



NEURAL NETWORKS IN ARTIFICIAL INTELLIGENCE

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Abstract: Neural network's function is an excellent instrument for analyzing, learning and predicting from the supplied data. It has proven successful in practical situations involving image recognition, speech recognition as well as natural language processing. This paper is all about a detailed analysis of AI neural network types, fields of application and their advantages and disadvantages. There is a discussion of recent developments in neural networks as well as their possible usage going forward. Based on the above analysis, ANN (Artificial Neural Network) models with feed-forward or backward propagation show prospective areas of research. It can be used for balancing such parameters as accuracy of data, speed in processing, time lag, fault-tolerance, volume, scalability, convergence and performance. In essence, neural networks are simply self-evolving learning mechanisms just like the human brain's highly dynamic learning mechanism which also adapts based on the data they receive. It can support many businesses which will develop into different industries. In the future, the use of neural networks will include solving even more complicated problems, like self-driving cars, disease diagnosis, or stock market exchange.

Index Terms - Artificial Intelligence, Artificial Neural Network, Deep neural networks, Image recognition

Introduction

Artificial neural networks (ANNs) are adaptive systems inspired by the human brain [1]. Systems that can modify their internal structure to achieve a specific function objective are called adaptive systems. They are highly effective in solving non-linear problems by reconstructing the fuzzy rules that govern the optimal solution for such problems. Artificial neural networks (ANNs) have become widely used in a range of fields which includes artificial intelligence, information security, big data, cloud computing, internet technology, and forensic science. The effectiveness of ANNs can be assessed by considering various factors such as accuracy, processing speed, latency, performance, fault tolerance, volume, scalability, and convergence [2] [3]. The demand for research in this field has been intensified due to the capability of its high-speed processing parallelly and large-scale implementations [4]. Furthermore, it is used for image recognition and natural language processing. The way through which the nodes modify themselves is called 'Law of Learning' [5]. The behaviour of an Artificial Neural Network is dependent on the time. Artificial neural networks (ANNs) are highly effective in handling both complex and noncomplex problems in various fields such as agriculture, science, medical science, education, finance, management, security, engineering, commodity trading and art. They are capable of managing problems in manufacturing, transportation, computer security, banking, insurance, property management, marketing and energy. However, to enhance their performance, they need to adopt a systematic approach in the development of ANNs. This includes addressing crucial factors such as the choice of data set, data accuracy, data instrumentation, data standardization, type of data inputs, data division, data preprocessing, validations, processing and output techniques.

ANN modelling poses several challenges that need to be addressed. These challenges include the development of techniques for improving the robustness of the models, ensuring pattern transparency, enabling extrapolation, and devising new approaches to uncertainty. Other challenges include improving convergence rates, dealing with the continuous gradient enigma, quantization of variable problems, and noise. Additionally, addressing the traversal of the error surface by utilizing quantization of variable and time-consuming convergence problems are common to most artificial neural systems that use supervised training. Some of the problems are mentioned below:

i. Artificial neural networks (ANNs) have the potential to enhance model robustness. It accurately predicting data under diverse conditions which includes financial market forecasts. Widespread recognition and validation of ANNs can result in reliable predictions, ensuring strong correlation and robustness of models in any given set of circumstances [6] [7].

ii. The use of trained ANNs enables understanding of input-output relationships.

iii. It's super important for our models to accurately predict the data range during calibration. They work best when we keep them within the calibration range and avoid extrapolating beyond the design [8] [9].

iv. ANNs are not always accurate, which limits how well they work. But new techniques like cognitive computing and deep learning are making these systems better, even though it's tricky to make machines that can think like humans.

v. ANNs need good quality and plenty of training data to learn well. If the data is messed up or biased, the network won't learn properly.

