# Applications of AI Techniques like Machine Learning Methods and Deep Learning Models (ANNs) in Emerging Areas: A Review

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**Abstract** In today's world, we come across numerous advancements in various fields of technology. In key areas, such as communication networks, microstrip antennas, signal and image processing (like speech and character recognition), Internet of things and embedded systems etc., there have been major breakthroughs aided and made possible through the use of artificial intelligence techniques such as machine learning and deep learning models (primarily including artificial neural networks). Some important developments propelled by the use of these techniques and its applications in the respective fields is what has been analysed in this paper.

**Keywords** Machine learning · Communication networks · Internet of things · Artificial neural networks · Speech recognition · Dynamic time warping · Microstrip antenna

## 1 Introduction

Important developments in various areas of technology today are aided by the use of Artificial Intelligence (AI) techniques, such as Machine learning (ML) and specific deep learning techniques like Artificial neural networks (ANNs) and their applications in the respective fields is relevant to be studied. Most of the modern emerging trends, such as next-generation communication networks, Internet of Things (IoT) and its corresponding embedded systems, antennas, signal and image processing, speech and character recognition, etc., are all boosted and developed further using AI. Looking into select few applications in such areas is helpful and gives a better understanding of how great the impact of different AI techniques has been in this modern era.

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# 2 Applications in Certain Fields

## *2.1 In Communication Networks and 5G Evolution*

For wireless communication network systems, ML methods are really useful and versatile as they are helpful in a vast set of different aspects pertaining to these wireless networks. For example, communication networks can use machine learning approaches to take use of big data analytics and observation-based decision making to create more efficient, independent and intelligent networks. Specifically, deeper ML techniques like reinforcement learning are as such utilised for aspects like independent decision-making. Along with this, a quite logical ML application is to use intelligent and predictive data analytics to improve situational awareness and overall network operations [1]. In this context, ML will enable the wireless network to parse through massive amounts of data generated from a variety of sources, ranging from wireless channel measurements and sensor readings to drones and surveillance images, in order to create a comprehensive operational map of the network's massive number of devices [2]. This map can then be used to enhance numerous services across the wireless network, such as fault monitoring and user tracking. Similarly, much like the aid provided by ML, ANNs are proposed for major applications in the wireless communication domains. They can be used for a variety of reasons, such as for predictions, inferences and intelligent and predictive analytics. ANNs in wireless networks can also be used to enable self-organising network operations by implementing ANN-based ML at the network's edge as well as across its multiple components [3].

ML is also a really promising AI method designed to support modern radio terminals, such as smart 5G mobile terminals [4] and 5G networks, which rely on the support of ML techniques, because they require huge amounts of data to accurately forecast actions, for which ML is really helpful. This acts as a perfect support for 5G, because it can carry more data at a faster rate than current networks [5]. The ML techniques also help the network in this scenario to autonomously gain access to the most valuable spectral bands with the help of sophisticated spectral efficiency learning and inference, in order to control the transmission power [4]. And also, by integrating ML into 5G technology, mobile devices will be able to construct dynamically adaptable clusters, based on learnt data and intelligent base stations will be able to make decisions for themselves. Due to this, network applications could become more efficient, have lower latency and be more reliable as a result. A large number of users are expected to be connected to several thousands of network nodes in such modern communication networks. By providing quick, flexible, adaptable and intelligent control, neural networks can help enhance the development of this new telecommunication infrastructure [6].

## 2.2 Application in Internet of Things (IoT)

The internet of things, or IoT, is a network of interconnected computing devices, mechanical and digital machinery that enables network data transfer without the need for human-to-human or human-to-computer interaction. One of the most crucial goals of IoT is to improve the quality of life for humans by reducing the physical interaction between humans and the devices. Thus, we see that techniques involving ANNs can be used to predict and analyse the user's behaviour to provide advanced information for the IoT devices. However, using ANNs for IoT has its own drawbacks. The practical deployment of an IoT system faces a number of obstacles [7], which include aspects like data analytics, computation, transmission capabilities, connectivity issues, end-to-end latency and security [8]. Another problem is that with the IoT, both energy and computing resources are limited. As a result, the energy and computational costs of training ANNs should be weighed against the accuracy requirement of a specific ANN-based learning method [3]. The higher the needed accuracy, the more computational and energy resources are required.

