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Notes of "Artificial Intelligence for Engineering/Engineers(KMC-101)"

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Notes Part-2

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Artificial Intelligence for Engineering

UNIT-4

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UNIT 4: Artificial Neural

4.1 Artificial Neural Networks (ANNs)

An ANN is the piece of a computing system designed to simulate the way the human brain analyzes and processes information.

It is the foundation of artificial intelligence (AI) and solves problems that would prove impossible or difficult by human or statistical standards.

ANNs have self-learning capabilities that enable them to produce better results as more data becomes available.

The term "Artificial Neural Network" is derived from Biological neural networks that develop the structure of a human brain.

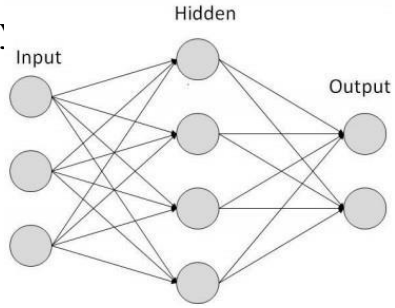
Similar to the human brain that has neurons interconnected to one another, artificial neural networks also have neurons that are interconnected to one another in various layers of the networks. These neurons are known as nodes.

Biological Neural Network	Artificial Neural Network
Dendrites	Inputs
Cell nucleus	Nodes
Synapse	Weights
Axon	Output

Architecture of an ANN:

Artificial Neural Network primarily consists of three layers:

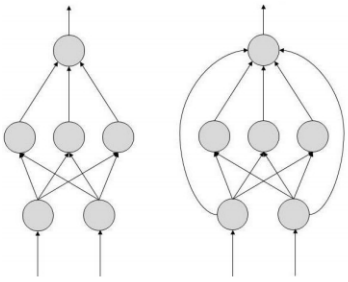
1. **Input Layer:** As the name suggests, it accepts inputs in several different formats provided by the programmer.
2. **Hidden Layer:** The hidden layer presents in-between input and output layers. It performs all the calculations to find hidden features and patterns.
3. **Output Layer:** The input goes through a series of transformations using the hidden layer, which finally results in output that is conve



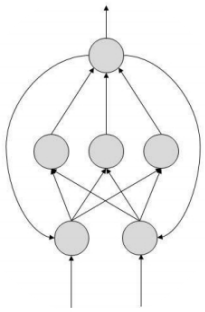
Types of Artificial Neural Network:

There are two Artificial Neural Network topologies.

1. **Feedforward ANN:** In this ANN, the information flow is unidirectional. A unit sends information to other unit from which it does not receive any information. There are no feedback loops. They are used in pattern generation/recognition/classification. They have fixed inputs and outputs.



2. **Feedback ANN:** Here, feedback loops are allowed. They are used in content addressable memories.



Advantages of Artificial Neural Network (ANN)

1. **Parallel processing:** Artificial neural networks have a numerical value that can perform more than one task simultaneously.
2. **Storing data on the network:** Data that is used in traditional programming is stored on the whole network, not on a database. The disappearance of a couple of pieces of data in one place doesn't prevent the network from working.
3. **Incomplete knowledge:** After ANN training, the information may produce output even with inadequate data. The loss of performance here relies upon the significance of missing data.
4. **Fault tolerance:** Extortion of one or more cells of ANN does not prohibit it from generating output, and this feature makes the network fault-tolerance.

Disadvantages of Artificial Neural Network:

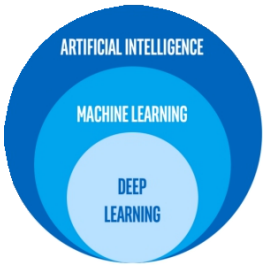
1. **Assurance of proper network structure:** There is no particular guideline for determining the structure of artificial neural networks. The appropriate network structure is accomplished through experience, trial, and error.
2. **Hardware dependence:** Artificial neural networks need processors with parallel processing power, as per their structure. Therefore, the realization of the equipment is dependent.
3. **Unrecognized behaviour of the network:** When ANN produces a testing solution, it does not provide insight concerning why and how. It decreases trust in the network.
4. **Difficulty of showing the issue to the network:** ANNS can work with numerical data. Problems must be converted into numerical values before being introduced to ANN. The presentation mechanism to be resolved here will directly impact the performance of the network. It relies on the user's abilities.
5. **The duration of the network is unknown:** The network is reduced to a specific value of the error, and this value does not give us optimum results.