I. DISCUSSION

2.1 Artificial neural networks

The application of artificial neural networks has gained significant attention in recent times across various industries. Organizations are investing in this technology to address complex problems in fields such as the economy, which were traditionally managed by operations research [10]. AI has a wide range of applications in science, engineering, social sciences, and the arts which make it a unique and valuable tool for data analysis [11]. The Artificial Neural Network (ANN) is a highly valuable information management model that effectively solves complex problems and enables efficient machine learning. This model closely mimics the complex biological nervous system function of the human brain, making it an indispensable tool for various applications. The human brain is highly efficient in its work and big in size. It works like an information processing system consisting a variety of complex operations to perform a task easily. The main element of the brain is "neurons". Neurons are interconnected with each other and help to solve the specific problems.

Artificial Neural Networks (ANN) is an algorithm that is excellent for learning. Its self-learning ability and flexible topology make it very powerful [12]. ANN is designed to adapt and learn, making it a valuable tool for many applications. The adaptivity of the ANNs allows it to perform well in dynamically changing environments or systems. However, ANNs have some limitations.

Some Pros and Cons based on Topology and Ability of the Artificial Neural Networks are listed below:

Feature	Pros	Cons
Topology	<p>i. It is possible to configure the hidden layer structure in a flexible manner to meet specific requirements [12].</p> <p>It is possible to have multiple output targets without significantly increasing the difficulty [13].</p>	<p>i. It is important to consider the potential impact of the model's complexity, which can result in either overfitting or underfitting [18].</p> <p>There are no specific rules or guidelines for designing the network [19]</p>
Ability	<p>i. For machine learning algorithms, there are two main types of tasks: complex regression problems and classification tasks [14].</p> <p>Dealing with problems that involve multiple variables and do not follow a linear pattern can be challenging [15].</p> <p>i. Having uncertain or limited experience can lead to various problems [12].</p> <p>The relationship between the</p>	<p>ii. Low learning rate can lead to local optimum in machine learning [16].</p> <p>ii. The performance of the system deteriorates when it is used beyond the data range [13].</p> <p>iii. It is challenging to provide clear explanations for the decisions [17].</p> <p>Determining weight and other crucial parameters can be challenging [17].</p>

	variables is not clear [16]	
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2.2 Content Analysis in ANN

Due to the increasing rate of daily data production, we need a powerful tool to extract useful information from large volumes of data sets. An important research area, data mining, was developed to extract helpful information and useful knowledge of the text, and data mining forms the foundation of artificial intelligence [20]. The word deep in this context will refer to a combination of several layers in deep learning. These are network algorithms that take the form of multi-layer systems. Various features comprise inputs. DLNNs are usually ANNs-based deep learning models [21]. A number of instances pointed out improvements in DLNNs as opposed to classical models. The most significant tool that is being employed for use in different areas of text mining and data mining is known as artificial neural network (ANN) since the mid-1990s [22]. Artificial intelligence refers to an area that explores such linguistic analytical methods that are applied to a text like SA (sentiment analysis) [23]. Researchers who want to do fresh research should first carry out a systematic review. The studies for all available electronic databases were identified in a SLR approach, and presented to answer the research questions using this method. A new approach of SLR (Systematic Literature Review) ensures new insight for novice researchers on advanced technology and scientific discipline. This Systematic Literature Review (SLR) adheres to the principles established by Kitchenham and Charters [24]. It corroborates undertakings associated with a particular theme [25].

This Artificial Neural Network should check the conformity of certain inputs for their respective output options. The Neural Network has found the sentiment analysis which is now classified using deep learning models' vector representation [26]. Bengio and Mikolov proposed learning methods for meaning representations of words for the text. These semantic vector embeddings were put together in their work, and then they converted words into vectors with them. The use of text classification as a route to searching for textual information and data exploration in Arabic using different methods of neural network classification [27]. Of late, the academic community has been taking deep interest in the application of Deep Learning techniques. Many deep learning techniques have been employed in the domain of NLP (Natural Language Processing) within this particular survey and their exceptional potentials. Recently, "deep learning" has become an influential method of machine learning able to learn many layers of "feature representations" and provide excellent predictions. In this survey, the major Deep Learning architectures and the relevant techniques used in NLP tasks have been shortly described. Deep learning approach is suitable for high dimensional data and has been applied in many fields relating to software engineering.

