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Techniques and Applications for Deep Learning: A Review

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ABSTRACT

Deep learning is a branch of machine learning that focuses on the development and refinement of complex neural networks for data analysis, prediction, and decision-making. Deep learning models use numerous layers of artificial neurons to automatically extract important features from raw data, making them superior at many tasks to typical machine learning models. Deep learning models' success in these fields has enhanced state-of-the-art performance and created new research and application prospects. Deep learning has been popular due to its capacity to tackle complicated issues in computer vision, natural language processing, speech recognition, and decision-making. In this study, we discuss deep learning techniques and applications, including recurrent neural networks, long short-term memory, convolutional neural networks, generative adversarial networks, and autoencoders. We also demonstrate deep learning's use in various fields. Deep learning has transformed artificial intelligence by enabling computers to learn from enormous datasets and accomplish complex tasks. As a result, scientists and engineers in fields as diverse as medicine, farming, manufacturing, and transportation have increased their focus on developing deep-learning methods and software. Current research trends and potential future paths in deep learning are also highlighted.

MSC.

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1. Introduction

Artificial intelligence (AI) which is the process of making machines as intelligent as the human brain, is when a machine can carry out tasks that people typically associate with human minds, such as learning and problem-solving. Machine learning is a subset of AI and deep Learning is the subfield of machine learning that focuses on the creation and education of artificial neural networks. With the advent of deep learning techniques, it is now possible for computers to learn from large datasets and make highly accurate predictions or decisions [1] Convolutional neural networks (CNNs) are widely used in deep learning for image recognition and computer vision applications. CNNs are commonly used for tasks like object detection, image classification, and facial recognition because of their ability to recognize patterns and features within images. Recurrent neural networks (RNNs) are another useful method; they

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are frequently employed in natural languages processing tasks like language translation and text classification. RNNs are used for pattern recognition and are optimized for use with sequential data like text and speech. Many other deep learning architectures and frameworks are also widely used in academia and the business world. Autoencoders, generative adversarial networks(GANs), and reinforcement learning are some examples [2].

Computer vision, speech recognition, NLP, autonomous vehicles, healthcare, and a great many other fields can all benefit from deep learning. For instance, deep learning is used in speech recognition systems, medical imaging for the detection of tumors and other abnormalities, and self-driving cars for object and pedestrian recognition[3]. Researchers and practitioners use Python and other programming languages, frameworks like TensorFlow and PyTorch, and specialized hardware like GPUs to develop and apply deep learning techniques. Additionally, model selection, evaluation, and hyperparameter tuning are all part of deep learning's process. The healthcare, financial, and advertising sectors, medical image analysis, drug discovery, and patient diagnosis are just some of the healthcare applications of deep learning[4]. Fraud detection and risk assessment, customer segmentation, recommendation systems, and personalized advertising are just a few examples of how deep learning is being put to use in the world of marketing.

In this research, we have touched upon some of the fundamental concepts and applications of deep learning. As deep learning continues to advance and impact numerous fields, it is essential to stay up-to-date with the latest techniques and tools to effectively apply this technology to real-world problems [5]. Overall, deep learning has the potential to revolutionize many industries and create new opportunities for innovation and growth. As the field continues to evolve, it will see new techniques and applications that emerge. Deep learning techniques are briefly discussed in Section 2, deep learning frameworks are highlighted in Section 3, and deep learning applications are summarized in Section 4. Finally, Section 5 gives a conclusion of the study.

2. Methodology of deep learning techniques

Deep learning networks are including several types:

- Multilayer Perceptron Networks (MLP)
- Convolutional Neural Networks (CNNs)
- Recurrent Neural Networks (RNNs)
- Long Short-Term Memory (LSTM)
- Autoencoders (AE)
- Generative Adversarial Networks (GAN)

Parameters, applications, and input data all vary amongst these models, and unsupervised pre-training and supervised fine-tuning are the two main training strategies for modern deep learning systems [6].