This is where the implementation of the big-little approach for IoT systems [9] is quite helpful in providing a solution as it works on the concept of taking a large trained neural network for a certain classification problem, and using it to distil a smaller neural network that only classifies a well-chosen subset of the output space. This smaller neural network is best suited for execution locally on embedded devices; whether or not the input is additionally transferred to the Cloud for evaluation with the larger neural network depends on the application's needs (Fig. 1).

This representation of the big-little neural network, depicts how the little neural network shown, is able to group just select output classes while being processing with less power from CPU. The findings obtained through the testing carried out in [9] suggest that prioritising a certain class can reduce the number of calculations required to get the same performance after classification. This can improve the overall network respond faster while retaining the same level of accuracy.

## 2.3 Applications in Microstrip Antennas

In telecommunications, a microstrip antenna (MSA) is the one that is produced on a printed circuit board (PCB) using photolithographic processes and it is similar to an internal antenna (as required in the system on chip integration). Microwave frequencies are where they are most commonly employed as at lower frequencies (<500 MHz) their size becomes larger. These antennas have grown in popularity in recent years as a result of their thin planar design, which may be accommodated into the surfaces of consumer goods, aeroplanes missiles, etc., and also due to their ease of manufacture by utilising printed circuit methods.

In the subject of communication, neural network modelling has been widely employed as a computational method to solve a variety of practical problems. In

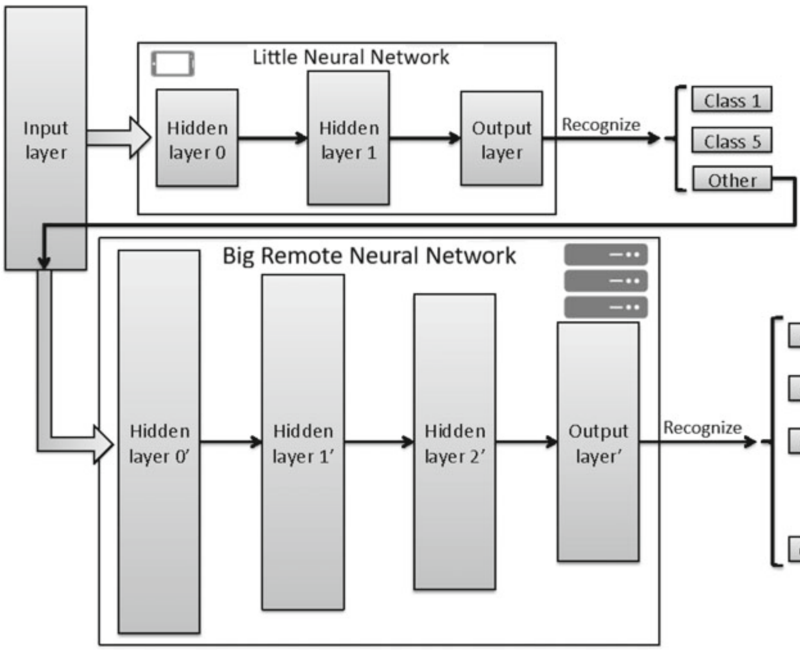


**Fig. 1** A diagrammatic representation of the big-little network, which allows reduced usage of the CPU system for its execution [9]

the context of MSAs, the ANN models for certain MSAs like the rectangular MSA (RMSA) and equilateral triangular MSA (ETMSA), have been found to provide a really accurate prediction of patch dimensions for a broad range of frequencies as well as substrate thickness [10, 11] (Fig. 2).

