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Analysing Deep Learning as A Machine Learning Algorithm

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Abstract*: Deep Learning (DL) is one of the most frequently used machine learning algorithms today and it has been the part of the research field for quite a long time. Still, it has a lot to contribute. Deep learning is an improvised version of simple neural network learning in the sense that there could be two distinct neuron sets in a simple neural network. Deep learning is beneficial in making the usage of the multiple processing layers to provide best results in areas like image processing, speech recognition, object identification, etc. The research in the deep learning field is an attempt to provide means to create models for doing fantastic representations and learning the same from large scale data of unlabeled nature. Some of the representations obtained through the models devised under deep learning are influenced from the advancements made in the field of neuroscience that is loosely associated with the information processing interpretation and communication patterns that are discussed i the nervous system, especially neural coding. This paper is an attempt to put light on deep learning concept and its scope in the research area.

***Keywords* — DL, DNN, CNN, RNN, DBM, DBN**

I. INTRODUCTION

Known by various names such as deep machine learning or hierarchical learning or deep structuring learning, deep machine learning algorithm is considered as the learning and findings of artificial neural networks and associated machine learning algorithms, specifically the one that consist of at least one hidden layer. Deep machine learning algorithm can be described as a series of machine learning algorithms that has the following features:

A. Several layers of units of nonlinear processing are cascaded in deep machine learning algorithm for the purpose of feature extraction as well as transformation. Moreover, the output from the previous layer is used by each successive layer as input. The most important feature of this algorithm is that it makes use of either supervised or unsupervised technique of machine learning and hence it finds application in pattern analysis (where it makes use of supervised learning technique) and classification (where it makes use of unsupervised learning technique).

B. It considers the unsupervised learning technique of using features or data representation of multiple levels where the derivation of higher level features is done from features of the lower level that is quite helpful in obtaining a representation of hierarchical in nature.

C. Finally, it makes the learning of data representation of multiple levels corresponding to myriad levels of data abstraction, hence it is quite useful in obtaining a concept hierarchy.

Deep learning is an improvised version of simple neural network learning in the sense that there could be two distinct neuron sets in a simple neural network where one set is responsible for receiving an input signal and the other set is responsible for sending an output signal; whereas the deep network involves several layers that exist between its input and its output and it is quite capable of thinking or taking its decisions on its own rather than having layers of neurons i.e. neurons are absent in its layers, As a result, deep learning is beneficial in making usage of multiple processing layers that is constituted from multiple non-linear and linear transformations.

This paper is an effort to do an analyzis of deep learning in the perspective of machine learning algorithm. The section 2 of this paper discusses the role of deep learning in research field while section 3 of this paper gives an anecdote on the evolution of deep learning field. The section 4 of this paper discusses some of the important architectural versions of Deep Neural Network and finally, we will wrap up the paper with a suitable conclusion in section 5.

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II. ROLE OF DEEP LEARNING IN RESEARCH FIELD

Deep learning is one of the most prominent areas of machine learning algorithm family. This family is very broad and works quite magnificently in carrying out learning tasks through data representations. Through deep learning as machine learning algorithm, the representation of any observation, especially image, can be done in several ways like a vector representing intensity values per pixel, an edge set or a set of regions representing the particular shape. The learning tasks such as face recognition, recognition of facial expression, can be represented in several ways. Deep learning is a quite promising algorithm that replaces handcrafted features and uses semi-supervised or unsupervised learning of features that guarantees an efficient and effective way of representing feature extraction of hierarchical nature.

The research in the deep learning field is an attempt to provide means to create models for doing fantastic representations and learning the same from large scale data of unlabeled nature. Some of the representations obtained through the models devised under deep learning are influenced from the advancements made in the field of neuroscience that is loosely associated with the information processing interpretation and communication patterns that are discussed in the nervous system, especially neural coding. This is an attempt to provide measures to define the association between myriad stimuli and the corresponding neuronal responses in association with them in the human brain.

To make the research of deep learning a worth, several architectures have been modeled in deep learning area including convolutional deep learning networks, deep neural networks, recurrent neural networks and deep belief networks. All such architectures are quite useful in the research fields such as automatic speech recognition, natural language processing, computer vision, bioinformatics and audio recognition where the deep learning architectures have proven to generate results of the state-of-the-art nature on various projects undertaken.

