STM JOURNALS

Journal of
Telecommunication, Switching Systems and Networks

ISSN: 2454-6372
Volume 11, Issue 2, 2024
May–August
DOI (Journal): 10.37591/JoTSSN

https://journals.stmjournals.com/jotssn

Review JoTSSN

Exploring Practical Applications of Artificial Neural Networks: A Review

Sabna[1], Farsana Muhammed[2,*]

Abstract

Computational models called artificial neural networks (ANNs) are modeled after the structure of the human brain. These models are designed to process information and learn from data. Artificial neural networks, or ANNs, are composed of interconnected artificial neurons layered to resemble the brain's neural network. Through training, ANNs adjust the connections between neurons based on labeled data, enabling them to recognize patterns and perform specific tasks. Despite their efficacy in areas such as image recognition and prediction, ANNs have limitations. They require substantial amounts of labeled data, can be challenging to interpret, and are susceptible to biases. However, their adaptability and capacity for continuous learning make them valuable tools in various applications, from computer vision to natural language processing. As research in artificial intelligence advances, ANNs are expected to drive further technological progress. This review explores the diverse applications of Artificial Neural Networks (ANNs) in fields such as wireless networking, internal combustion engines, and power systems. It explores the fundamentals of ANNs, their evolution, and training methods. The study discusses ANNs' use in weather prediction, evaluating construction project bids, and modeling industrial processes. It also examines challenges and advanced techniques in using ANNs. It also examines challenges and advanced techniques in using ANNs.

Keywords: Artificial Neural Network (ANN), Artificial Intelligence (AI), Machine Learning (ML), computational models, Global Voltage Stability Index

INTRODUCTION

The human brain, with its complex interconnections, has provided the basis for artificial neural networks (ANNs) that have grown in importance within the machine learning field. The architecture of these networks consists of nodes (artificial neurons) which are connected such that they analyze information by changing connections between the neurons depending on the input data. This has made ANNs a favorite among many as it is able to learn complex patterns in data, adapt to new information and generalize from examples. Because of their adaptability, they can be applied to a variety of fields, including as financial forecasting, natural language processing, picture and audio recognition, and medical diagnostics. This introductory section aims at discussing fundamental principles of ANNs, their architectures, training methods and applications which explain why they had a great influence on technological development and computational power. Artificial Neural Networks (ANNs) were first conceptualized in the 1940s by

*Author for Correspondence
Farsana Muhammed
E-mail: farsanamuhammed217@gmail.com

[1]M. Tech Scholar, Department of Electrical & Electronics Engineering, Thangal Kunju Musaliar College of Engineering, Kollam, Kerala, India
[2]Assistant Professor, Department of Electrical & Electronics Engineering, Thangal Kunju Musaliar College of Engineering, Kollam, Kerala, India

Received Date: June 06, 2024
Accepted Date: July 07, 2024
Published Date: July 18, 2024

Citation: Sabna, Farsana Muhammed. Exploring Practical Applications of Artificial Neural Networks: A Review. Journal of Telecommunication, Switching Systems and Networks. 2024; 11(2): 1–11p.

McCulloch and Pitts. Progress was slow until the 1980s when the backpropagation algorithm improved learning. This led to Multilayer Perceptron (MLPs) and ANNs being used for tasks like pattern recognition. Advances in computing power and data availability in the 1990s and 2000s led to deep learning and convolutional neural networks (CNNs) for tasks like image recognition. Today, ANNs are crucial to machine learning and AI, with broad applications and ongoing research driving innovation. The feed forward network is depicted in the Figure 1 [1, 2].