The above provided model is based on the supervised network. It gets trained via input and target data. With the aid of target data, the ANN learns from the input data and transforms it into the desired output. This particular model displays input neurons, that represent dielectric constant ($\varepsilon_r$), RMSA resonant frequency ($f_r$),

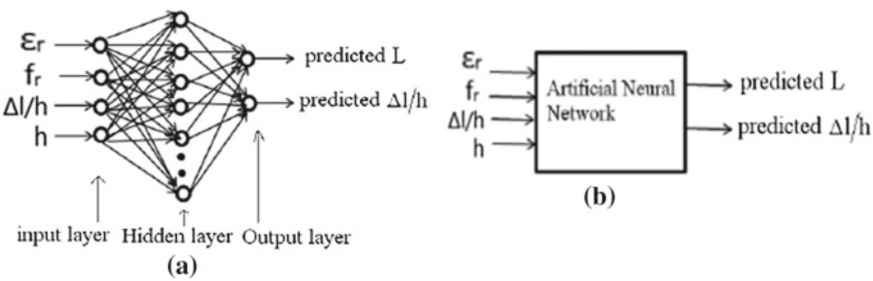


**Fig. 2** **a**, **b** ANN Model representation of the RMSA (coaxially suspended) [14]

thickness of the air substrate ($h$) on which the RMSA is present and '$\Delta l/h$', where '$\Delta l$' is the fringing field length extension. The equations to calculate '$\Delta l$', patch width '$W$' using patch length '$L$', and '$f_r$' are provided in [12, 13]. Using the data from input neurons at different resonant frequencies, the patch side length '$L$' and '$\Delta l/h$' can be predicted. For the predicted values, the experiment conducted in [10] is able to show how the model is useful in aiding to design RMSA for different substrates on any frequency. That depicts the importance of the predictive ability of ANNs as we can see in this case for MSAs.

## *2.4 Speech and Character Recognition*

**Speech Recognition**: Human-to-human communication relies heavily on speech. As a result, users have evolved to expect spoken computer interfaces. We still require sophisticated languages that are difficult to learn and utilise in order to communicate with robots in the modern era. automatic speech recognition (ASR) is quite helpful remedy in this case. It is a computer science and computational linguistics multi-disciplinary topic that develops approaches and technology that allow computers to recognise and translate spoken language into text.

Hidden Markov Models (HMMs) [14] are some important ML models used in developing several speech recognition systems. Because a voice signal can be considered as a piecewise stationary signal or a short-time stationary signal, HMMs are utilised in speech recognition. Speech can be approximated as a stationary process for a small-time frame. For many stochastic applications, speech can be thought of as a Markov model. Also, HMMs are used to provide effective frameworks for designing time-varying spectral vector sequences [15]. Due to this, these models are found in practically all current large vocabulary continuous speech recognition (LVCSR) systems.

Apart from the usage of HMMs, Dynamic Time Warping (DTW), is another special type of algorithm that is highly useful and impactful in speech processing. It helps with recognising the compatibility of sound [16] and this method is used to compare the similarity of a pattern across time frames. It is a sound-based algorithm that determines the best warping path among two datasets and outputs the path warping values as well as the distance between them. The warping path is the separation between two patterns when compared; the narrower the warping path, the more similar the two patterns are.