Even though the characterization of Deep learning is done by many data scientists and scholars as a neural networks' rebranding or as a buzzword, deep neural nets of deep learning have shown in the recent times that they are quite able to override or out-perform other algorithms of machine learning, especially in the tasks of object recognition or threat recognition in computer vision research area.

III.EVOLUTION OF DEEP LEARNING FIELD

Deep Learning is one of the prominent branches of machine learning which incorporates algorithms to do *data processing* or the development of *abstractions*. The history of deep learning is as fascinating as the area of Deep Learning itself. The first work in deep learning was done by Walter Pitts and Warren McCulloch (sometimes pronounced as Pitts & McCulloch) in 1943 when a computer model was created by them whose working followed the similarity that of the neural networks of the human brain. A combination of mathematics and algorithms was used by them to develop a logic which they termed as "threshold logic" and which was based on the mimic of human thought process. Deep learning has evolved quite wonderfully and steadily since then except two major breaks during its progress and both the breaks were done by the infamous writers of Artificial Intelligence.

The development of basics related to a continuous Back Propagation Model was the major development in deep learning field in 1960 whose credit is given to Henry J.Kelly. A simpler version of this model was developed in 1962 by Stuart Dreyfus even through the back propagation concept was still there in the early 1960s and it was quite clumsy and so was inefficient. The back propagation model didn't come into use until the year of 1985.

Alexey Grigoreyevich Ivakhenko was given credit for doing the earliest efforts in the development of Deep Learning algorithms. They were responsible for the development of the *Group Method of Data Handling.* Another scientist who was given credit to the development of deep learning algorithm was Valentin Grigo'evich Lapa who authored *Cybernetics and Forecasting* Techniques in 1965**.** They were believed to use models through polynomial activation functions even though such functions composed of complicated equations. Later on, the models were started to be analyzed statistically.

The first break in Deep Learning research occurred in the 1970s when the no funding was done to support Deep Learning and Artificial Intelligence research works.

Kunihiko Fukushima used the first *convolutional neural networks* late 1970 when he was credited to develop neural networks containing convolutional layers and multiple pooling. He is recognized for the development of Neocognitron – an artificial neural network that was supposed to use a multilayered, hierarchical design. This network design is considered as the major breakthrough in the field of visual pattern recognition that resembles the networks of modern versions except that reinforcement learning technique in tandem to the recurring activation in several layers was used to train them with the limitation that their strength

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improves over time. In 1970, another important development came in the area of deep learning was the use of errors in back propagation in Deep learning models' training but that concept could be made applicable in neural networks only from 1985 when Rumelhart, Hinton and William were able to show the fascinating distributions representation through back propagation in neural network. This discovery was really a milestone in the area of Deep learning as it put light on cognitive psychology to understand whether the understanding of human depends on symbolic logic (rightly known as "computationalism") or distributed representations (rightly known as "connectionism"). Further development was made through the practical demonstration, for the very first time, of backpropagation in 1989 by Yann LeCun at Bell Labs. The combination of convolutional neural networks with that of the back propagation done by LeCun onto "handwritten" digits of readable nature helped this discovery to do the reading of a large number of handwritten checks successfully.

1985-86 was the time when the second break up in Deep learning and AI research appeared which had made the research related progress slower in the field of Deep learning and neural networks. This time, the effect was so severe that the reputation of Artificial Intelligence reached to its worst phase so much so that its status was described simply a pseudoscience. But some of the enthusiastic researchers hadn't stopped there and due to their continuous work in DL and AI, some major developments were made in the respective fields. Once such development was made by Dana Cortes and Vladimir Vapnik in 1995 when their effort had led to the development of Support Vector Machine (SVM) and it helped to do mapping and recognition of similar kind of data. Further development in Deep learning was observed in 1997 when Sepp Hochreter and Juergen Schmidhuber developed Long Short-Term Memory (LSTM) for recurrent neural networks.

The major developments in the area of deep learning continued in 1999 also and this time, the developments of GPU (Graphics Processing Unit) and fast computers was giving tough competition to SVM. GPUs were capable of working at computational speeds of about 1000 times. However, the neural network was still capable of offering better results as compared to SVM since it had the capability to get improved with each addition of training data.

By the year of 2000, the research area of Deep Learning took a great leap after the development of the famous "Vanishing Gradient Problem" that led to the discovery of "features", sometimes referred to as lessons, where the upper layers were unable to learn about their lower layers due to the unreachability of learning signal between these layers. A research report of 2001 by META Group (known by the name of Gartner in the present times) explained the opportunities and challenges of growth in data as three-dimensional – volume, variety, and velocity that was clearly a sign of the beginning of developments of Big Data field.