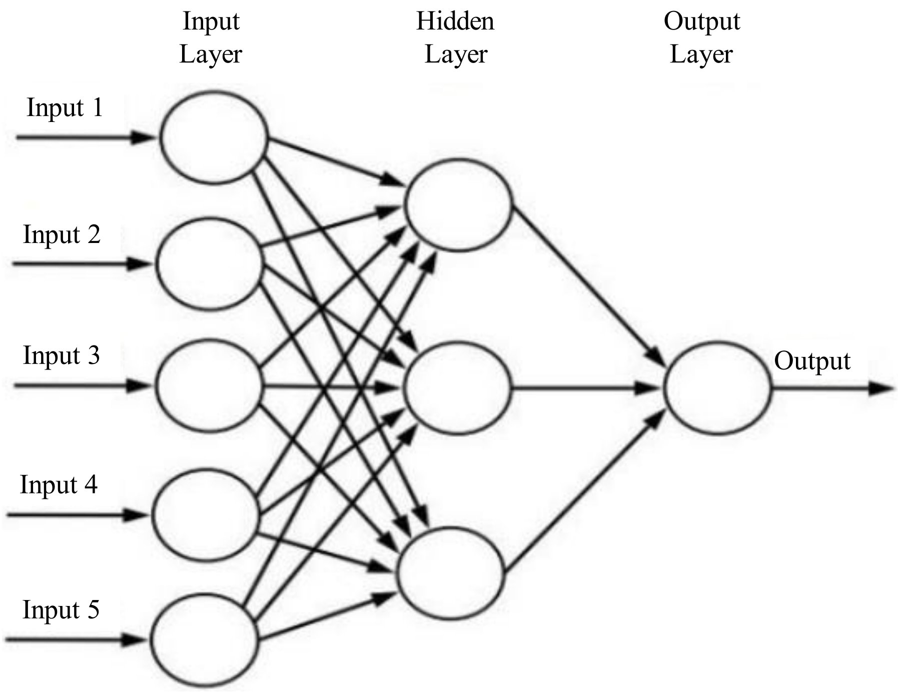

Figure 1. Feed Forward Network.

The study offers a thorough tutorial on applying machine learning (ML) algorithms based on artificial neural networks (ANNs) to a variety of wireless networking issues. It discusses the main ANN types: recurrent, spiking, and deep neural networks, and provides concrete examples that are pertinent to the design of wireless networks. The study also discusses various wireless communication issues that can be tackled using ANNs, such as unmanned aerial vehicles, virtual reality applications, edge computing, and caching. The study presents a use case scenario, identifies related obstacles, and summarizes the primary reason for utilizing ANNs for each application. Overall, the tutorial aims to lay the groundwork for developing future wireless networks that rely on artificial intelligence, serving as a valuable resource for researchers and practitioners in the field [1]. The study proposes using artificial neural networks, specifically the Elman recurrent neural network, cascade forward neural network, and feedforward neural network, for predictive modelling of internal combustion engines. Simulations and test results confirm that neural network models can effectively map nonlinear input-output relationships efficiently. Among the three networks, the Elman neural network showed the best performance in predicting engine torque and nitrous oxide emissions. Neural networks are advantageous for representing non-linear input-output relationships in physical systems, making them powerful modelling tools for various applications, including thermal, electrical, and chemical systems [2].

The study proposes using Artificial Neural Networks (ANN) for voltage stability analysis in power systems, employing the Global Voltage Stability Index (GVSI) as a stability indicator. It implements a multi-layer error Cascade Feed-forward Back Propagation Neural Network (CFBNN) and Radial Basis Function Neural Network (RBFNN) with a backpropagation learning algorithm to estimate GVSI. The methodology is tested on the IEEE 14 bus system, demonstrating the proposed index's effectiveness in determining the voltage collapse point and the location for reactive power compensating devices. The study concludes that the ANN-based approach using GVSI is effective in assessing voltage stability and identifying the most vulnerable load buses from a voltage stability perspective [3]. The study suggests using artificial neural networks (ANNs) for weather prediction, noting their ability to accurately capture the complex and nonlinear nature of weather patterns. Specifically, feed-forward neural networks are preferred for their capability to extract data, detect trends, and make predictions, even for patterns not encountered during training. Accurate weather forecasting is essential for sectors like agriculture, industry, and disaster management, given the changing nature of weather conditions over time. ANNs offer a reliable method for processing nonlinear weather data and making predictions [4]. The study discusses using Artificial Neural Network (ANN) systems to automatically evaluate construction project bids, ensuring fairness and objectivity. These systems offer advantages like parallel processing, robustness, and adaptability. They consider factors such as tenderer's conditions and information in bidding documents, processing them through input, hidden, and output layers to generate competitive bid indices. The study provides specific data and values used in simulations to demonstrate the reliability and validity of the ANN systems [5].

The studies presented a Generalized Regression Neural Network (GRNN)-based automatic modelling scheme. This scheme focuses on outlier identification and treatment, trend identification and treatment for effective detrending, and preprocessing for automatic pattern identification and treatment. Despite its effectiveness, a main limitation of the model is its potential lack of generalizability. To mitigate this, the study proposes using multiple GRNNs to address the spread factor issue [6]. The study discusses various approaches for pattern recognition, including structural, statistical, and hybrid methods. It also covers evaluation metrics such as MAPE, MAE, RMSE, VAPE, and R-squared. However, there are challenges related to limited access to data for result comparison in different studies and a lack of access to data for relative comparison across different areas [7]. The study discusses advanced techniques of Artificial Neural Network (ANN) structure and training, including Neuro-TF, neural network inverse modelling, hybrid deep neural network techniques, multivalued neural network method, derivative-based method, invertible neural network method, ANN approach to EM-based modelling, behavioural modelling of nonlinear circuits, and KBNN with adaptive mappings for microwave modelling. However, there is limited discussion on specific challenges in microwave-oriented ANN structures, and no exhaustive review of all valuable contributions to microwave ANN techniques [8]. The study proposes special neural network setups for modelling batch and semi-batch processes, common in industries like chemical engineering. These configurations are intended to efficiently manage the complexity of these procedures.

