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Comparative Analysis of Deep Learning Techniques

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Abstract: ***Deep learning is a sub part of machine learning & artificial intelligence. Deep Learning is one of the rising focus areas in data science. With a tremendous rise of accessibility of data in recent years, it has become vital to develop models that will solve the new technology problems. Recently, deep learning has been utilized in varied recognitions and classifications model due to its high potential to deliver exceptional results. As compared to other learning algorithms, deep learning aims to solve real world problems with limited resources. This paper summarized the need of deep learning along with its differentiation factors with respect to machine learning algorithms. It has addresses a comparative study of four different neural networks used in deep learning techniques. A comparative table of algorithms is discuses in the end, that emphasizes the use case and specialty of particular algorithms. Overall, this paper serves as a smaller picture depicting all aspects of deep learning and a wider knowledge of horizon. It can be used for academic purposes and industry uses.***

Keywords: Deep learning, machine learning, artificial intelligence, neural networks, hidden layers, perceptron

1. Introduction

Deep learning is a part of the machine learning circle. Deep learning techniques associated with the formations and functioning of the human brain are called artificial neural networks. With the tremendous increase in data and the need for more accurate performance with models, it becomes troublesome to correctly identify the target solutions. With deep learning, the older methods in use prove to be less efficient in terms of classifying and selecting. However, with due practice and training on supervised data, deep learning makes it to the top with ample benefits.

The main focus behind getting better results is a collective effort of more data in bigger models with larger computations. The insights and improvements formed by implementing models, helps to develop better algorithms.

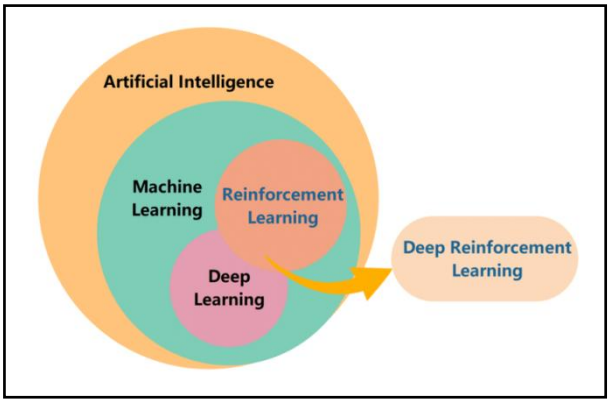

Figure 1.1: Understanding learning algorithms

Feature learning is another most popular feature in deep learning, as it enables the model to perform automatic feature extraction from raw data. Feature learning is an area that not all models have the capacity to deal with it. But with deep learning, it feels like simpler and cakewalk experiences. The deep learning method aims towards building hierarchies with features from high level to low level of features. These hierarchies having multiple levels of abstractions, thus formed, help the model to learn complex functions that maps input to output directly, without depending on external human interventions.

Deep learning is named “deep” due to its ability to drive in deep and develop a fast and greedy algorithm. The algorithm directs belief networks by taking one layer at a time by providing the top two layers form an undirected associative memory. Deep learning has multiple stages required in the process of recognizing objects. And the stages adopted, all are a part of the training. As stated by one researcher, the problems requiring depth greater than 10 are used for very deep learning techniques.

2. Machine Learning & Deep Learning

Deep learning is a specialized form of machine learning. Machine Learning has commonly used with AI that self learns according to the algorithm. Whereas Deep Learning is a machine learning method applied to large datasets.

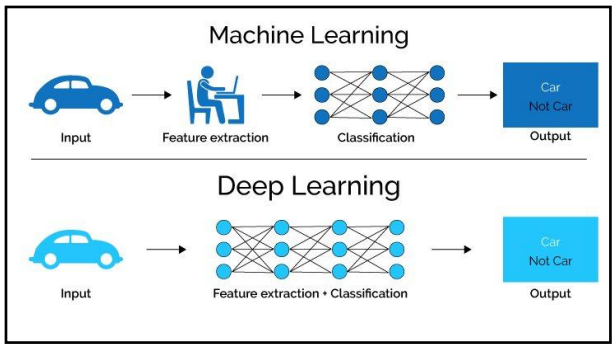

Figure 2.1: Machine Learning v/s Deep Learning

In machine learning, the features are extracted from input images and then the extracted features are used to create a model that categories object in images. But in Deep Learning, relevant images are automatically extracted from input images, for further processing. Deep Learning follows “end-to-end learning”. This means that when raw input data is given to the Deep Learning model, it learns automatically to complete the task.