2.1. Multilayer Perceptron Networks (MLP)

A multi-layer perceptron (MLP) is a type of artificial neural network that uses feed-forward. In supervised learning problems, we employ feedforward networks or multilayer perceptron networks. The architecture of an MLP consists of at least three layers of nodes: an input layer, one or more multiple hidden layers of computation nodes in the dataset's hidden layers to capture more intricate correlations, and an output layer and propagation for training[7]. Backpropagation is a supervised learning technique used to train the network. Each node, except the input nodes, is a neuron with a nonlinear activation function. The multilayer perceptron is the simplest type of deep neural network (MLP), which is also referred to as a "deep feedforward neural network" (DFN), Figure 1 illustrates an MLP [7].

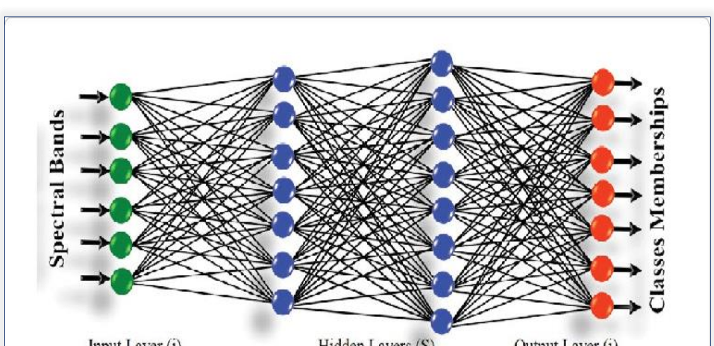

Figure 1. Multilayer Perceptron Networks.

2.2. Convolutional Neural Networks

A simple convolutional neural network (CNN) is described as a set of convolutional layers connected by pooling layers and non-linearity to transform one type of activation received at one end into a different type of activation received at the other end using a loss function. It is best to divide a picture into overlapping image tiles and submit them to a tiny neural network rather than feed the network an image as a grid of numbers. The network's very good feature extractor, which is even better than handcrafted features, however, requires more time to train and test as the number of nodes grows. ConvNet adjusts its weight to provide the appropriate output by backpropagation, as depicted in Figure 2 [8].

2.2.1. CNN Architecture

- **Convolutional layer**: Filters or kernels for convolutional computation are used to create convolutional layers. These filters divide the entire image into three or five small grids and then convolve these small grids with kernels or filters to create a feature map. In CNN the convolution layer is the most crucial one because it takes up the majority of the network's time, extracts local spatial data, and performs the majority of the computationally intensive tasks[6].
- **Pooling layer:** This layer is added after the ReLU layer and before the convolutional layer, the pooling layer promotes translational invariance in networks, strengthens the output features' resistance to feature relocation in the image, and helps prevent overfitting[6].
- **Fully-connected layer:** This layer is in charge of carrying out the entire process by taking input from all feature extraction layers and doing a global analysis of the output from all preceding layers. It is fully connected to all activations of the previous layers[6].
- **Activation functions:** Activation processes help neural networks make decisions and learn intricate aspects from incoming images. When learning complicated patterns from raw input data, using the right activation function can speed up the training process [6].

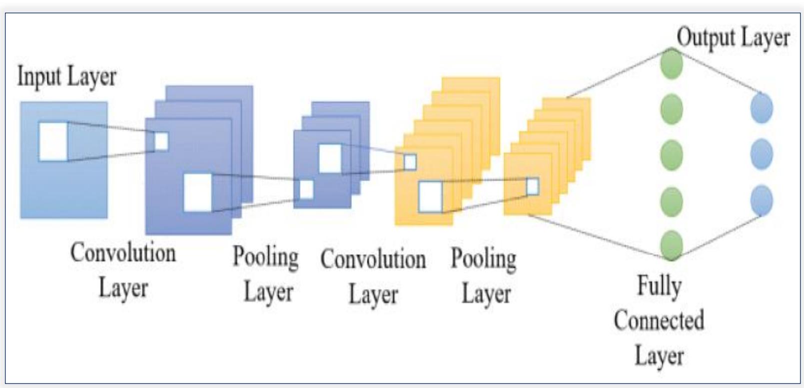

Figure 2. Convolutional Neural Networks architecture.