They also adapt the backpropagation learning algorithm, a key method for training neural networks, to suit these setups. The approach relies on historical process data to build models, making it practical for real-world industrial use [9]. The study discusses using artificial neural networks (ANNs) trained with constellation data for detecting fibre bends. Experiments confirmed accurate bend estimation through received signal analysis. Different ANN models were developed for scenarios with and without optical amplifiers. However, the accuracy degraded with increased Amplified Spontaneous Emission (ASE) noise, prompting the need for further investigation. Future work includes evaluating ANN training with optical power and Q factor [10].

FUNDAMENTALS OF ARTIFICIAL NEURAL NETWORKS

Overview of Artificial Neural Networks

Artificial Neural Networks (ANNs) are the computational equivalent of the brain; they excel at processing intricate data correlations, picking up knowledge from examples, and making deft judgments. For instance, in internal combustion engines, ANNs predict performance and emissions based on past data, using methods like 'Levenberg-Marquardt' and 'Bayesian regression' to improve accuracy. The Elman Neural Network, a type of ANN, stands out for its performance in simulations, especially with sequential data. In wireless network design, ANNs such as RNNs, SNNs, and DNNs are crucial. RNNs analyse sequences like signal changes or user movements, SNNs excel at spotting events or anomalies, and DNNs are great for tasks like signal processing and network optimization. Overall, ANNs are powerful tools for understanding and predicting outcomes in various applications, handling large amounts of data quickly, finding hidden patterns, and making networks more efficient [1, 2]. An essential component of voltage stability analysis in power systems is the use of artificial neural networks (ANNs). ANNs, such as the Radial Basis Function Neural Network (RBFNN) and the Counter propagation Neural Network (CFBNN), are key models used for this purpose. These models are trained using input patterns that include variables like Vj (voltage magnitude), Qij (reactive power), Zij (impedance), and Xij (reactance). By analysing these variables, ANNs can predict voltage stability in power systems, helping to ensure the reliability and efficiency of the electrical grid [3]. Artificial Neural Networks (ANNs) process data to produce output based on input, mimicking the way the human brain functions. They consist of interconnected layers of nodes, including input, hidden, and output layers in a multilayer ANN. These networks can detect trends and predict patterns not explicitly present in the training data, making them powerful tools for data analysis and prediction. Time series forecasting applications can benefit from the use of Recurrent Neural Networks (RNNs), a form of artificial neural network (ANN) that processes input sequences while preserving internal memory [4]. Three basic components make up the structure of Artificial Neural Networks (ANNs): the input layer, hidden layers, and output layer. Information is processed by neurons in each layer before being transferred to the one above. Until the desired result is produced, this process is repeated. ANNs use this structure to model complex relationships in data and make predictions based on patterns they learn [5].

ANN modelling involves determining the spread factor, inputs, and forecasting strategies. Various types of ANNs include feed-forward Multilayer Perceptron (MLPs), recurrent, Radial Basis Function (RBF), and Bayesian networks. However, inconsistent results can occur due to issues such as validation, preprocessing, sample size, and parameter settings [6]. Human brains serve as the inspiration for computer models known as Artificial Neural Networks (ANNs). They are made up of nodes that analyse data and find patterns in it.

ANNs use networks of nonlinear units for recognizing complex relationships in data. Some common ANN models are GAN, SAE, DBN, RNN, and CNN, used in biometrics, image processing, and bioinformatics for tasks like image recognition. ANNs go through stages like data acquisition, preprocessing, classification, and post-processing to extract useful information from input data [7]. ANNs play a crucial role in Microwave Computer-Aided Design (CAD) for both forward and inverse modelling of active and passive components. They learn complex microwave relationships from either measured or simulated data, providing a powerful tool for modelling microwave devices. ANNs solve computationally demanding problems in forward modelling, providing a quicker and more effective substitute for conventional techniques.