Most deep learning model examples are usually created for text classification (e.g., fast-text and Text-CNN or pre-trained language models such as BERT (Bidirectional Encoder Representations from Transformers) [28]. Considering that the internet has undergone immense growth, text data constitutes as the major format of big tourism data. Normally, text is a prevalent way in which users' judgement, expression, or evaluation takes place. In the previous period, several different kinds of text mining approaches have been designed and put in use for analyzing tourism value analysis model, building recommendation systems for tourism, crafting tourist profile and policy formulation on oversight of tourism market. Recently, text bigdata mining has become possible in terms of a key text analysis technique, NLP has experienced significant growth. Machine learning as well as current deep learning that demonstrated remarkable achievements have recently been widely utilized for NLP. These successes have been greatly improved with the advancement of natural language processing (NLP), machine learning, and deep learning [29]. Over the years, deep neural networks (DNNs) have advanced NLP in many ways. However, it has been discovered that CNN and RNN as the two types of DNN architectures provide varying performances for different NLP tasks, where their effectiveness is affected by hidden size and the amount. Thus, it implies that optimization of these two components is important to optimal performance of the two networks, (CNNs & RNNs) [30].

2.3 Concepts and Definitions

- Text mining:

In that regard, text mining is crucial in extracting useful and worthwhile knowledge from unorganized raw textual information that helps the investigators accomplish their objectives. Information retrieval refers to various methods aimed at automatically analyzing huge quantities of information using text mining methods in order to extract useful data and information such as the subject, patterns, and keywords.

- NLP:

Artificial intelligence under natural language process (NLP), commonly known as “AI”, provides computer with capability to understand the text as well as spoken words in such a way similar to how humans do it. Superlative technology of the information age includes NLP. In fact, Natural Language Processes started being applied as far back as the early fifteen years. Applications include among others classification/classification, clustering, sentiment analysis, text summarizing.

- Deep learning:

Deep learning is an extended version of ML which uses deep neural networks for extraction and analysis of features from vast sized dataset which is a part of ML in which the computer learns without having any initial information about people’s knowledge or previous characteristics. Several popular Deep Learning Models draw their inspiration from Artificial Neural Networks (ANNs). First described in the 1960s, the artificial neural network has increasingly gained ground since 2006, and it is subdivided into layers operating together. The input and output layer perform the calculation. The middle layer is comprised of hidden layers. Through the training process, the neuron’s weight gets adjusted to improve a perfect network. Two of such models are CNN and RNN. It incorporates neural networks, CAD/CAM, design optimization, artificial intelligence, pattern recognition, and signal-processing technologies. The deep learning architecture has become “the algorithm of the century” due to its ability to generalize, learn, and meet practical requirements.

- Supervised Learning:

Machine learning here uses data that has been labelled and trains a learning algorithm. This implies that it forms pairs having two elements, one element being an input vector that a vector can label and the other as a supervisory signal for the desired output [21].

- Unsupervised Learning:

In contrast to the supervised learning, here the learning algorithm is trained by using an input data set which has no label output. There isn’t a single right or wrong answer for a given input object, and no human interference to correct or adjust as in supervised learning [21].

- RNN:

RNN (a neural network invented by David Rumelhart in 1986) is employed for speech recognition, natural language processing, and sequential data processing. Rather than using a sequential shift register, it uses each node as a memory cell enabling it to readily recall prior inputs in order to process consecutive patterns. RNNs are used with time series, text, and audio data, but can’t remember long sentences because of the Vanishing gradient issue. It is hard to train RNNs and their combination with convolutional networks. Such operations allow modelling sequences of vectors and approximating probabilistic distributions, and they produce the next term from any input.

- CNN:

A Convolutional Neural Network (CNN) is a type of neural network utilized in artificial intelligence, natural language processing, speech, and image processing. From this we derive that this network is referred to as Hubel and Wiesel. For this reason, these networks are called the convolutional neural network centered on the convolution layer. There are series of number in the array called input layer. This model used the Relu activator function of developing data set of their image Net database. Such networks possess higher performance speeds and lesser training times compared to most current technologies thus resulting in a high precision rate of image recognition and feature recognition with minimal involvement of humans. However, in cases like language modelling where dependency is an issue, LSTM (Long short-term memory) is recommended over CNN since it lacks the capacity for long-term dependency. This network may also have a lot of inputs on its side as one of its drawbacks.