Applications of Artificial Neural Networks

- ✔ **Aerospace**: Autopilot aircrafts, aircraft fault detection.
- ✔ **Automotive:** Automobile guidance systems.
- ✔ **Military:** Weapon orientation and steering, target tracking, object discrimination, facial recognition, signal/image identification.
- ✔ **Electronics:** Code sequence prediction, IC chip layout, chip failure analysis, machine vision, voice synthesis.
- ✔ **Financial:** Real estate appraisal, loan advisor, mortgage screening, corporate bond rating, portfolio trading program, value prediction, document readers, credit application evaluators. corporate financial analysis, currency
- ✔ **Medical:** Cancer cell analysis, EEG and ECG analysis. prosthetic design, transplant time optimizer.
- ✔ **Speech:** Speech recognition, speech classification, text to speech conversion.
- ✔ **Telecommunications:** Image and data compression, automated information services, real-time spoken language translation. Transportation - Truck Brake system diagnosis, vehicle scheduling, routing systems.
- ✔ **Software:** Pattern Recognition in facial recognition, optical character recognition, etc.

4.2 Deep Learning

Deep Learning is a part of machine learning, which is a subset of Artificial Intelligence. Deep Learning is a subfield of machine learning concerned with algorithms inspired by the structure and function of the brain called artificial neural networks. It is useful in processing Big Data and can create important patterns that provide valuable insight into important decision making.



Deep learning is a branch of machine learning which is completely based on artificial neural networks, as neural network is going to mimic the human brain so deep learning is also a kind of mimic of human brain.

Working:

1. First, we need to identify the actual problem in order to get the right solution and it should be understood, the feasibility of the Deep Learning should also be checked (whether it should fit Deep Learning or not).
2. Second, we need to identify the relevant data which should correspond to the actual problem and should be prepared accordingly.
3. Third, Choose the Deep Learning Algorithm appropriately.
4. Fourth, Algorithm should be used while training the dataset.
5. Fifth, Final testing should be done on the dataset.

Languages used:

R, Python, Matlab, CPP, Java, Julia, Lisp, Java Script, etc.

Advantages:

- ✔ Best in-class performance on problems.
- ✔ Reduces need for feature engineering.
- ✔ Eliminates unnecessary costs.
- ✔ Identifies defects easily that are difficult to detect.

Disadvantages:

- × Large amount of data required.
- × Computationally expensive to train.
- × No strong theoretical foundation.

Applications:

1. **Automatic Text Generation**: Corpus of text is learned and from this model new text is generated, word-by-word or character-by-character.
2. **Healthcare:** Helps in diagnosing various diseases and treating it.
3. **Automatic Machine Translation:** Certain words, sentences or phrases in one language is transformed into another language (Deep Learning is achieving top results in the areas of text, images).
4. **Image Recognition:** Recognizes and identifies peoples and objects in images as well as to understand content and context. This area is already being used in Gaming, Retail, Tourism, etc.
5. **Predicting Earthquakes**: Teaches a computer to perform viscoelastic computations which are used in predicting earthquakes.

4.3 Recurrent Neural Networks (RNNs)

Recurrent Neural Network(RNN) are a type of Neural Network where the output from previous step are fed as input to the current step. In traditional neural networks, all the inputs and outputs are independent of each other, but in cases like when it is required to predict the next word of a sentence, the previous words are required and hence there is a need to remember the previous words.

Why Recurrent Neural Networks?