2.2.2 . Transfer Learning

Convolutional neural networks (CNN) were trained on a large and diverse dataset (ImageNet). Deep learning models develop model weight and bias while being trained with a big volume of data, then alternative network models are tested using these weights. Pre-trained models are used since learning a network from scratch can take weeks and requires more processing power when training massive models on massive datasets. Using weights that have already been trained to train the new network helps speed up learning [9]. The two most popular methods include using models that have undergone extensive pre-training and fine-tuning. These models can be applied directly or through transfer learning, and they can be modified as necessary the model can be pre-trained using publicly available datasets, and the feature extractor settings can be reused [10]. In recent years have seen considerable advancements in deep network architecture with numerous pre-trained models already present in libraries, Keras and TensorFlow. There are many pre-trained architectures available, such as VGG16, VGG1, GoogleNe, ResNet50, InceptionV3, MobileNet, and Xception. The convolutional network architecture used by the VGG and AlexNet networks is conventional[11]. MobileNet is an Xception architecture that has been simplified and is tailored for mobile apps.

EfficientNet, ResNet, Inception, Xception[12], and RegNet architectures, as a result of their adaptability, have become reference points for future studies on computer vision [11].

2.3. Recurrent Neural Networks

The original application of backpropagation was for training recurrent neural networks (RNNs). When the task at hand calls for sequential inputs, RNNs are often the preferred choice. For example, speech and language can process an input sequence element by element and store a state vector in their latent units, which contains implicit knowledge of the history of all elements in the sequence. It is possible to train RNNs with backpropagation, as shown in Figure 3 [13], by treating the outputs of the hidden units at different discrete time steps as though they were the outputs of different neurons in a deep multilayer network.

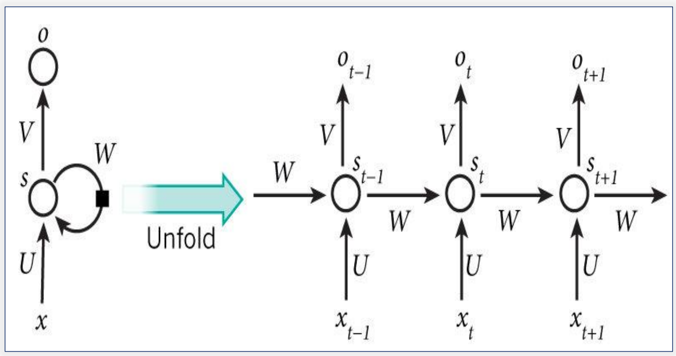

Figure 3. Recurrent Neural Networks architecture.

2.4. Long Short-Term Memory

An application of a recurrent neural network is the LSTM; in contrast to feed-forward network topologies, the LSTM can remember previous states and be taught for tasks requiring memory. Gradients can flow through LSTM without being altered, which overcomes a significant RNN constraint. Due to RNN's ability to retain information in both long-term and short-term memory, it is possible to utilize it to predict time series. As illustrated in Figure 4 [14], Signals pass through blocks of memory cell state in an LSTM, It is managed by input, forget, and output gates.
These gates regulate the cell's methods for storing, reading, and writing information. Long Term dependencies can be tracked using LSTM recurrent neural networks, as a result, sequential data and models that rely on context and previous states are well suited to these learning strategies. LSTM-blocked cells store important info from earlier states and the cell values needed to generate the LSTM block's output are determined by the input, forget, and output gates respectively [15].