Scalability is another aspect of differentiation between both algorithms. Deep Learning algorithms can scale with larger data. But in machine learning algorithms, the model creates a plateau when more inputs are added after a certain interval of time. Moreover, as the size of data increases, Deep Learning models starts performing better.

Selection & customization are ruling the personalization domains. With industries demanding a variety of needs, features fed into the model should be carefully selected. In a machine learning algorithm, features need to be manually selected and then they are further used to sort datasets. But in Deep Learning, automatic feature extractions paves the way for more acceptability.

3. Choosing the Right Algorithm

Selecting the type of algorithm (Machine Learning or Deep Learning), entirely depends on the use case.

There are 3 major factors that might help you in choosing the right algorithm for the application. 3 major factors are as follows:

1) Field of application
2) Size of the dataset
3) Type of the problem

For processing more amount of data, the computational needs also get increased. The higher the performance of GPU you consider, the more the accuracy is achieved. And so, while considering algorithms, another major factor to determine is the performance level of GPU and the amount of labelled data. If the use case doesn't require both the factors, one can go for Machine Learning models. Elsewhere, Deep Learning models can be used. But the input images should count towards thousands to get appropriate results. And with a high-performance GPU, time will be consumed to process those thousands of images.

4. Deep Learning Techniques

The majority of deep learning models use artificial networks, which are referred to as deep neural networks. The term "deep" in Deep Learning represents the presence of hidden layers in the neural network. Traditionally, only two to three hidden layers are present However, for deep neural networks, the hidden layers may go upto as many as 150.

The Deep Learning model can be classified into 3 parts, as follows:

1) Input layer
2) Hidden layers
3) Output layer

As shown in the above figure, the Deep Learning model is majorly divided into 3 layers. The input layer, hidden layer and output layer. The hidden layer can be in the range of 2 to 150, depending upon the scale of application.

The input layers are responsible for taking and processing the input given by the machine. Hidden layers act as an intermediate source between input and output. Here, all the computation work is done. And output layers helps to produce results for the inputs received from the input layer.

Inspired from human brain neural networks, Deep Learning models are an effective way to tackle problems that are too complex for human brains to interpret. Following are the most common techniques used in Deep Learning models.

1) Classic Neural Network

Classic Neural Network is also known as a fully connected neural network. This method is often identified due to the presence of multilayer perceptrons. In this Neural Network, the neurons are fully connected to the continuous layer. Here the model is adapted into fundamental binary data inputs. Classic Neural Network includes the following two functions:

a) Linear function: Linear function represents a single line. It multiplies its inputs with a constant multiplier.
b) Non-Linear function: Non-linear function is divided into 3 subsets:
   - Sigmoid Curve: Sigmoid curve ranging from 0 to 1, depicts an S-shaped curve.
   - Hyperbolic Tangent: Hyperbolic tangent or tanh is again an S-shaped curve. But it ranges from -1 to 1.
   - Rectified Linear Unit: Rectified Linear unit or ReLU is a function that outputs 0 when the input is lesser than the predefined value. Else, it outputs the linear multiple of input.

Major application areas of Classic Neural Network are:

a) Dataset having rows and columns, and CSV format
b) Classification & regression problems with real inputs.
c) Models have higher flexibility than ANNs.

2) Convolutinal Neural Network

Convolution Neural Network is a type of advanced method of Artificial Neural Network. Convolutional Neural networks are mostly used to tackle higher complexity problems, data compilations and preprocessing. The reference guide for working on this model is the same as that of the visual cortex of the animal brain. The Convolutional Neural Networks are one of the most flexible models for treating image and non-image data.