Recurrent neural networks were created because there were a few issues in the feed-forward neural network:

- × Cannot handle sequential data
- × Considers only the current input
- × Cannot memorize previous inputs

The solution to these issues is the Recurrent Neural Network (RNN). An RNN can handle sequential data, accepting the current input data, and previously receive inputs. RNNs can memorize previous inputs due to their internal memory.

Types of Recurrent Neural Networks

There are four types of Recurrent Neural Networks:

1. **One to One RNN:** This type of neural network is known as the Vanilla Neural Network. It's used for general machine learning problems, which has a single input and a single output.
2. **One to Many RNN:** This type of neural network has a single input and multiple outputs. An example of this is the image caption.
3. **Many to One RNN:** This RNN takes a sequence of inputs and generates a single output. Sentiment analysis is a good example of this kind of network where a given sentence can be classified as expressing positive or negative sentiments.
4. **Many to Many RNN:** This RNN takes a sequence of inputs and generates a sequence of outputs. Machine translation is one of the examples.

Applications of Recurrent Neural Networks

- ✔**Image Captioning:** RNNs are used to caption an image by analysing the activities present.
- ✔**Time Series Prediction:** Any time series problem, like predicting the prices of stocks in a particular month, can be solved using an RNN.
- ✔**Next Word Prediction:** Taking a sequence of words as input, we try to predict the possibility of the next word.
- ✔**Machine Translation:** Given an input in one language, RNNs can be used to translate the input into different languages as output.

4.4 Convolutional Neural Networks (CNNs)

- ✔CNNs are class of Artificial Neural Networks which are used to process images. They can detect image features such as bright or dark or specific color spots edges in various orientations , patterns and others.
- ✔So, if an image is input to a CNN, it should rightly recognize it . So, CNN needs to be trained with all such images using whose features it can rightly recognize the input image.
- ✔Convolutional neural networks can operate directly on a raw image and do not need any pre-processing.
- ✔Convolutional neural networks (CNN) are one of the most popular models used today.
- ✔This neural network computational model uses a variation of multilayer perceptrons and contains one or more convolutional layers that can be either entirely connected or pooled.
- ✔These convolutional layers create feature maps that record a region of image which is ultimately broken into rectangles and sent out for nonlinear processing.

Comparison of Different Layers

There are three types of layers in a CNN. Each of these layers has different parameters that can be optimized and performs a different task on the input data.

1. **Convolutional layers:** are the layers where filters are applied to the original image, or to other feature maps in a deep CNN. This is where most of the user- specified parameters are in the network. The most important parameters are the number of kernels and the size of the kernels.
2. **Pooling Layers:** They are used to reduce the dimensions of the feature maps. This layer summarizes the features present in a region of the feature map generated by a convolution layer.
3. **Fully connected layers:** They are placed before the classification output of a CNN and are used to flatten the results before classification.

What do CNN layers learn?

1. Each CNN layer learns filters of increasing complexity.
2. The first layers learn basic feature detection filters: edges, corners, etc
3. The middle layers learn filters that detect parts of objects. For faces, they might learn to respond to eyes, noses, etc
4. The last layers have higher representations: they learn to recognize full objects, in different shapes and positions.

Advantages

- ✔ Very High accuracy in image recognition problems.
- ✔ Automatically detects the important features without any human supervision.
- ✔ Weight sharing.

Disadvantages

- × CNN do not encode the position and orientation of object.
- × Lack of ability to be spatially invariant to the input data.
- × Lots of training data is required.

Applications of CNN

- ✔ Image and Video recognition
- ✔ Recommender systems
- ✔ Image classification
- ✔ Medical Image analysis
- ✔ Computer Vision
- ✔ Natural Language processing
- ✔ Financial time series
- ✔ Autonomous Cars

CNN	RNN
CNN stands for Convolutional Neural Network	RNN stands for Recurrent Neural Network
CNN considered to be more potent	RNN includes less feature compatibility
Ideal for images and video processing	Ideal for text and speech Analysis
Suitable for spatial data like images	RNN is used for temporal data
Takes fixed-size inputs and generates fixed size output	RNN can handle arbitrary input/ output lengths

4.5 Universal Approximation Theorem

The Universal Approximation Theorem states that a neural network with 1 hidden layer can approximate any continuous function for inputs within a specific range.