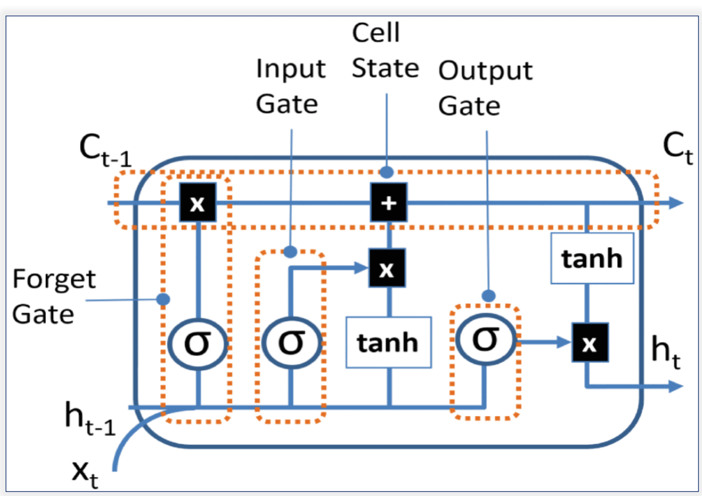

Figure 4. Long Short-Term Memory architecture.

2.5. Autoencoders

Autoencoders are neural network (NN) algorithms that are used to efficiently code a dataset to reduce its dimensionality. One key advantage of the AE is that it can continuously extract useful features while propagating and filtering out useless information. Input is compressed and then decoded to reconstruct it; lower hidden layers are used for encoding, and higher hidden layers are used for decoding. Layers for decoding and error back-propagation are used for training[6]. To save on compute resources, autoencoders learn to decode compressed data by coding it in a supervised fashion and training just one layer for each operation. The autoencoder procedure uses a network to encrypt the data in the hidden layer if the input and output layers are more dimensional, this is known as feature compression, Figure 5 [15] shows a deep autoencoder representation.

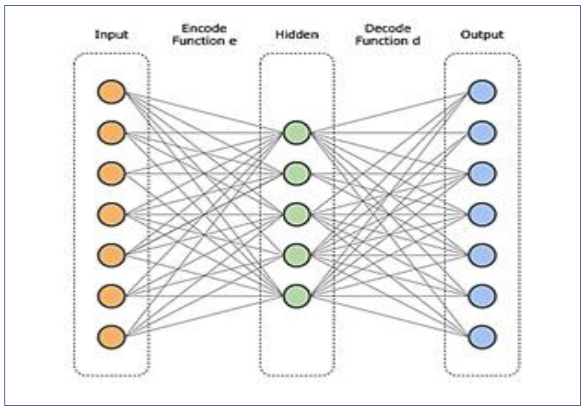

Figure 5. Autoencoders architecture.

2.6. Generative Adversarial Network

Through unsupervised learning, the generative model technique GAN may learn to replicate a certain information distribution. These algorithms efficiently strip the data down to its core characteristics or produce brand-new data points with unique characteristics. In several pictures generating tasks, such as text-to-image synthesis, super-resolution, and image-to-image translation, it has attained state-of-the-art performance. GAN can capture, duplicate, and analyze variations in a dataset since it takes two fundamental structure pieces (multiple neural networks) that compete with one another, as shown in Figure 6 [16]. Both of the networks are referred to as (Generators & Discriminators), while the discriminator neural net judges the validity of the created images, the generator neural network assists in the creation of new instances. The discriminator penalizes the generator for providing implausible results by determining whether or not each instance of data it analyzes belongs to the real training set. Insufficient data is a major barrier to the development of successful deep neural network models. But GANs are the answer for data augmentation in computer vision to reduce model overfitting, they generated realistic images that depart from the initial training data[17].