For inverse modelling, ANNs are particularly valuable in handling the non-uniqueness problem, where multiple solutions can exist for a given set of measurements. Overall, ANNs are extensively used in microwave CAD for their ability to learn, model, and optimize microwave components and systems [8]. Artificial Neural Networks (ANNs) serve as input-output mapping structures for complex relationships, making them valuable for tasks like fault diagnosis, dynamic modelling, and sensor data analysis. They excel at handling nonlinear relationships and noisy input information, making them effective in various applications such as disease detection, physical properties estimation, and forecasting. Ongoing research focuses on optimizing ANNs architecture, weight values, learning rate, and other parameters to enhance their performance and applicability [9]. ANNs simulate neural networks with interconnected neurons and synapses, resembling the human brain's structure. During training, ANNs update neuron weights based on input and label data, allowing them to learn and make predictions. The architecture typically includes input, hidden, and output layers, with output layer neurons indicating the presence of a fibre bend. By using ANNs for fibre bend detection, it is possible to identify bends before they lead to breakage, improving the overall reliability and durability of fibre optic systems [10].

THEORETICAL FOUNDATION OF ARTIFICIAL NEURAL NETWORKS

Computational models called Artificial Neural Networks (ANNs) are modelled after the architecture and operations of the human brain. They are made up of layers of networked nodes, or neurons. Every neuron takes in input signals, processes them using a mathematical function, and then outputs a signal. To enable the network to learn from data, weights, the strength of connections between neurons, are changed during training. Each neuron's output is determined by activation functions, like sigmoid or RELU, which take into account the weighted sum of its inputs. An artificial neural network (ANN) may learn intricate patterns and classify or forecast data by putting it through several layers of processing.

In order to reduce the discrepancy between the network's anticipated outputs and the true outputs in the training data, weights are adjusted during training ANNs. Usually, an optimization technique that determines the gradient of a loss function is used for this, like backpropagation. The difference between the actual and predicted outputs is measured by the loss function. ANNs are capable of deep learning since they can have several hidden layers. Because of this depth, ANNs can learn hierarchical representations of data, which makes them useful for a variety of applications including natural language processing, picture and audio recognition, and more.

APPLICATIONS OF ANN IN MODERN TECHNOLOGIES

Unmanned aerial vehicles (UAVs), wireless virtual reality (VR), and mobile edge caching are modern technologies changing industries. UAVs, or drones, are used for tasks like photography and delivery. Wireless VR lets users explore virtual worlds without cables. Mobile edge caching stores data closer to users, speeding up access. Multiple radio access technologies let devices connect to different networks, and the Internet of Things connects objects to the internet for data collection and automation. These technologies are advancing connectivity and innovation. Artificial neural network preliminaries, types of artificial neural networks, and applications of ANNs for wireless communications are shown in the form of a block diagram in Figure 2 (Sections II, III, and IV) [1], conclusions are finally drawn.

2D model of Organisation is shown in Figure 2.

Artificial Neural Networks (ANNs) are used to predict how internal combustion engines will perform and what emissions they will produce. They analyse data from engine sensors to estimate fuel consumption, power output, and emissions levels. ANNs are also used to model how physical systems like thermal, electrical, and chemical systems behave. They can predict things like temperature distribution, voltage levels, and reaction rates. Additionally, ANNs can predict engine vibration and output torque by analysing sensor data, which is useful for designing more efficient engines. Overall, ANNs are valuable tools for improving engine performance, reducing emissions, and optimizing system design. The Elman Neural Network is indicated shown in Figure 3 [2].

Artificial Neural Networks (ANNs) are employed in voltage stability analysis in power systems, where they analyse data to predict and maintain stable voltage levels, ensuring efficient power distribution. Additionally, Radial Basis Function Neural Networks (RBFNNs) are utilized in engineering for their rapid convergence, allowing for quicker and more efficient solutions in various engineering applications [3]. Artificial Neural Networks (ANNs) are used in weather forecasting, agricultural predictions, and natural disaster warnings by analysing historical data and patterns to make predictions about future weather patterns, crop yields, and potential natural disasters. They are also employed in data-intensive processes, financial forecasting, trend detection, and pattern prediction, where they analyse large amounts of data to identify trends and make predictions about future events in fields such as finance and business [4]. Artificial Neural Networks (ANNs) are applied in engineering project bid evaluation systems to analyse historical bid data and other relevant information, aiding in