2.4 Classification of ANN

NN are composed of neurons, architecture of these neurons and learning algorithm. The networks may consist of one or more layers consisting of neurons. In most Neural Network models, like Perceptron, Linear Associator, Multi-layer feed-forward networks with Back-Propagation Boltzmann Machine, and Grossberg model, the output from one Trainability of a neuron implies that it can update its threshold value as well as weight inputs. These changes are controlled by a set of learning algorithms, which vary as far as how are synaptic weights being adjusted.

General Classification of Artificial Neural Network model is given below [31]:

Artificial Neural Network Model:

1. Feedback
 - a. Constructed
 - i. Hopfield
 - b. Trained
 - i. Adaptive Resonance Theory (ART)
2. Feed Forward
 - a. Linear
 - b. Non-linear
 - i. Supervised
 1. Back-Propagation (BP)
 - ii. Unsupervised

2.5 Laws of ANN

The last, but not least components of any ANN are called “the laws/learning algorithms”. The dynamics of any neural network are controlled by Neural Dynamics which include Activation-State dynamics and Synaptic-weight dynamics. Learning Algorithms or Laws may be considered as the synaptic dynamics, but they must be expressed as the first derivative of the weights. Learning in such laws may either be supervised, unsupervised, or a combination thereof.

Some of the commonly known Learning Algorithms are:

- I. Hebb's Law:
- II. Definition: Hebb's Law is a principle in neurophysiology that states "cells that fire together, wire together" [32]. In the context of ANN, it implies that the connection strength between two neurons increases if they are activated simultaneously.
- III. Uses: Hebb's Law is fundamental in the learning process of neural networks, contributing to the strengthening of connections between neurons that frequently participate in the activation patterns. It is frequently used in unsupervised learning.
- IV. Perceptron Learning Law:
 - a. Definition: The Perceptron Learning Law is a supervised learning rule for a single-layer perceptron. It adjusts the weights of the connections based on the error in the output, aiming to minimize the difference between the actual and desired outputs [33].
 - b. Uses: Commonly used in binary classification problems, the Perceptron Learning Law is suitable for tasks where a linear decision boundary is sufficient.
- V. Delta Learning Law:
 - a. Definition: The Delta Learning Law, also known as the Widrow-Hoff rule, is a supervised learning rule used for adjusting weights in a neural network [34]. It considers the error between the desired and actual output to modify the weights.
 - b. Uses: Delta Learning Law is widely applied in training multi-layer perceptron and is suitable for a variety of pattern recognition tasks.
- VI. Correlation Learning Law:
 - a. Definition: The Correlation Learning Law involves adjusting connection weights based on the correlation between the input and output patterns. It is used frequently in unsupervised learning when the network seeks statistical relationships between input and output [35].
 - b. Uses: Applied in tasks where the goal is to uncover patterns and correlations within the data without explicit guidance on desired output patterns.
- VII. Instar Learning Law:
 - a. Definition: The Instar Learning Law is a rule in unsupervised learning where neurons compete, and the winning neuron adjusts its weights to become more sensitive to the input pattern [36]. It's used to construct self-organizing maps.
 - b. Uses: Applied in tasks where the goal is to organize and categorize input patterns based on competitive learning, often used in clustering and feature extraction.

VIII. Outstar Learning Law:

- a. Definition: The Outstar Learning Law is a supervised learning rule used in radial basis function networks. It adjusts the weights of the connections from the hidden layer to the output layer based on the error between the desired and actual output [37].
- b. Uses: Applied in tasks where radial basis function networks are used, such as function approximation and classification problems.

2.6 Characteristics of ANN

Artificial neural networks are constructed to perform like the basic workings of biologic neurons. These elements hold significant attributes that enable them to learn from different instances, derive from known instances for unseen ones as well as recognize vital signals amidst noise related inputs. Therefore, artificial neural networks imitate the way brain works by means of learning, generalizing, and abstracting information from data.

