

A-State-Of-Art Review on The Advances and Applications of Artificial Neural Networks

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Abstract

In field of Artificial Intelligence (AI), Artificial Neural Networks (ANNs) have been widely accepted as a cutting-edge computing technology. There is a lot to learn about AI and ANN in this study, which focuses on modern applications of these technologies. Using a combination of Neural Networks (NNs) and fuzzy logic, it hopes to improve the data's capacity to be interpreted. The past two decades, ANNs have been intensively explored and deployed as a major soft-computing technique. Pattern recognition, data analysis, control, and grouping are most common uses of NNs in problem solving. There are several advantages to ANNs, including rapid processing rates and the capacity to learn from examples. Research in this article focuses on the newest applications of NNs and offers an overview of the sector in which NNs are utilized. It explores how NNs play a key role in several fields, such as AI.

Keywords: Artificial Neural Networks; Artificial Intelligence; Neural Networks, Newest Applications

1. INTRODUCTION

As a branch of computer science, AI aims to build intelligent machines that can think and act like people. By copying the structure and behavior of the real brain, an ANN mimics its ability to learn.

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AI research has given rise to the phrase "neural network," which refers to models developed to better comprehend and simulate the functioning of the human brain. In computer science, AI is a branch that focuses on the construction of intelligent machines, systems that can think and act like people. The ANN has shown itself to be a superior option for handling complicated issues in several fields in the last few years. The ANN has three layers: input, hidden and output. Various inputs are processed by hidden layers for creating desired output from them. NN efficiency is dependent on the learning method used for pattern recognition. An answer is provided for every input in every case of supervision learning, while in unsupervised learning, the correct answer is derived from prior assumptions and inferences; but it is unknown to the system in hybrid learning, which combines the best features of both supervised and unsupervised learning [1] [2].

1.1. ANNs

As extensions of mathematical models of organic nerve systems, ANNs have been established. After McCulloch and Pitts (1943) introduced simpler neurons known as connectionist models, there was a first wave of interest in neural networks. The ANN is collection of extremely basic processors (referred to as "Neurons"), each of which may have a (little) local memory. Local data and inputs received through unidirectional connections are all that the units have access to. There is a method for computing the output signal that is transmitted to other network units, as well as a rule for summing the signals that are flowing into the unit [3]. Calculation rules, according to Callen, are referred to as the activation function.

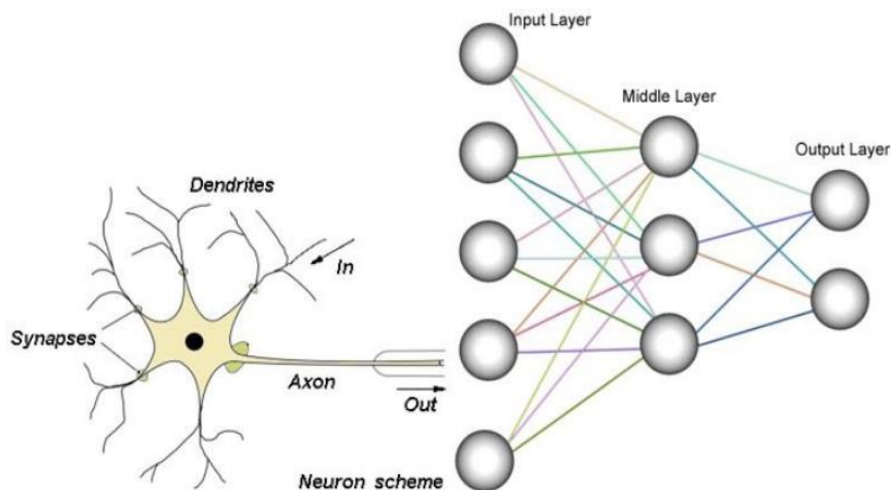


Figure 33 Biological vs. ANNs

Figure 1 depicts the three layers of a neural network. There are three layers: an input layer, a hidden unit that does computations based on functions supplied, and an output layer from which we get our

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results. The synaptic weights between neurons in NNs are how knowledge is stored. Until the output data is created, input data is sent through each layer of network. For example, if the output of a multilayer perceptron network is different than desired, an error is computed and transmitted through the network in reverse. As the mistake spreads, so do the synaptic weights. As of Late a silicon-based electrical network that is modeled on the human brain's workings and shape is seen in Figure 1. ANNs are so strong because they are able to generalize. When it comes to the human brain, it is able to recognize and retain patterns. In the same way, the NNs created can retain and learn patterns.