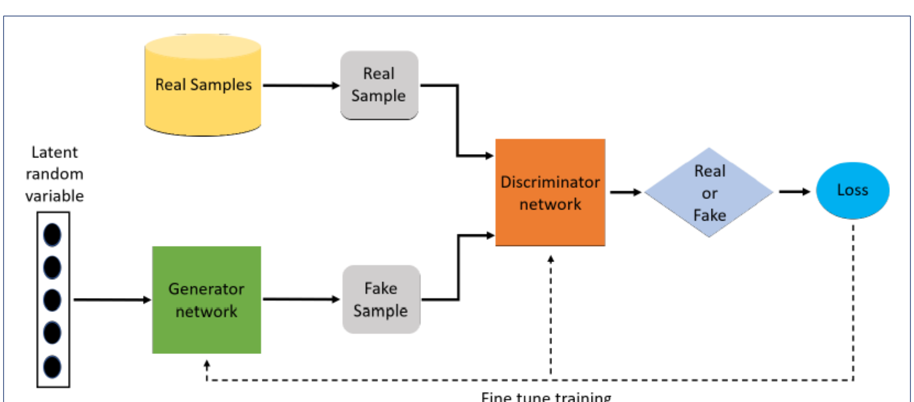

Figure 6. Generative Adversarial Network architecture.

3. Deep learning frameworks

- TensorFlow-supported languages include Python, C++, and R; created by Google Brain, it enables us to use both CPUs and GPUs for our deep learning models. A GPU code for image categorization can run up to twice as quickly as a CPU equivalent[18].
- Keras is an API, based on TensorFlow and developed in Python. It allows for quick experimentation and operates on both CPUs and GPUs and supports both CNNs and RNNs[18].
- PyTorch is capable of both doing tensor computations and creating deep neural networks. Tensor computations are offered via the Python-based library PyTorch using PyTorch and you can build computational graphs [18].
- Caffe was created by Caffe Yangqing Jiaadditionally, It's open-source. Regarding processing speed and picture learning, Caffe is superior to other frameworks, we may access pre-trained models through the Caffe Model Zoo framework which enables us to handle a variety of challenges[18].
- Deeplearning4 It is more effective than Python because it is implemented in Java, working with multi-dimensional arrays or tensors is possible thanks to the ND4J tensor package that Deeplearn-ing4j uses. It supports both CPUs and GPUs, images, CSV, and plaintext are all supported by Deeplearning4j[18].

4. Deep learning applications

In this section, we covered the techniques of deep learning networks, and their various applications are summarized in Table 1. And the different application fields of deep learning techniques with the methodology used and the purpose of that methodology is summarized in Table 2.

Table 1: Summary of network applications and articles of researchers.

Networks	Applications Domains	Year	Researcher
Multilayer Perceptron Networks (MLP)	Detection of liner surface defects in solid rocket motors	2020	Simões et al.[19]
	Prediction of financial distress	2022	Wu et al.[20]
	Prediction of the rainfall	2022	Hunasigi et al. [21]
	Future prediction	2018	Olawoyin et al.[22]
	Analysis of Patients suffering from influenza	2016	Sarangi et al.[23]
	Polyjet 3d printing: predicting color	2022	Wei et al. [24]
	Deepfake detection	2022	Kolagati et al.[25]
	Intelligently preparing for bankruptcy	2022	Brenes et al.[26]
	Image processing to ascertain the age and gender	2018	Avuçlu et al.[27]
	3D shape retrieval	2017	Avuçlu et al.[28]
	Purchases in B2B E-commerce	2017	Vincent et al. [29]
Convolutional Neural Networks (CNNs or ConvNets)	Visualizing a sentiment classifier	2020	Chawla et al. [30]
	Covid-19 automatic detection and classification using X-Ray	2021	Thakur et al. [31]
	Differentiating artifacts	2021	Real et al.[32]
	Drone recognition using radar	2022	Garcia et al. [33]
	Distraction detection for drivers automatically	2022	Uzzol et al.[34]
	Classification of remote sensing scenes	2016	Nogueira et al.[35]
	Segmentation of medical images 3D(CNN)	2021	Niyas et al.[36]
	Air quality forecast	2021	Chauhan et al.[37]
	A brain capable of MRI segmentation	2020	Thyreau et al. [38]
	Automatic inspection for defects in CFRP thermograms	2019	Saeed et al.[39]
CNN Pre-Trained Models	Efficientnet-B3: automatic Covid-19 screening uncertainty	2022	Gour et al.[40]
	Efficientnet: classification of land cover images	2021	Papoutsis et al.[41]
	Resnet-34: diabetes retinopathy diagnosis	2021	Moosawi et al. [42]
	Alexnet & Googlenet: Recognition of handwritten characters	2020	Mohammed et al[43]

