs so that we can remove the limitations of artificial neural networks and make it more useful for a wide variety of applications. If the artificial neural network concept is combined with computational automata, FPGA and fuzzy logic, then we will certainly solve some limitations of neural network technology.

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