The Convolutional Neural Network consists of four different organizations:

1) Convolutional Neural Network has a single, two-dimensional input layer, primarily used for analyzing image data.
2) Some Convolutional Neural Networks have a single-dimensional output layer, which helps to process images via scattered connected convolutional layers.
3) The Convolutional Neural Networks also include a third layer called 'sampling layer'. This helps to limit the number of neurons involved in the corresponding network layers.
4) Overall, Convolutional Neural Networks consists of single or multiple connected layers that connect the sampling to output layers.

Convolutional Neural Networks are proved useful for carrying out the following tasks:

1) Image systems that need OCR analysis.
2) A conversion system of 2 dimensions to 1 dimension is required for quicker analysis.

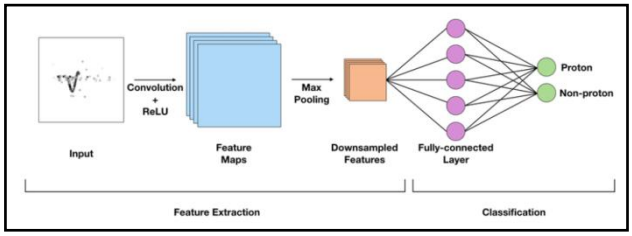

Figure 4.1: Convolutional Neural Network

As seen above from the figure 4.1,

- First, the input is been taken into the system. And convolutions process derives the feature maps from the input dataset. This further gets transferred to apply functions to the maps created.
- The second step is to make the max pooling. Max pooling helps the Convolutional Neural Network to detect the presence of images according to any given modifications.
- After the data is been detected with images and instructions given, the features are downsampled. This means that the data generated is flattened or reduced down for the Convolutional Neural Network models to analyze.
- And this brings an end to the feature extraction step. The next step is for the classification area.
- Once the features extracted are been down sampled, a full connection is been established to compile the loss function for the model.
- These connections are also referred to as hidden layers.
- And the last step terminates to classify the target sample according to the data and labels are given to the model.

3) Recurrent Neural Network

Recurrent Neural Networks were initially designed for the prediction of sequences. One such common example is the Long Short-Term Memory or LSTM algorithm. This algorithm is known for its multiple functionalities. These networks work entirely on data sequences, having variable input lengths.

Recurrent Neural Network as the name suggests 'recurrent' uses the previous gained state as an input for further prediction stages. This process helps to achieve short-term memory in a network, which leads to effective management of stock price changes, or other time-based data systems.

Broadly, In Deep Learning there are two major types of Recurrent Neural Networks used:

- LSTMs: LTSM or Long Short-Term Memory are useful in the prediction of data in time sequences with the help of memory. LTSM has three gates, which are Input, Output, and Forget.
- Gated Recurrent Neural Networks: Gated Recurrent Neural Networks are useful in the data prediction of time sequences using memory. It is similar to LTSM. But it has two gates, which are Update and Reset.

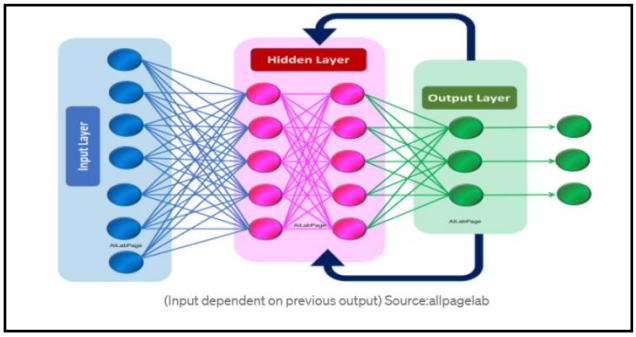

Figure 4.2: Recurrent Neural Network

As shown in the figure 4.2, the data moves through the three major layers, the input layer, the hidden layer and the output layer. First, the data moves from the input layer to the hidden layer and from the hidden layer to the output layer. But as the process is recurrent, the output produced is again back propagated to hidden layer, so as to use it for the next prediction. This process goes on until the outputs are been formed and sent out of the model.