1.2. NN ARCHITECTURE

There are many different designs regarding the neural networks. Different aspects like the number of layers, learning methods and activation functions are all unique to each. NNs may be built in two basic ways:

- **Feed Forward NNs**

This kind of network allows just one path of signal flow, from input nodes to output nodes via hidden nodes. In feed forward neural networks, there is no feedback or looping. In these networks, perceptrons are structured into layers, much as in any other neural network. If you don't link hidden layer with either input or output layer, it won't work. It's dubbed a "feed forward NNs " since information is sent from one layer to other.

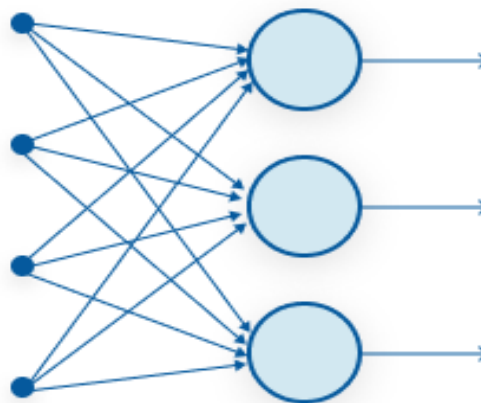


Figure 34 Feed forward NN

- **Feedback NNs**

When loops are included into feedback NN, signals may flow in both ways. Feedback signals are travelling from one layer to the next in computer architecture. As their name implies, feedback or recurrent networks are constantly changing their state until a sufficient answer is received.

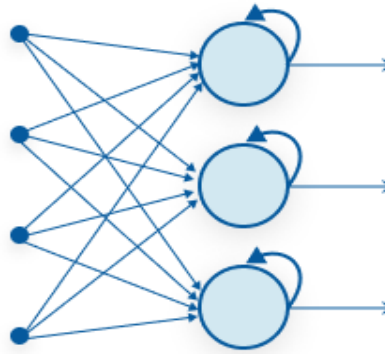


Figure 35 Recurrent/Feedback NN.

- **Feed Forward Back Propagation NN**

Basically, it's combination of two different kinds of NN. Back propagation refers to process by which networks learn to identify patterns, while feed forward refers to the technique by which the networks learn to recognize patterns. Essentially, "feed forward" defines how NNs learn and remember patterns.

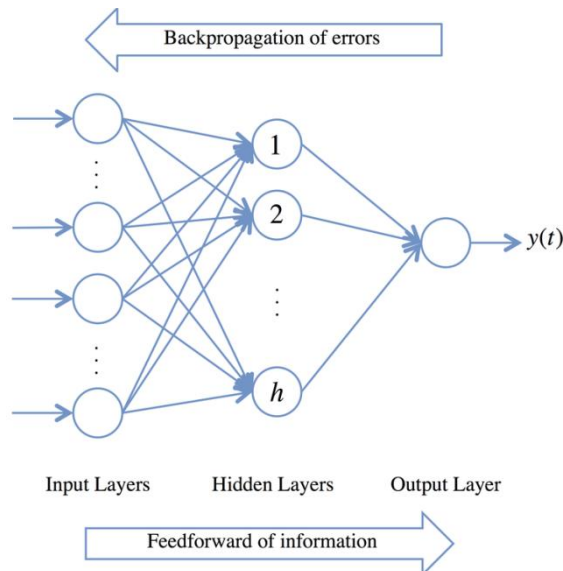


Figure 36 Feed forward back propagation NN

In order for back propagation to operate, network must be given input and the intended output. Errors are calculated by comparing expected results to actual results. Back propagation is a technique in which the NN's weights and input threshold are adjusted to reduce the computed error.

1.3. Activation Functions

The NN's behavior is strongly influenced by the activation function. Weighted inputs are combined with activation function to generate output response. The rate at which a cell fires, is abstracted by the activation function. Most NNs use activation functions to transfer the output of layers. The output of a NN is scaled by activation functions to the suitable range. For neurons in similar layer, same activation functions are employed for their activation.

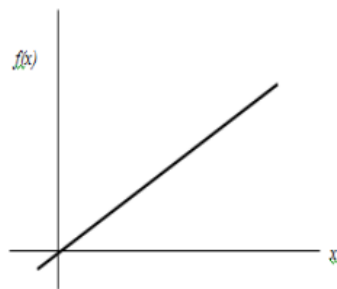
Activation functions that are often used include:

- **Linear Activation Function:**

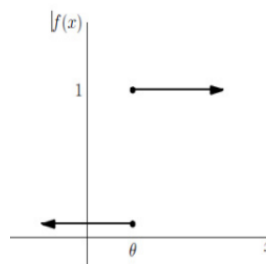
In single-layer networks, these functions are the most prevalent. In order to get the identity function, we use Equation

$$F(x) = x \text{ for all } x$$

As can be seen in Figure 5(a), the output has a constantly changing value.