An AI professor of Stanford University, Fei- Fei Li had launched ImageNet in 2009 that helped to assemble a database containing around 14 million of labeled images and that database was free to access. This was a huge development in the field of Deep Learning, Big Data and the Internet for the reason that the Internet has, and had, a huge number of unlabeled images which can be effectively used through the training of neural nets by labeled images.

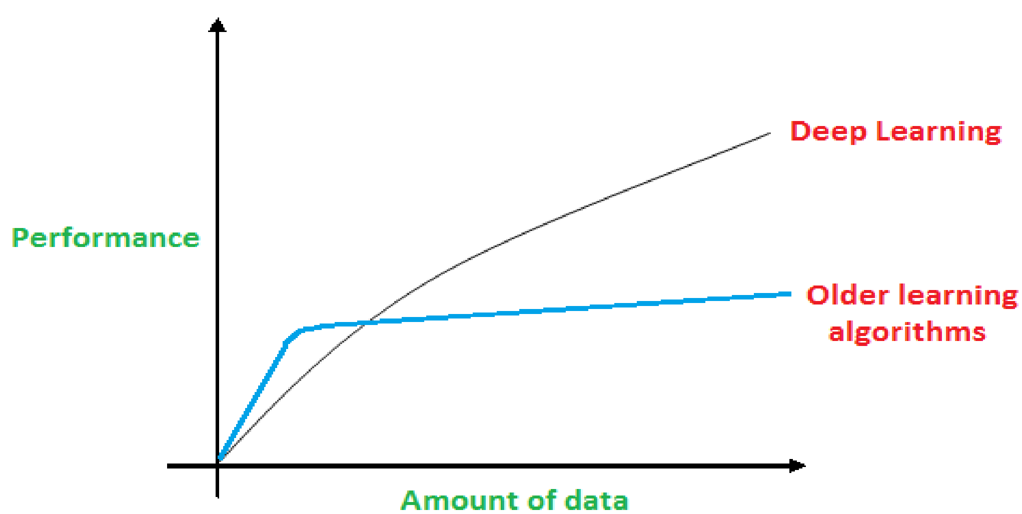

Fig – 1: Understanding why Deep learning is important

The significant increase in the speed of GPUs by 2011 made convolutional neural network to get trained in possible manner without the need of layer-by-layer pre-training. For example, a convolutional neural network like AlexNet had its architecture to win various

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competitions worldwide during the period of 2011 and 2012. Google Brain made a great contribution to the development of deep learning area after releasing the findings of the "The Cat Experiment" – it was an unusual project developed in 2012 that helped to explore the challenges faced during unsupervised learning. However, Deep learning uses supervised learning technique which implies that the labelled data, say images taken from ImageNet, is used to train the convolutional neural net. In contrast to this, unsupervised learning technique uses unlabeled data to train the convolutional neural net, followed by the task of seeking out the recurring patterns. The Cat Experiment was such a huge project that it spanned over 1,000 computers taking about ten million of unlabeled images from YouTube randomly that were later displayed to the system, followed by the running of the training software. The climax of such training came out in the form of obtaining a neuron at the highest layer that responded strongly to the cat's images. The greatest benefit of the Cat Experiment could be understood from the fact that it performed 70 percent better than the other techniques that appeared after The Cat Experiment in terms of doing processing on unlabeled images. However, it was observed that about 16 per cent of the total objects in The Cat Experiment worked in worse manner.
The ultimate goal of Deep learning at present is to work through unsupervised learning technique. Moreover, the Big Data processing and the developments related to the Artificial Intelligence field all rely on the growth of Deep learning research to generate more and more creative ideas.