Recurrent Neural Networks works best for the following four series:

- One to One: Here, a single input is connected to a single output. For e.g. Image classification.
- One to many: Here a single input is linked to output sequences. For e.g. Image captioning, that includes several words from a single image.
- Many to One: Here, a series of inputs generate a single output. For e.g. Sentiment Analysis.
- Many to many: Here a series of inputs yield a series of outputs. For e.g. Video classification.

4) Generative Adversial Network

Generative adversarial networks or Generative Adversarial Network is a combination of two Deep Learning techniques, which are:

a) A Generator
b) A Discriminator

A Generator Network helps to yield artificial data, whereas a Discriminator helps to differentiate between real and false data.

Both these networks are competitive enough due to their capabilities of dealing with models. The Generator network keeps producing artificial data identical to real data. And the Discriminator network continuously detects real and unreal data.

Generative Adversarial Networks work best in fields like:

- Generations of Text & image files
- Enhancement of images
- New Drug discovery processes.

5) Comparison of Networks

Every neural network differ in a way or other for functioning and applications.

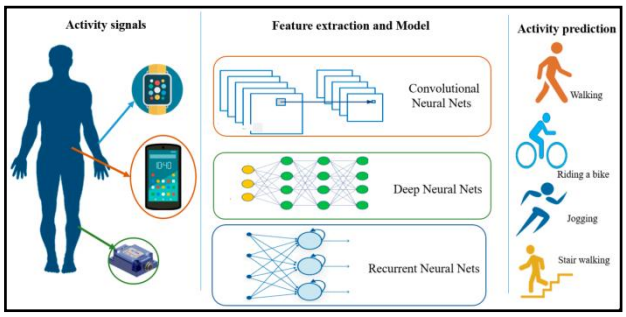

Figure 5.1: Difference of Neural Networks

From the figure 5.1, one can note the differences in neural networks. Instead of having initial and final goals as same, these networks differ in structures and functioning.

Table 5.1: Comparison of Neural Networks

Parameters	Multi Perceptron Layer/ Classic Method	Recurrent Neural Network	Convolutional Neural Network
Type of data	Tabular data	Sequence data like Time series, text, audio	Images
Recurrent connection	No	Yes	No
Shares Parameter	No	Yes	Yes
Spatial Relationship	No	No	Yes
Include Vanishing & Exploding Gradient	Yes	Yes	Yes
Structure of Network	Input Layer	Input Layer	Input Layer
	Hidden Layer	Hidden Layer	Convolution Layer
	Output Layer	Output Layer	Pooling Layer Full connected Layer
Applications	Classification, pattern recognition	Emotion analysis, Natural language processing	Image processing, speech signal.

5. Deep Learning IN & AS Healthcare

Deep learning has emerged as a valuable tool in the healthcare sector, offering various benefits, including improved diagnosis, more efficient medical image analysis, personalized treatment plans, and drug discovery. Mentioned below are some real-life examples that highlight the usage of deep learning in healthcare sector:

1) Medical Image Analysis:

Deep learning models have exhibited exceptional performance in interpreting medical images, such as X-rays, MRIs, and CT scans. For example, in detecting and diagnosing diseases like cancer, these models have achieved accuracy rates comparable to or even surpassing that of human experts. In 2020, a study published in Nature Medicine [13] demonstrated how a deep learning model developed by Google Health could detect breast cancer from mammograms with greater accuracy than human radiologists. The model reduced false negatives by 9.4% and false positives by 5.7%.