(a)



(b)

Figure 37 (a) Identity activation function (b) Binary Step Activation Function

- **Binary Step Activation Function:**

Equation depicts the binary step activation function mathematically.

$$F(x) = 1 \text{ if } x \geq \theta = 0 \text{ if } x < \theta.$$

Where, θ indicates threshold value. Figure 5(b) shows its variation of output of function with input values.

- **Log Sigmoid Transfer Function:**

0 to 1 are the possible values returned by this function. Using Equation, we can determine the final output.

$$\text{LogS}(n) = \frac{1}{1 + \exp(-n)}$$

- **Hyperbolic Tangent Sigmoid Activation Function:**

Scaled between -1 and 1, this transfer function returns a result. The derivative of the hyperbolic tangent function makes it suitable for gradient descent-based training. Equation is used to determine the final result.

Networks with just one layer are the most usual place to find these functionalities. Equation represents the identity function.

$$n = \frac{2}{(1 + \exp(-2 * n))} - 1$$

2. APPLICATIONS OF ANNs

ANNs may be used in variety of fields, including medicine, business, agriculture, and more. For example, the outcomes are more accurate and quantifiable and error-free when employing ANNs. There are a slew of issues to contend with, including ANN training, implementation, NN interpretation, and the gathering of pertinent data. Table 1 provides a literature review of the numerous sectors in which ANNs have been used.

Table 3 Applications of ANNs

Area	Study	Results	References
Automotive	Prediction of engine performance, combustion and emission characteristics.	ANN models are designed to reduce error based on the Empirical Risk Minimization Approach (ERM).	[4]
Chemical industry	Production of bio-based chemicals or a bio refinery using ANNs	Biochemical processes, such as fermentation and anaerobic digestion, may benefit greatly from real-time, dynamical use of bio-chemical methods for quick parameter observing and management.	[5]
Pavement Engineering	Monitoring and maintenance. And pavement design, construction, inspection	Many of obstacles associated with using ANNs in pavement design and cost analysis are due to a lack of adequate data collecting and	[6]

		parameter optimization, as well as difficulties in model transferability and low-cost data annotations.	
Low-energy buildings	ANN -based smart aerogel	The design and operation of aerogel glazing systems may enhance multi-criteria performance (such as thermal, acoustic, and visual performance), raise economic competitiveness with optimum geometrical design parameters, and give realistic guidance for dependable system operations.	[7]
Plastic Waste	Plastic pretreatment, plastic type, mixing circumstances, percentage of addition, and bitumen characteristics were analyzed in this study.	Plastic waste in bitumens that may be used in both mild and hot regions. There should be no more than 5% added, so that the bitumen's workability does not suffer.	[8]
Photovoltaic cells	photovoltaic fault detection and diagnosis	The claimed success rate for categorization is more than 90%. Furthermore, comparisons of the suggested model's performance with those of other machine learning algorithms have shown its superiority in several circumstances.	[9]
Wastewater Treatment	ANN modeling of wastewater treatment and distillation make use of membrane methods	The employment of ANN approach instead of more traditional methods based on transport-based models has shown to be very effective. The ANN models that have been built may be utilized to simulate, control,	[10]

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		and optimize membrane process activities.	
Composite Materials	In the context of composite materials constitutive modeling ANN prototypes provide a number of advantages and drawbacks.	It seems that modern endeavours in the modeling of composite materials have shifted in the direction of the use of ANN prototypes in combination with physical tests and data science, creating an innovative new hybrid system that takes use of all the potentials of each component.	[11]
Solid Waste	ANN framework, algorithm, data set partition, input parameters, hidden layer, and performance evaluation	ANNs have been discovered to be extensively used in waste generation and technical parameter prediction and shown useful in tackling meso-microscale and micro scale concerns, involving waste conversion, emissions and microbiological and dynamical methods. Most studies used a sample size of 101–150 due to the difficulties in collecting data on numerous solid waste-related concerns. Data should be divided into three sets: Training, Validation, and Testing (TVT), with the training set accounting for around 70% of total data.	[12]
Micro grids	Distributed generation, scheduling, power sharing, supervisory control and optimization of micro grid distributed generating sources.	The non-linearity and parallel processing capabilities of (NNs), as well as other positive properties, make them well-suited to help MGs overcome the needs and obstacles they meet in the traditional power grid.	[13]