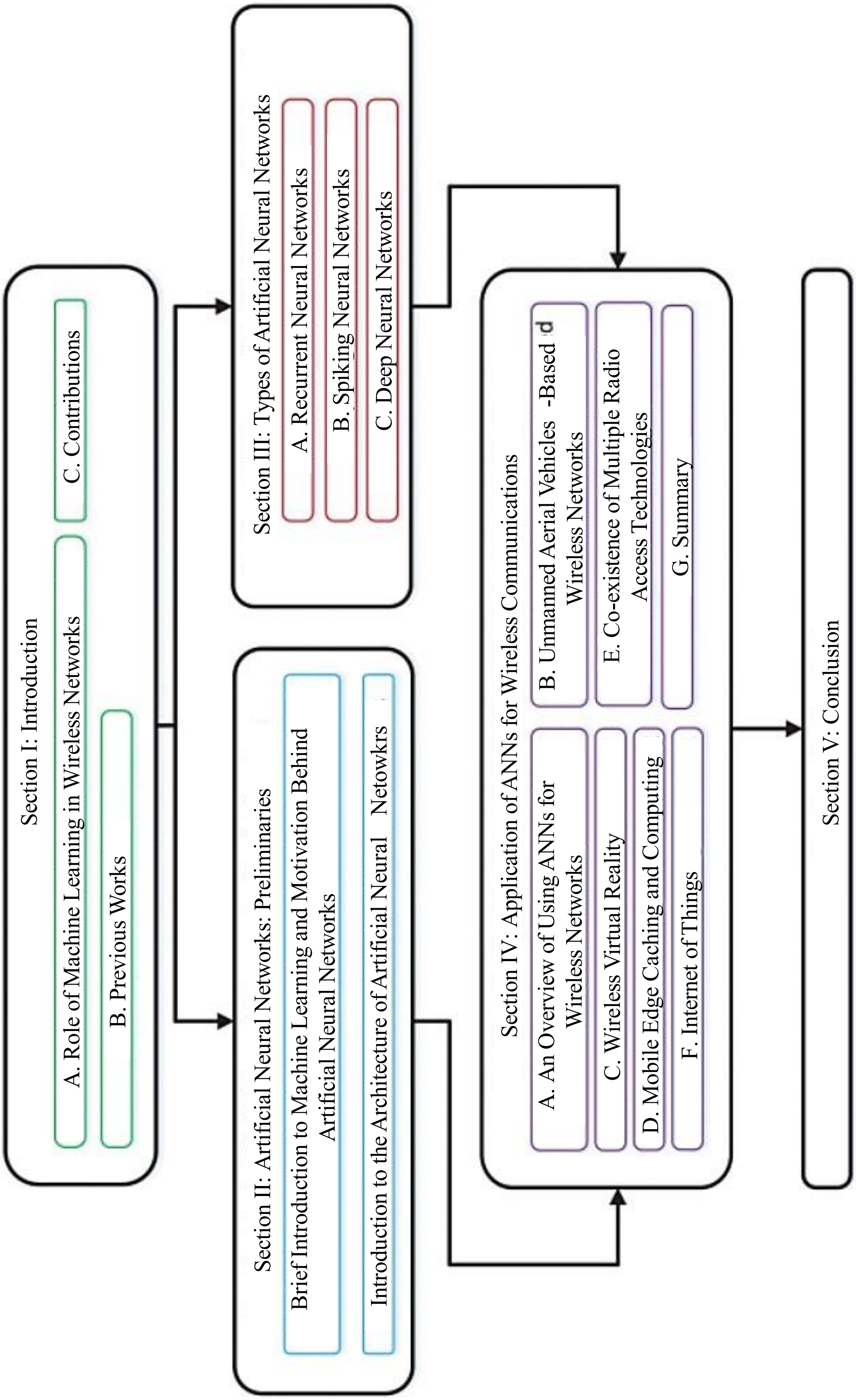

Figure 2. Organization of information.

Journal of Telecommunication, Switching Systems and Networks
Volume 11, Issue 2
ISSN: 2454-6372

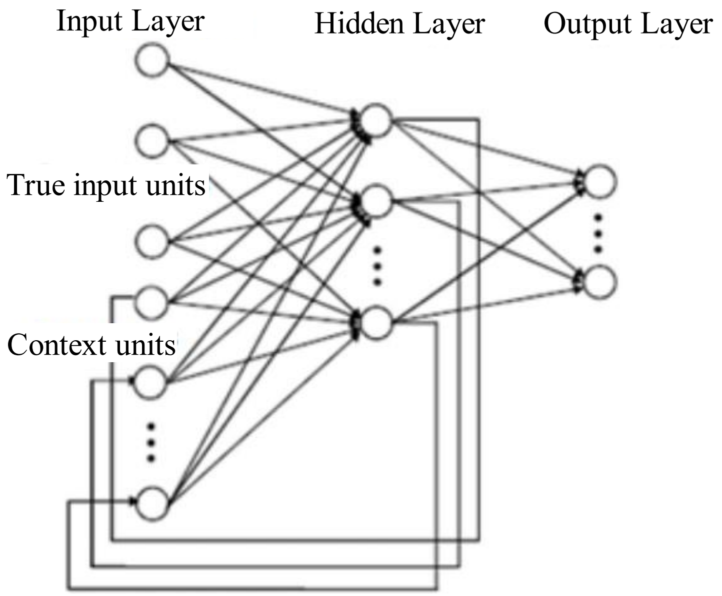

Figure 3. The ELMAN Network.