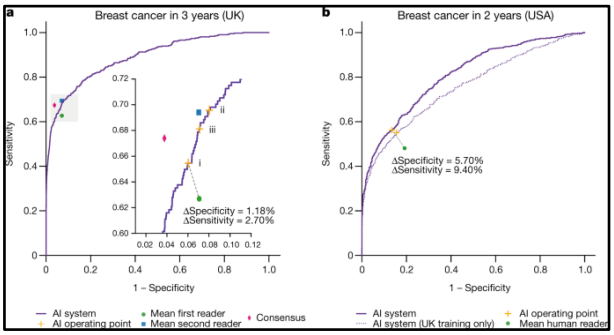

Figure 6.1: Results of Proposed AI system for breast cancer screening

2) Early Disease Detection:

Deep learning algorithms can help identify patterns and markers in patient data, enabling early detection of diseases and conditions. This early detection can significantly improve treatment outcomes and reduce healthcare costs.

A team of researchers from Harvard and the University of Vermont developed a deep learning model that analyzes electronic health records to predict sepsis [14] (a life-threatening condition) up to 12 hours before clinical recognition. The model achieved an area under the receiver operating characteristic curve (AUC-ROC) of 0.83, outperforming traditional prediction models.

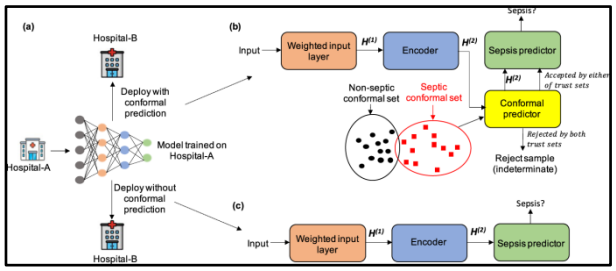

Figure 6.2: AI prediction algorithm for sepsis

3) Drug Discovery and Development:

Deep learning is accelerating drug discovery by predicting potential drug candidates, optimizing molecular structures, and analyzing drug-target interactions, thus reducing the time and cost involved in bringing new drugs to market.

In 2019, Insilico Medicine used deep learning algorithms [15] to identify a novel drug candidate for idiopathic pulmonary fibrosis (IPF), a fatal lung disease. The candidate was predicted in just 21 days, whereas traditional methods would have taken months to years.

4) Personalized Treatment Plans:
Deep learning models can analyze patient data and medical history to tailor treatment plans based on individual characteristics, leading to more effective and personalized healthcare.

Researchers at Stanford University developed a deep learning algorithm [16] that could predict patient mortality risk, allowing physicians to make personalized end-of-life care decisions. The model analyzed electronic health records and achieved a prediction accuracy of approximately 90%.

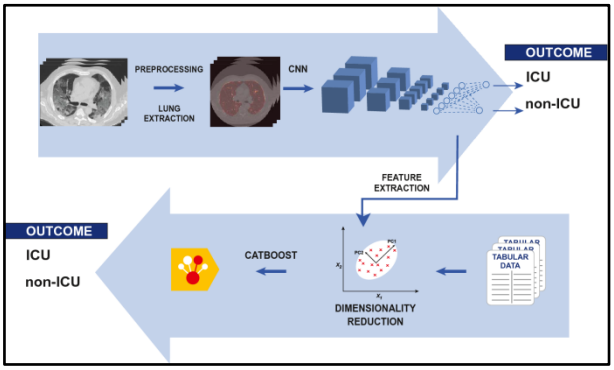

Figure 6.3: Deep Learning Predictive Model for Clinical Data

5) Medical Virtual Assistants:
Deep learning-based virtual assistants can help streamline administrative tasks, schedule appointments, answer patient queries, and provide basic medical advice, freeing up healthcare professionals to focus on more critical tasks.

In 2021, Mayo Clinic [17] launched a voice-based virtual assistant, built using deep learning technology, to help patients find reliable health information and answer common health-related questions.

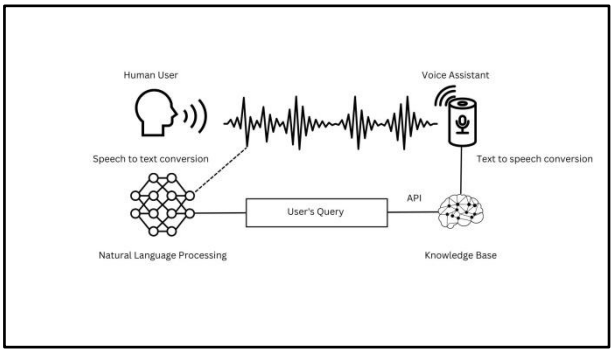

Figure 6.4: Deep Learning-based Voice Assisted Solution

6) Predictive Analytics:
Deep learning models can leverage patient data to predict disease progression, treatment responses, and potential complications, leading to better patient outcomes and resource allocation.