	Vgg-16: recognizing student behavior in the classroom	2021	Abdallah et al. [44]
	Alexnet, Googlenet: system of face recognition	2021	Alhanaee et al. [45]
	Vgg16, Vgg19, Alexnet, InceptionV3: Recognizing multiclass sign language words for the deaf and dumb	2021	Islam et al. [46]
	InceptionV3, Mobilenet: mapping tree species in RGB pictures	2022	Carvalho et al.[47]
	Vgg-16: recognizing hockey activities	2020	Rangasamy et al. [48]
	Vgg: classification of multi-crop leaf disease images	2020	Paymode et al. [49]
	Mobilenet-V1 & Resnet: vehicle type classification	2022	Taqiyuddin et al.[50]
Recurrent Neural Networks (RNN)	System for detecting intrusions	2023	Kasongo[51]
	Text sentiment analysis	2022	Onan [52]
	Prediction of the Covid-19 mortality risk change	2023	Villegas et al.[53]
	Time series prediction for pore-water pressure	2021	Wei et al.[54]
	Arrhythmia classification using the ECG	2022	Falaschetti et al.[55]
	Methodology for predicting crop rotation	2023	Dupuis et al. [56]
	E-commerce review classification and statistical analysis	2018	Agarap [57]
	Anomaly detection in data from aircraft	2016	Nanduri et al. [58]
	Botnet detection for smart homes	2021	Popoola et al. [59]
Long Short-Term Memory (LSTM)	Identifying dangerous construction conduct	2021	Kong et al.[60]
	intelligent power distribution	2021	Sahu et al. [61]
	Forecasting the weather	2018	Salman et al. [62]
	groundwater quality forecasting for irrigation	2023	Docheshmeh et al.[63]
	Positive Covid-19 forecasting	2023	Sunjaya et al. [64]
	AI for Covid-19 virus reverse engineering	2021	Haimed et al.[65]
	Robot cell predictive maintenance application	2022	Joseph et al.[66]
	Prediction of air pollution	2022	Drewil et al. [67]
	Flood forecasting	2019	Le et al. [68]
	Malware detection for android	2018	Vinayakumar et al.[69]
	Sentiment analysis of text	2016	Li et al.[70]
Autoencoders (AE)	Age estimation	2018	Zaghbani et al.[71]
	Diagnostics for faults in industrial processes	2022	Qian et al. [72]
	Forecasting of power prices	2021	Demir et al. [73]
	Stock prediction	2022	Wu et al.[74]
	Automotive audio anomaly detection	2021	Pereira et al.[75]
	Forecast the course of Alzheimer's disease	2022	Chen et al.[76]
	Detecting trespass within the vehicle	2022	Hoang et al.[77]
	Identifying and fixing faults in building automation	2021	Choi et al. [78]
	Monitoring the health of machinery	2021	Ye et al. [79]
Generative Adversarial Networks (GAN)	Image Inpainting	2021	Qin et al. [80]
	Reconstruction of remote sensing images	2023	Zhu et al. [81]
	Using X-ray pictures to identify Covid-19 & pneumonia	2021	Motamed et al. [82]
	Picture steganography across WSN	2022	Ambika et al.[83]
	Monitoring water quality in water delivery networks	2023	Li et al. [84]
	Production of artificial demand statistics for power users	2022	Yilmaz et al. [85]
	Noise reduction for optical coherence	2020	Chen et al. [86]
	Body-part-aware human motion transfer	2021	Jiang et al. [87]
	Translation of Chinese calligraphy	2021	Xiao et al.[88]
	Real-photographic denoising	2021	Vo et al. [89]

Table 2: Summary of applications field and deep learning techniques.