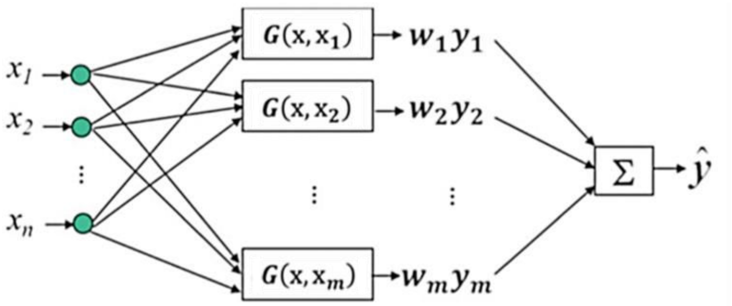

Figure 4. Typical GRNN Structure.

the selection of the best bids and ensuring successful project completion. Additionally, ANNs are utilized in the analysis of tenderer and bidding documents to extract relevant information, identify patterns, and optimize bidding strategies [5]. Artificial neural networks (ANNs) are used in many fields like finance, weather forecasting, security, science, medicine, engineering, computer vision, agriculture, graphics, and social science. For example, in finance, ANNs can predict economic trends, while in weather forecasting, they improve the accuracy of weather predictions. In security, ANNs can detect anomalies and threats, and in medicine, they assist in diagnosing diseases. ANNs are also used in engineering to model and control complex systems, in computer vision for object recognition, in agriculture for predicting crop yields, in graphics for image processing, and in social science for analysing social networks and predicting behaviour. Overall, ANNs are a versatile tool that is transforming many fields [6, 7]. Typical GRNN structure is shown in Figure 4.

Improving the efficiency of RFIC inductors using neural network methods, implementing neural network-based machine learning for real-time range-adaptive impedance matching, utilizing analogue fault diagnosis with ANNs for gross fault diagnosis, employing self-attention Bi-LSTM networks for radar signal modulation recognition, and applying ANN-based millimetre-wave interferometric radar for automotive velocity sensing are all innovative approaches that demonstrate the versatility and effectiveness of neural networks in various engineering applications [8]. Artificial Neural Networks (ANNs) are used in various fields. In chemical engineering, they improve processes and model reactions. For disease detection, they analyse medical data for early diagnosis. They estimate physical properties like viscosity. In pattern classification, they categorize data. In speech recognition, they convert speech to text. In image analysis, they detect objects. They also forecast trends and model complex systems with nonlinear relationships. Overall, ANNs are valuable for solving complex problems and making predictions based on data [9]. Schematic representation of time-dependent neural network with single subnet (Model 3): S: summation, P: product, p(S): polynomial function of summation value is shown in Figure 5.

Artificial Neural Networks (ANNs) are used to diagnose network issues, locate faults, and predict when components may fail. By analysing data from network sensors, they may identify issues early on and cut down on maintenance expenses and downtime.

ANNs also monitor optical signal performance, fibre condition, and physical fibre bending in optical networks. By analysing sensor data, they ensure the network runs smoothly and efficiently. Figure 6 shows Structure of an artificial neural network (ANN) for fibre bends detection [10].

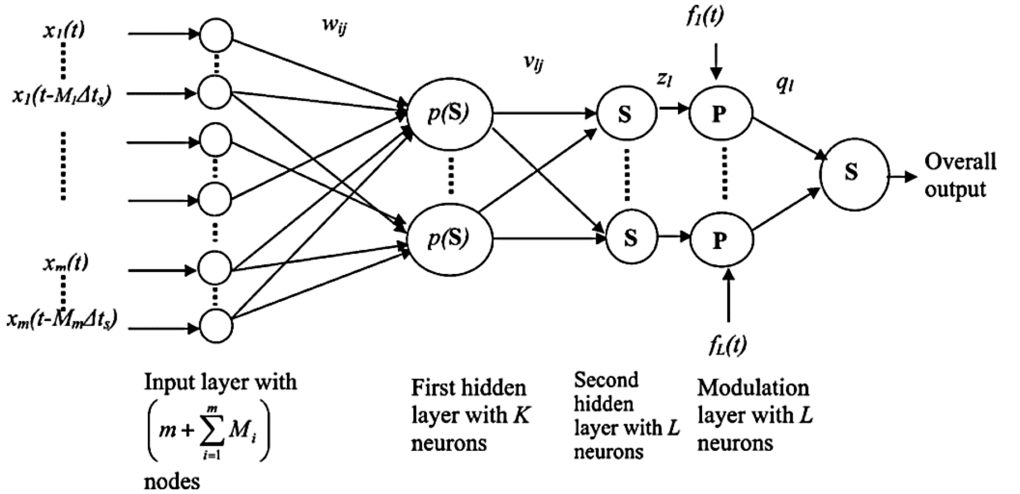

Figure 5. Schematic representation of time-dependent neural network with single subnet (Model 3). S: summation, P: product, p(S): polynomial function of summation value.