A study published in JAMA Cardiology used a deep learning model to predict heart failure hospitalizations [18] up to 1 year in advance with an accuracy of around 80%.

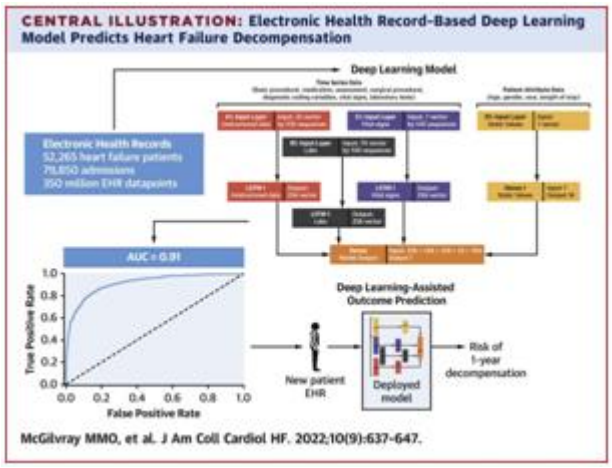

Figure 6.5: Heart Failure Decompensation based on Deep Learning [19]

6. Advantages & Disadvantages

1) Advantages

a) Skips Feature Engineering
Feature engineering is the process of treating and cleaning the data well before sending into the model. It is basically used to extract features from raw data that help to improve accuracy of the model. Deep learning has the capability to implement feature engineering on its own. The deep learning algorithm scans the data, identifies the appropriate features in it and then combines to enable a feaster learning process for the model.

b) Good Results with Unstructured data.
The data present need not be in structure format. The data available in organizations are usually mixed in form of images, PDFs, audios, videos, and many more. And this data is hard to analyze for other learning algorithms. But this is where deep learning comes into role. Using Deep learning algorithms the data can be treated into different formats relevant to the purpose of training.

c) Doesn't require labeling of data
Data labeling is an important characteristic of training data. And finding good training data is an expensive job. Deep learning algorithms excel at learning algorithms without any labels for the data. Whereas the other forms of learning algorithms doesn't support this feature. For e.g. with adequate amount of data, a deep learning algorithm can detect any physical anomalies of humans at earlier stages than doctors.

2) Disadvantages

a) Large Amount of Data
To train the model well, data is a must. But the exact quantity is unknown. As the data scientist quote, more the data, more powerful the abstraction becomes. As compared to other learning algorithm, deep learning requires more amounts of data. The reason behind large data is that deep learning is a two-folded algorithm. Firstly it understands the domain and then solves the problem. And hence a large amount of data is required by deep learning models to tune and analyze the correct parameters.

b) Over fits the model

Over fitting refers that the model is trained much more than required. Over fitting can be identified from the point where accuracy stops improving after certain number of epochs. This happens when the models learns noise too. And overfitting causes a negative impact on the performance of models.

As in deep learning, more amounts of data is used and the process of feature engineering is self-executed. There might be cases where it is not done well. This will cause over fitting of the model. Hence, disturbing the accuracy of model.

7. Conclusion

Deep learning method has a lot of potential to work well in the market. However there are a lot of challenges on the road, which must be treated well. The enthusiasm is increasing day-by-day amongst the data scientists. With the incredible increase in real world applications of technology, more researchers are tending towards using new algorithms.

Deep learning algorithms are applied to CRM models, social media engagements, improving customer segments, detecting frauds and many more. The list of application continues to infinite. In near future, higher expectations are keen towards predicting this technology and more of current challenges are expected to solve.

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