IV. ARCHITECTURES OF DEEP NEURAL NETWORK

DNN acronyms for Deep Neural Network and it can be defined as an ANN (i.e. Artificial Neural Network) which consists of several hidden layer units between the input layers and the output layers. DNNs are similar to shallow ANNs in terms of having non-linear relationships of complex nature. The architectures of DNN, for instance for parsing and object detection, are responsible for generating compositional models that are meant for expressing the object as a layered composition of primitive images. Moreover, the designing of DNNs is basically done as feedforward networks even though the successful research on DNN is done with having recurrent neural networks whose major application is in language modeling. Similar things are observed in another DNN version of CNN (Convolutional Neural Networks) that has the major application in computer vision where it has well-documented success story to tell even though it can also be applicable in ASR (Automatic Speech Recognition) which makes the usage of acoustic modeling to achieve further benefits. Some of the important architecture versions of DNN are described in this section which can be easily analysed for their further applications. Make sure that whatever architecture we discuss with respect to DNN one thing is sure that backpropagation algorithm is discriminatively used to train the DNN and its architectural versions because this algorithm works wonderfully in the context of control theory. The idea of deriving continuous backpropagation in the context of control theory was given by Arthur E. Bryson and Henry J. Kelley where the weight updates can be done through stochastic gradient descent with the help of the equation given below:

$$\mathbf{W_{ij}(1+t) = W_{ij} + \left[\frac{dC}{dW_{ij}}\right] n + E(t)}$$

Where, n is the rate of learning, E(t) is the stochastic term and C is the cost function.

A. Convolutional Neural Network Architecture

This architectural version of DNN is frequently used to do visual processing and for performing other two-dimensional tasks. This architectural version basically consists of several convolutional layers that have few fully connected layers on top. Pooling layers along with tied layers are also incorporated in CNN architecture.

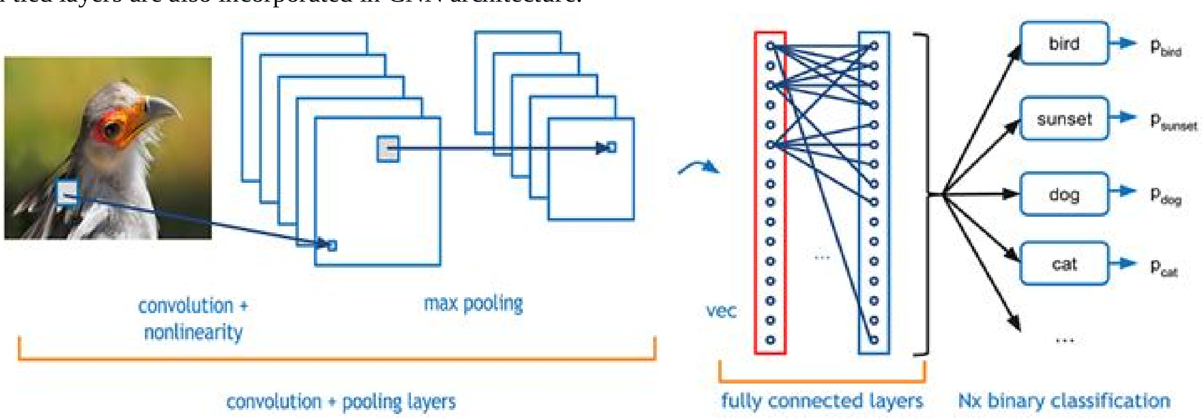

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Fig – 2: Understanding convolutional neural network

This kind of architecture is fully capable to work effectively and efficiently on input data with 2D structure. This architecture has shown excellent results in both the areas of image as well as speech applications in comparison to other DNN architecture versions.

B. Recursive Neural Network Architecture

This architectural version of DNN is composed of same set of weights that are applied recursively while doing traversal in a topological order over a graph like structure of differentiable nature. This architectural version is capable in learning process of structure with distributed representations, somewhat in logical terms.

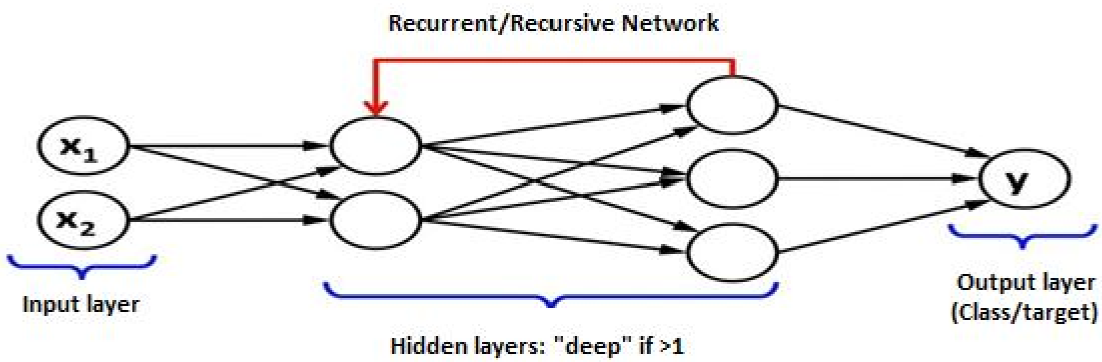

Fig-3: Understanding Recursive Neural Network

One special case of this architecture is itself that corresponds to a linear chain specifically. The major area of application of this architecture version of DNN is natural language processing.