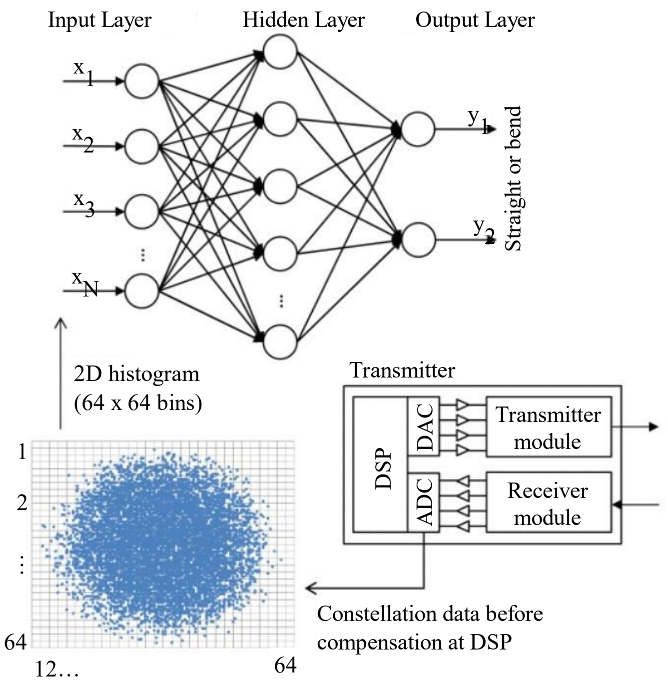

Figure 6. Structure of an artificial neural network (ANN) for fiber bends detection.

Artificial Neural Networks (ANNs) have a wide range of applications across various fields, showcasing their versatility and effectiveness in solving complex problems and making predictions based on data. In engineering, ANNs are used for tasks such as optimizing RFIC inductors, real-time impedance matching, and fault diagnosis. In science and technology, ANNs aid in weather forecasting, disease detection, and physical system modelling. In addition, they are essential to social science, graphics, agriculture, security, and other fields. All things considered, ANNs continue to spur discoveries and breakthroughs in a variety of domains, underscoring their significance in contemporary research and technology.

Comparison of Papers on Neural Network: Comparison of Various articles and applications with techniques is shown in Table 1.

Table 1. Comparison Table.

Application	Techniques	Advantages	Challenges
Wireless Networking [1]	Recurrent, Spiking, Deep Neural Networks	Captures complex network behaviour	N/A
Internal Combustion Engine Modelling [2]	Elman, Cascade Forward, Feedforward Neural Networks	Efficiently models non-linear relationships	N/A
Power System Voltage Stability [3]	CFBNN, RBFNN	Effective voltage stability assessment	Limited to specific test system
Weather Prediction [4]	Feed-forward Neural Networks	Accurate capture of non-linear weather patterns	N/A
Construction Project Bid Evaluation [5]	ANN Systems	Fair, objective, parallel processing	Limited details on specific challenges
Automatic Modelling [6]	Generalized Regression Neural Network (GRNN)	Effective outlier/trend identification	Potential lack of generalizability
Pattern Recognition [7]	Various ANN approaches	N/A	Limited discussion on specific challenges
Microwave Modelling [8]	Advanced ANN Techniques	N/A	Limited discussion on specific challenges
Batch/Semi batch Process Modelling [9]	Specific Network Setups + Backpropagation	Handles process complexities	N/A
Fiber Bend Detection [10]	Constellation Data Trained ANNs	Accurate bend estimation	Degrades with high noise, needs further research