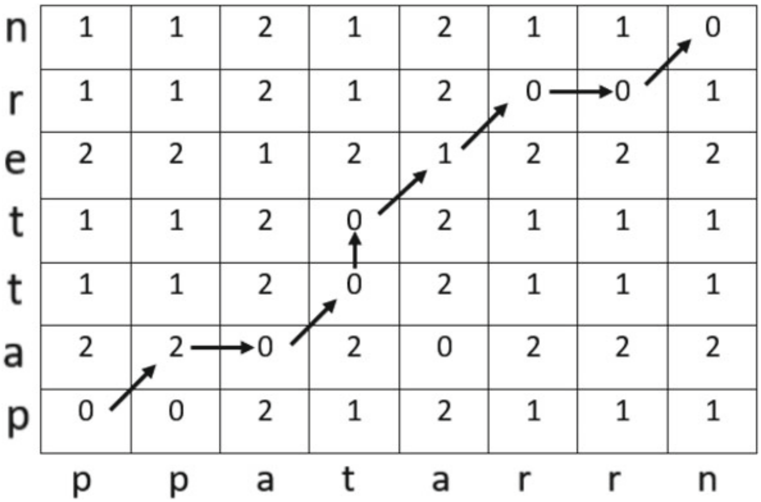


**Fig. 3** A cost matrix diagram to show the DTW to compare 2 words (the reference word on the vertical axis and speech input word on $Y$-axis), with a particular warping path indicated

Words when spoken by different people can have different time periods or structures as compared to the original word when analysed by a recognition device (or application), such as in the diagram given above (where the reference word is "PATTERN", but the input word is "PPATARRN"). DTW solves this issue by correctly arranging words and determining the shortest distance between the two words [17]. The purpose of DTW is to use dynamic programming (DP) to find the optimum mapping with the shortest distance (which is realised by formulating a program code for it). Because both $x$ and $y$ are usually vectors of time series, we need to compress or expand in time to obtain the optimal mapping, the approach is termed "time warping."

For this particular method, looking at Fig. 3, the values in each position indicate the relation ($d[I][J]$) between the corresponding row and column letters. So, if the particular row and column letters are different consonants, then the value at that position is 1. Similarly, the value will be 2 for a vowel and consonant pair, and 0 if the letters are same. To find the optimum distance, for each step we will take the distance (value) between each of the points in question and add it by the shortest distance we've determined so far. This gives us the best distance between two sequences up to that point. The formula becomes

$$\text{Table}[I][J] = d(I, J) + \min(\text{Table}[I-1][J], \text{Table}[I-1][J-1], T\text{able}[I][J-1] \quad (1)$$

$I$, $J$ are the indexes of the present position (labelled from 0 till the end on the respective axes). Initially the value of "Table" will be 0, but moving along the different warping paths will provide different final values. The lowest possible value results in getting the best match. This ultimately helps us determine the shortest and most optimum distance through the matrix which helps in providing the best possible match for the word via the speech recognition application which utilises this method. This is how dynamic time warping can be very helpful as a technique to help build such AI-based speech recognition devices/applications.

**Character Recognition**: Character identification is a fascinating subject that falls within the Pattern Recognition umbrella. Many neural networks have been designed to recognise handwritten characters, whether letters or digits, automatically. The advantage of neural networks over other pattern recognition systems is that they give the designer a lot of flexibility [18], allowing expert knowledge to be incorporated into the architecture to reduce the number of parameters set by training by examples.

Following are some ANNs which have been used for character recognition.

- Multilayer neural networks such as Backpropagation neural networks.
- Neocognitron.

The pattern of connection from one layer to the next is localised in backpropagation neural networks, despite the fact that there are numerous hidden layers. Similarly, neocognitron contains numerous hidden layers, and training for such applications is done layer by layer.

### *2.5 Other Miscellaneous Applications*

Neural networks are capable of learning, adapting to changes, and simulating human thought processes with a minimal human input. They could be extremely beneficial to today's computer-integrated manufacturing systems as well as future intelligent manufacturing systems [19]. Traditional rule-based decision support systems [20] are becoming obsolete as advanced production systems become more complex and dynamic. In all facets of manufacturing operations, neural network technology is gaining traction. Apart from this, ANNs are useful for various other applications as well because there are several characteristics/attributes that make them quite effective. The table provided below depicts some of the key attributes of ANNs and the specific areas where their applications come in handy.

While discussing the different areas where ML and other techniques like ANNs are applied extensively, we can also refer to certain data which represents the expected increase in adoption/implementation of some of these emerging trends in a collection of surveyed companies in 2025 (compared to the same data from 2018) (Table 1).