Field	Methodology	Target Objects	Ref.
Computer Vision & Image Classification	CNN	Robotics & self-driving car deployment	[90]
	Alexnet, Vgg-16, Googlenet, and Resnet.	Segmentation of Images and Videos	[91]
	CNN, RNN, LSTM, GAN and Auto-Encoders	Recognition of Biometrics (Face, Iris, Fingerprint, Palmprint recognition)	[92]
	Pre-trained CNN models	Scene classification using remote sensing images	[93]
	LSTM & RNN	Classifying of images and texts	[94]
Medical Applications	CNN models (Resnet18, Resnet50, Vgg16, Resnet101, Vgg19) and (SVM)	X-Ray images for Covid-19 detection	[95]
	CNN	Diagnoses of diabetic retinopathy	[96]
	CNN & Vgg16 for feature extractor	MRI scans for Alzheimer's detection	[97]
Text Classification	CNN & Alexnet model	Classification of poisonous comments	[98]
Prediction	Neural Networks	Modeling of Energy Consumption	[99]
	YOLO V2	Goal coordinates by RGB-D camera	[100]
	MLP & LSTM	Prediction of Web Navigation (WNP)	[101]
Natural Language Processing (NLP)	Bert, Bidirectional LSTM, K-NN, And NB (Naive Bayes)	Email spam detection	[102]
	Bert (bidirectional encoder representations from transformers) for question-answering and LSTM for machine translation.	Providing Remote Education for Schools	[103]
	Multilayer perceptron (MLP)	Recognition of Voice Gender	[104]
Agricultural Applications	GAN and vision transformers (VIT)	Automation in agriculture	[16]
	Resnet50 for image classification	Disease detection in plants	[105]
Network Security	CNN, LSTM, and InceptionV3	Malware classification	[106]
	CNN and LSTM	Attack detection on the IOT	[61]
Image Clustering	Pre-trained CNN features	Complicated natural image clustering	[107]
Image Recognition	(CNN) object detection & YOLO	Road fault detection	[108]
Construction Industry	CNN, LSTM, and RNN	Facility management and upkeep for ventilation, heating, air conditioning	[109]
Classification of Vertices and Graphs	CNN & (LSTM)	Classification of dynamic graphs	[110]

5. CONCLUSION

Deep learning techniques have shown to be important and useful in many fields since they assist specialists and clients in making decisions, save time and effort, and help with choice-making. One of the important benefits of deep learning is its capacity for autonomous instruction and feature extraction from data, which is particularly useful for tasks such as image classification or speech recognition. This is achieved through the use of convolutional neural networks (CNNs), recurrent neural networks (RNNs), autoencoders (AE), generative adversarial networks (GANs), and Long Short-Term Memory(LSTM). The healthcare, financial, and advertising sectors are just a few of the many that can benefit from deep learning. It could radically alter how we tackle difficult problems. It will be important to keep up with the latest developments in the field of deep learning as new methods and applications emerge. Deep learning has the potential to revolutionize how researchers, engineers, and business professionals do their work and open new avenues for advancement. When applied to solving difficult problems and making accurate predictions from massive datasets, deep learning has proven to be an invaluable tool. More and more creative uses of deep learning are likely to emerge in the years ahead as research in this area continues to develop.

This study's objective is to highlight the significance of deep learning research over the past few decades, a period that has seen the emergence of many new fields that can benefit from deep learning. Several recent publications' contents were briefly summarized, and their respective implementations were presented in tables along with a brief explanation of deep neural networks and their uses. The purpose of this article is to draw attention to the most consequential deep learning applications that have recently seen significant uptake and are expected to feature prominently in future research. These examples can serve as a springboard for further research by the reader.

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