Mathematically speaking, any neural network architecture aims mathematical function y= f(x) that can map attributes(x) to output(y).

The accuracy of this function i.e. mapping differs depending on the distribution of the dataset and the architecture of the network employed.

The function f(x) can be arbitrarily complex. The Universal Approximation Theorem tells us that Neural Networks has a kind of universality i.e. no matter what f(x) is, there is a network that can approximately approach the result and do the job. This result holds for any number of inputs and outputs.

In the mathematical theory of artificial neural networks, universal approximation theorems are results that establish the density of an algorithmically generated class of functions within a given function space of interest.

Most universal approximation theorems can be parsed into two classes. The first quantifies the approximation capabilities of neural networks with an arbitrary number of artificial neurons ("arbitrary width" case) and the second focuses on the case with an arbitrary at finding any number of hidden layers, each containing a limited number of artificial neurons ("arbitrary depth" case).

Universal approximation theorems imply that neural networks can represent a wide variety of interesting functions when given appropriate weights.

On the other hand, they typically do not provide a construction for the weights, but merely state that such a construction is possible.

4.6 Generative Adversarial Networks (GANs)

- Generative Adversarial Networks (GANs) were introduced in 2014 by Ian J. Goodfellow and co- authors.
- GANs perform unsupervised learning tasks in machine learning. It consists of 2 models that automatically discover and learn the patterns in input data.
- The two models are known as **Generator and Discriminator.**
- They compete with each other to scrutinize, capture, and replicate the variations within a dataset. GANs can be used to generate new examples that plausibly could have been drawn from the original dataset.

1. Generator

A Generator in GANs is a neural network that creates fake data to be trained on the discriminator. The main aim of the Generator is to make the discriminator classify its output as real.

2. Discriminator

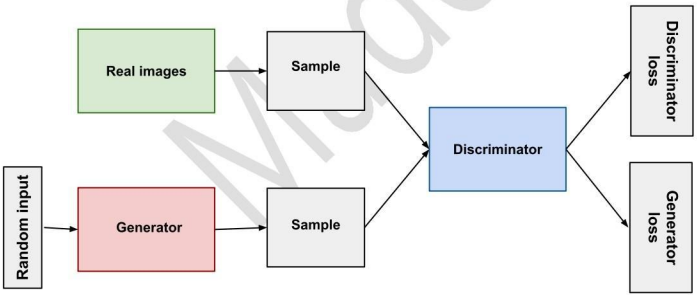
- The Discriminator is a neural network that identifies real data from the fake data created by the Generator. The discriminator's training data comes from different two sources:
- The real data instances, such as real pictures of birds, humans, currency notes, etc., are used by the Discriminator as positive samples during training.
- The fake data instances created by the Generator are used as negative examples during the training process.

How does GANs work?

1. GANs consists of two neural networks. There is a Generator G(x) and a Discriminator D(x). Both of them play an adversarial game.
2. The generator's aim is to fool the discriminator by producing data that are similar to those in the training set.
3. The discriminator will try not to be fooled by identifying fake data from real data. Both of them work simultaneously to learn and train complex data like audio, video, or image files.
4. The Generator network takes a sample and generates a fake sample of data. The Generator is trained to increase the Discriminator network's probability of making mistakes.

Applications of GANs:

1. Photo to photo translation.
2. Deep Fake
3. Voice Cloning
4. Generate Cartoon Character
5. Face Aging
6. Super-resolution
7. 3D object generation
8. Clothing translation
9. Photograph editing 10.Image enhancement



Steps for Training GAN

1. Define the problem
2. Choose the architecture of GAN
3. Train discriminator on real data
4. Generate fake inputs for the generator
5. Train discriminator on fake data
6. Train generator with the output of the discriminator