Audio signals	Classification of audio signals	For vast data sources, automated categorization method utilizing AI is more feasible than the manual categorization. Several kinds of AI estimations have been anticipated in writing like K-Nearest Neighbors (KNN) Principal Component Analysis (PCA), Gaussian Mixture Model (GMM), and Hidden Markov Model (HMM) etc.	[3] [14]
Surface Coatings	ANN modeling and optimization of surface coating process parameters	An ANN capable of performing complex nonlinear processes is the ideal choice for future studies on surface coating approaches.	[15]
Accuracy measurement	Extraction of Interpretability-accuracy balanced Rules from ANNs.	Approaches include Decomposition Approach, Pedagogical Approach, and Eclectics Approach, all of which examine the relationship between input and output, such as by calculating a gradient.	[16]
Solar Energy	Instrumentation for measuring solar irradiance and estimating solar power production based on this data	The appropriate control and correction of the solar irradiance equipment may increase predicting accuracy to some extent. This suggests that minimizing apparatus faults that determine the weather parameter might enhance solar forecasting accuracy.	[17]
Solar Energy Systems	prediction of different SE appliances working, like solar collectors, solar stills, solar supported heat pumps,	It is possible to forecast and improve the performance of solar energy equipment using ANNs.	[18]

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	solar dryers, solar air and water heaters, solar cookers, and PhotoVoltaic/Thermal (PV/T) systems.		
Health Care	health care organizational decision-making	In setting of complicated, unstructured, or restricted information, ANN-based solutions applied on the mesa- and macro-level of decision-making reveal the potential of its usage. Ethical, social, and economic considerations may need to be better understood before ANN can be successfully implemented and adopted in health care organizations. PLOS ONE	[19]
Modularization	ANN modularization methods	Modular Neural Networks (MNNs) are NNs that represent the perceptions and principles of modularity	[20]
Environment	Management of odors in the environment using an ANN—measuring and describing, controlling and treating—as well as continuously monitoring.	The robustness of ANN outcomes is shown in terms of strong correlation (R^2), decreased residuals (RMSE) and excellent classification scores when compared to conventional statistical approaches. ANN was also able to adapt to the data set, particularly when it came to developing a well-defined pattern despite the presence of background disturbances.	[21]
Forecasting	Time series forecasting	Despite the fact that several research has examined the use of	[22]

		NN models for forecasting, only a few have developed novel models that take into account theoretic support and a systematic approach while building the model.	
Chemical engineering	Application of ANNs for Catalysis	The study illustrates how ANNs may be used well for catalysis estimate, the design of novel catalysts, and the sense of catalytic structures.	[23]
Medical	Lung Cancer Detection	Detecting lung cancer early is crucial because treating lung cancer becomes progressively difficult as the disease progresses and because the endurance rate of lung cancer patients in later phases is quite poor. The ANN model is especially beneficial in this scenario.	[24]
Food	analytical chemistry and specifically of food control.	Their adaptability and capacity to deal with extremely non-linear patterns in the data allowed for considerably excellent outcomes in many situations for which the employment of classic chemometric approaches failed.	[25]
Commercial Hardware	training and implementing the ANN within a computer	It represents model and monitor the temperature inside of a kiln for the ceramic industry and evaluation of ANNs and neuro-fuzzy methods utilized for developing and operating a real system.	[26]
Medical	ANNs are being used in the fields of cancer, critical care,	NNs have a place in clinical verdict support, but their	[27]

	and cardiovascular medicine to improve clinical diagnostics, prognosis, and survival analysis outcomes.	attainment depends on a number of factors, which include improved combination with clinical protocols, an understanding of the requirement of combining various patterns to produce the easiest and most universal overall perceptive structure, and a willingness and ability to estimate this in a real clinical environment.	
Composite Materials	Fiber-reinforced polymeric composite material mechanical behavior simulation modeling.	Further study is needed to improve the prediction capacities of NNs, such as finding the right design, number of hidden layers, and number of neurons in each hidden layer, among other things.	[28]

3. CONCLUSION

As a general solution for many different issues, including control and pattern recognition, ANNs have gained popularity. Approaches based on NNs have a lot to offer the computer industry. As a result, they are very adaptable and strong. The inherent processes of a job do not need the creation of an algorithm in order to carry out that task. Parallel design makes them ideal for real-time applications because of their rapid reaction and calculation speeds. Computers that can think like humans are the ultimate objective of AI. The AI issue over the past decade has academics attempting to bridge the gap between human and AI.

In the future, AI will strive to create machines and computers that are much more advanced than they are now. It is predicted that robots with basic common sense, comparable to human humans, would be produced in the future, but only in specified sectors. Furthermore, it is anticipated that future intelligent robots would execute human-like mental activities such as learning by doing, learning by rehearsing, cognition, and perception.

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