FUTURE DIRECTION

Future research in artificial neural networks (ANNs) is set to advance significantly in several key areas. Understanding how noise affects ANN performance in fibre bend detection will be crucial for improving the reliability of these systems. Exploring new ways to train ANNs with additional parameters could enhance their accuracy. Evaluating how well ANNs perform in real-world DWDM systems will help validate their usefulness in practical applications. Further work on TVNN architectures, including exploring multi-input single-output systems, could lead to more efficient ANN designs. Creating compact TVNN structures with common weights may also improve efficiency. Developing ANN models for nonlinear and time-varying systems could expand their use to a wider range of problems. Research into advanced ANN structures for handling wider input ranges and dimensions could make these systems more versatile. Other important areas for future research include finding ways to reduce the need for large training datasets, incorporating EM and multi-physics concepts into ANN modelling, and focusing on inverse modelling for faster design solutions. Additionally, applying machine learning to speed up design processes will be important. Further research is also needed to explore the various ways ANNs can be used in pattern recognition problems, object classification, location problems, and fault recognition in machines and plants. Investigating ensemble methods to improve time-series forecasting and exploring boosting techniques for better predictions are also promising areas. Enhancing LSTM networks for weather forecasting and using advanced data mining techniques for better weather predictions are future research directions. Implementing ANNs for real system analysis, refining activation functions and neurons for better problem-solving, and comparing different training algorithms for neural networks are also important. Lastly, exploring ANNs use in mobile edge caching and resource allocation in UAV-based wireless networks could lead to new advances in these areas.

CONCLUSION

The diverse applications of Artificial Neural Networks (ANNs) in various fields demonstrate their effectiveness in capturing complex behaviours and modelling nonlinear relationships. ANNs have shown promise in wireless networking for their ability to model intricate network behaviour. In internal combustion engine modelling, ANNs efficiently capture nonlinear relationships. For power system voltage stability, ANNs like CFBNN and RBFNN offer effective stability assessment, though with limitations on specific test systems. In weather prediction, ANNs provide accurate modelling of non-linear weather patterns. In construction project bid evaluation, ANNs offer fair and objective evaluation with parallel processing capabilities. In automatic modelling, ANNs like GRNN effectively identify outliers and trends, but generalizability might be a concern. In batch/semi batch process modelling, ANNs handle process complexities well. However, challenges exist, such as limited data access for pattern recognition and potential degradation of accuracy in fibre bend detection with high noise levels, warranting further research. Overall, ANNs continue to be a valuable tool in various domains, with ongoing efforts needed to address specific challenges and improve their applicability.

Acknowledgements

We would like to express our sincere gratitude to all those who contributed to the completion of this review. Firstly, we extend our heartfelt appreciation to the authors of the primary studies we analysed, whose research laid the foundation for our work. We are also grateful to the faculties whose insightful comments and suggestions significantly improved the quality and clarity of this manuscript. Additionally, we acknowledge the support and guidance provided by our friends and mentors throughout the writing process. Lastly, we would like to thank our families for their unwavering encouragement and understanding during this endeavour.

REFERENCES

1. Chen M, Challita U, Saad W, *et al*. Artificial Neural Networks-Based Machine Learning for Wireless Networks: A Tutorial. *IEEE Commun Surv Tutor.* 2019; 21(4): 3039–3071.
2. Mohanasundaram N. Non linear predictive modelling for IC engine using artificial neural network. In 2020 IEEE 4th International Conference on I-SMAC (IoT in Social, Mobile, Analytics and Cloud)(I-SMAC). 2020 Oct 7; 801–807.
3. Subramani C, Jimoh AA, Kiran SH, *et al.* Artificial Neural Network based voltage stability analysis in power system. *IEEE 2016 International Conference on Circuit, Power and Computing Technologies (ICCPCT), Nagercoil, India.* 2016; 1–4.
4. Fente DN, Singh DK. Weather forecasting using artificial neural network. In 2018 IEEE 2nd international conference on inventive communication and computational technologies (ICICCT). 2018 Apr 20; 1757–1761.
5. Wang Y, Sun L. Applying artificial neural network to build engineering project bid evaluation system. In 2011 IEEE 2nd International Conference on Artificial Intelligence, Management Science and Electronic Commerce (AIMSEC). 2011 Aug 8; 211–214.
6. Yan W. Toward automatic time-series forecasting using neural networks. IEEE Trans Neural Netw Learn Syst. 2012 Jun 1; 23(7): 1028–39.
7. Abiodun OI. Comprehensive Review of Artificial Neural Network Applications to Pattern Recognition. *IEEE Access.* 2019; 7: 158820–158846.
8. Feng F, Na W, Jin J, *et al*. Neural Networks for Microwave Computer-Aided Design: The State of the Art. *IEEE Trans Microw Theory Techn.* 2022; 70(11): 4597–4619.

9. Ganesh B, Kumar VV, Rani KY. Modeling of Batch Processes Using Explicitly Time-Dependent Artificial Neural Network. *IEEE Trans Neural Netw Learn Syst.* 2014; 25(5): 970–979.
10. Tanaka T, Kawakami W, Kuwabara S, *et al*. Intelligent Monitoring of Optical Fiber Bend Using Artificial Neural Networks Trained with Constellation Data. *IEEE Networking Letters.* 2019; 1(2): 60–62.