These chart values give a clear indication of the upward rise and growth in the implementation of these mentioned modern technologies within the different sectors that the surveyed companies belong in. And this is helpful in understanding the importance and relevance of these technologies that are supported by AI methods, as they are expected to fuel future growth in a variety of industries, as well as boost demand for new job types and skill sets. As such, this is just one of the various several

**Table 1** Some applications of ANNs that are based on their most distinctive attributes

| Attribute | Description | Application example |
|---|---|---|
| Adaptive learning | Neural networks model complex and non-linear relationships and algorithms, and improve on their existing knowledge | They exhibit Adaptive learning in different aspects such as for improving accuracy in predictive analysis and pattern recognition and by adapting to the most optimal model and changing inputs while training |
| Self-organisation | The ability to gather and classify large volumes of data makes neural networks uniquely suited for organising the complicated visual problems posed by medical image analysis | Self-organizing neural networks (SONNs) help create maps of input data and are used for classification and visualisation of higher dimensional data in lower dimension |
| Real-time operation | Neural networks can help in forming a large array of algorithms, that are capable to help shape up the design of devices which require quick and simple responses in real time | ANNs help in developing driverless vehicles that have the ability to recognise and respond to their surroundings in real time, allowing them to safely navigate. Another example of its real-time operation is in designing of AI-based drones for navigation |
| Fault tolerance | It is the property that allows an ANNs to operate suitably in the event of one or more components being lost. They enable the systems with fault to immediately replace faulty components with backups | It is a highly useful attribute especially necessary for systems requiring security, data protection, data integrity, etc. |
| Prognosis/forecasting | Some multi-layer ANNs contain hidden layers of nodes, and through the various input–outputs of this nodes, they are able to analyse and predict outcomes | On time series data, such as weather data, ANNs can be utilised to create predictions |

methods using certain simplified data to showcase the rise of AI and its impact on the industries of today and in general on the entire world (Fig. 4).

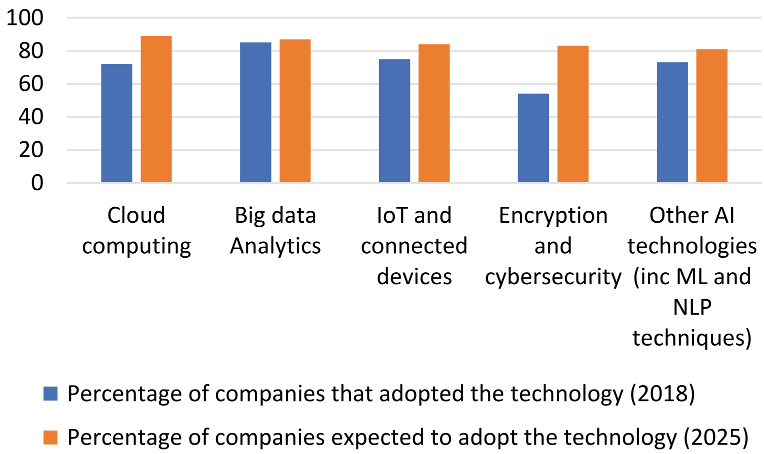


**Fig. 4** Percentage comparison of the emerging trends being adopted in companies surveyed in 2018 versus its expected values in 2025 ( Source—Future of Jobs Survey 2020, World Economic Forum)

## 3 Conclusions

In this paper, we have gone through some key areas such as next-generation communication networks, IoT, microstrip antennas, speech recognition, etc., wherein modern AI techniques such as machine learning applications and deep learning Artificial neural network methods. For some of the aspects such as in IoT or speech recognition, etc., we have looked into techniques like Big-little neural networks, HMMs, Dynamic Time Warping and others as well. Some of the key characteristics/attributes of ANNs and their uses are also put forward to give some added insight into their modern-day resourcefulness. Also, we have analysed some data with regards to a few miscellaneous applications of AI techniques to showcase how here has been positive growth in their implementation in several surveyed companies of different industries.

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