The characteristics of Artificial Neural Network are:

- 1) Learning:
 - NN is an example-based learner that can be trained using known instances after which it can be tested using unseen information sets.
 - By adapting their behaviour in their given surrounding and making changes that are determined by what they receive as input will ensure that they give out similar answers.
- 2) Parallel Operation:
 - NNs are designed in a way to conduct processing in parallel which leads to fast and distributed computing.
- 3) Mapping:
 - This is because neural networks present a mapping ability that maps the input patterns to the corresponding output patterns without necessarily explaining the reasons behind it.
- 4) Generalization:
 - NNs are good at generalisation where they can predict new trends based on previous trends.
 - They become unresponsive to trivial changes in input once they are trained and this proves vital when identifying patterns in the natural world.
- 5) Robustness:
 - NN is robust and fault tolerant, remembering complete patterns from incomplete, partial or noisy input stimuli.
- 6) Abstraction:
 - There is some ANN architecture which makes sense out of a group of inputs, identifying contributing properties for categorization or clustering.
- 7) Applicability:
 - Although it is a bit limited as far as some tasks are concerned (for example, not good for doing payroll calculations), ANN performs much better than normal computers in situations where a problem can be described as a pattern whose characteristics need detecting from among other ones.
- 8) Expressive Hypothesis Space:
 - The hypothesis space for ANNs is highly expressive, requiring cautious selection of networks topologies to avoid overfitting.
- 9) Handling Redundant Features:
 - Since the weights of unimportant features are trained during this learning process, ANN will disregard unnecessary features automatically.
- 10) Sensitivity and Noise Handling:
 - Learning an ANN is very expensive, particularly when it has dozens of hidden layers.
 - For instance, ANNs are extremely susceptible of errors arising out of noise in training data sets. Using validation sets or tuning weights of iterations can be used to overcome this problem.

2.7 Application of Artificial Neural Network

- 1) Speech Processing:
 - a) Vowel Classification
 - b) Recognition of vowel-consonant segments
 - c) Recognition of stop consonant-vowel utterances in Indian languages
 - d) Net talk
 - e) Phonetic Typewriter
- 2) Image Processing:
 - a) Recognition of Symbols (used in Olympics)
 - b) Recognition of handwriting
 - c) Segmentation of image
 - d) Classification and segmentation of texture
- 3) Social Media:
 - a) 'People You May Know' feature on platforms like Facebook
 - b) Facial recognition for security using convolutional neural networks
- 4) Marketing and Sales:
 - a) Personalized recommendations on E-commerce sites (e.g., Amazon, Flipkart)
 - b) Tailoring marketing campaigns based on customer preferences using ANN
- 5) Healthcare:
 - a) Medical Research applications in Cardiology, Neurology, Radiology, Biochemistry, Genetics, etc.
 - b) Oncology for identifying cancerous tissue at a microscopic level
 - c) Facial analysis for early detection of rare diseases
 - d) Enhancing diagnostic abilities of medical experts
- 6) Personal Assistants:
 - a) Speech recognition and Natural Language Processing in personal assistants like Siri, Alexa, Cortana
 - b) Managing language syntax, semantics, and conversation using artificial neural networks
- 7) Prediction:
 - a) Predicting targets using echo patterns from sonar, radar, seismic, and magnetic instruments
 - b) Crime prediction by analysing a large dataset of crime details
- 8) Detection:
 - a) Data mining, cleaning, and validation for fault detection and fraud prevention
 - b) Fraud detection in credit cards, insurance, or taxes by analysing past records
- 9) Employee Hiring:
 - a) Efficiently used in employee hiring to match skills with productivity expectations
- 10) Power System Analysis:
 - a) Predicting instability in the voltage of power systems using Soft Computing and ANN
 - b) Low-cost methods for power system analysis and predicting pending voltage instability

2.8 Advantages of Artificial Neural Network

- i. Storing Information on the Entire Network:
 - a. Information is distributed across the entire network, unlike traditional programming where it's stored in a centralized database.
 - b. Network functionality is not compromised by the loss of specific information in one location.
- ii. Ability to Work with Incomplete Knowledge:
 - a. Post-ANN training, the network can generate output even with incomplete information.
 - b. Performance loss is contingent upon the importance of the missing information.
- iii. Fault Tolerance:
 - a. Corruption of one or more cells in the ANN doesn't hinder its ability to generate output.
 - b. This fault tolerance feature enhances the robustness of the network.

- iv. Distributed Memory:
 - a. To facilitate learning, ANN requires examples to be presented, teaching the network based on desired outputs.
 - b. Network success is directly linked to the quality of selected instances, allowing for the potential production of accurate output even with incomplete data.
- v. Gradual Corruption:
 - a. Over time, the network may experience a gradual slowdown and relative degradation.
 - b. Immediate and catastrophic failure is not characteristic of ANN.
- vi. Ability to Make Machine Learning:
 - a. ANN can learn from events and make decisions based on similarities with previously encountered events.
 - b. This capability contributes to the adaptability and evolving nature of neural networks.
- vii. Parallel Processing Capability:
 - a. Artificial neural networks exhibit parallel processing capabilities, enabling them to perform multiple tasks simultaneously.

2.9 Disadvantages of Artificial Neural Network

- i. Hardware Dependence:
 - a. ANN relies on processors with parallel processing capabilities, necessitating specialized hardware for optimal functioning.
 - b. The hardware dependency poses a challenge in terms of equipment realization.
- ii. Unexplained Behaviour of the Network:
 - a. The most significant drawback of ANN is its tendency to produce results without providing insights into the reasoning behind them.
 - b. Lack of transparency in the decision-making process reduces trust in the network.
- iii. Determination of Proper Network Structure:
 - a. There's no specific rule for determining the structure of artificial neural networks.
 - b. Achieving an appropriate network structure relies on experience and trial-and-error methods, posing a challenge in network design.
- iv. Difficulty of Showing the Problem to the Network:
 - a. ANNs primarily operate with numerical information, requiring problems to be translated into numerical values before introduction.
 - b. The choice of a display mechanism directly influences network performance, relying on the user's ability to effectively present problems.
- v. Unknown Duration of the Network:
 - a. The completion of training is often determined when the network reaches a certain error value on the sample.
 - b. This value, however, does not guarantee optimum results, leaving uncertainty about the optimal training duration.
- vi. Ongoing Development of ANN:
 - a. Artificial neural networks, introduced in the mid-20th century, are rapidly evolving.
 - b. While disadvantages persist, it is crucial to note that the shortcomings of ANN, as a developing science branch, are being addressed gradually, contributing to the increasing advantages of these networks.
- vii. Evolutionary Nature of ANN:
 - a. Artificial neural networks are subject to ongoing advancements, and their disadvantages are gradually being eliminated. ANN will keep evolving and become more important in our lives.

III. CONCLUSION

Finally, a thorough investigation on artificial neural networks (ANN) shows significant implication and limitless abilities in several fields. There are different types of ANN that form the basis of AI devices including recurrent, convolutional, feedforward, and auto associate networks. The creation and subsequent use of such a digital simulator of the brain has now become key factor for creating the new generation of computers.

There are many modern uses for ANNs, which have significantly impacted on complex analysis across several disciplines such as medical and engineering. Their flexibility has been demonstrated by their extensive use in the gaming industry. ANN is also used for handwriting identification purposes in banks and assists in disease diagnosis as well as complex CT scan interpretation in medicine.

Autonomous learning is possible for neural networks since they can act in regard to abstract problems and improve themselves from errors. Such brain to computer interface will be envisaged in the future; thus, no hindrance among humans and machines. Such transformative technology would be able to turn these mental cues into the required electrical signals for robot responsiveness, thereby, setting the scene for communication or interaction with the environment that is mainly mental in nature.

Nevertheless, it must be noted that though ANNs are powerful, knowing what they can do and can't do matters. It is because of this that their learning by example system, which makes them extremely useful for problem solving or machine learning purposes. Future exploitation of the capacities of neural network into the computing world requires an insightful comprehension of their strengths and weaknesses if they are to effectively address various problems that prevail in modern society.

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