C. Deep Boltzmann Machine Architecture

DBM (Deep Boltzmann Machine) is an architecture version of DNN that is obtained as an undirected graphical model of probabilistic nature, sometimes referred to as part of pairwise Markov random field, that is made up of several layers containing hidden random variables. Further, this architecture version is coupled with stochastic binary units arranged in a symmetric network.

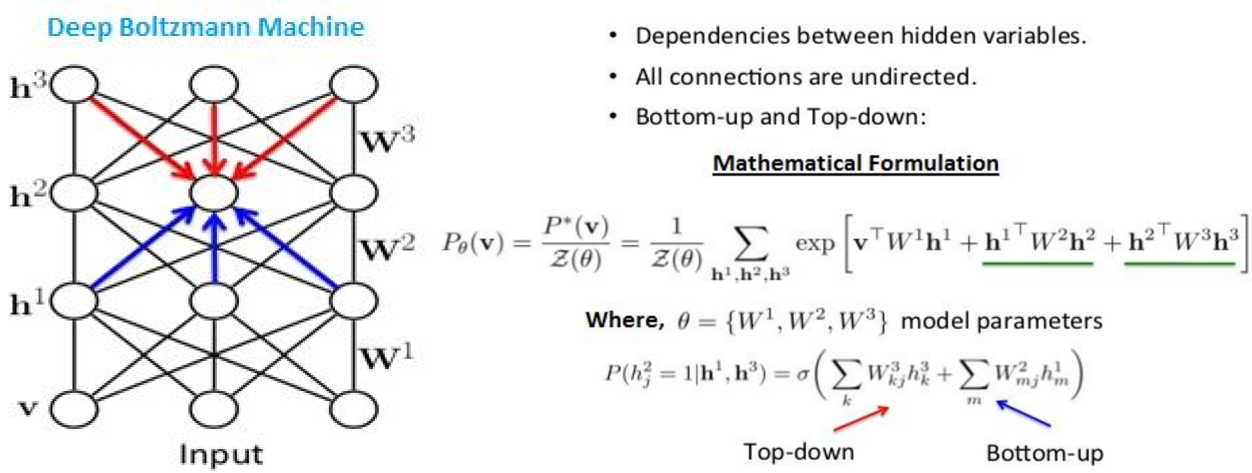

Fig-4: Understanding Deep Boltzmann Machine

One of the major benefits of this architecture version is that it can learn abstract and complex representation of inputs, especially in the field of speech and object recognition.

D. Stacked Auto-Encoding Architecture

This architecture version of DNN involves deterministic mapping, represented as f_s that helps in the transformation of an input vector, say x, into hidden representation, say y, where s = {W, b}. W is defined as weight matrix whereas b is defined to be as an offset vector (sometimes referred to as bias). The decoder, on the other hand, helps to map back the y hidden representation to reconstruct z input through g_t The major application of stacked auto-encoder is to achieve good representation that is obtained after comparing the reconstructed input with that of original input so as to minimize the error to let the obtained input to achieve the closeness to the reconstructed value of the original value.

D. Deep Belief Network Architecture

DBN (Deep Belief Network) is an architecture version of DNN which can be defined as a probabilistic generative network that is composed of several layers of hidden units. This network architecture is considered to be obtained through the composition of learning modules of simplistic nature that helps to build each layer of the DBN. This architectural version has the major application of providing generatively pre-training to the DNN through the usage of the learned DBN weights in the place of initial DNN weights. This process is then followed by applying back-propagation and other such algorithms in order to fine-tune the DNN weights. This way of using DBN in DNN filed is quite useful in the situation when limited training data are available.

V. CONCLUSIONS

Deep Learning (DL) is considered as one of the prominent research area fields of machine learning. It is quite useful in the applications like image processing, speech recognition, object recognition and much more for the reason that it works well over the data and pattern representation. There are various architectural versions of Deep Neural Network (DNN) available in this regard including convolutional neural network, recursive neural network, deep belief network, stacked auto-encoders and deep Boltzmann machine. We have analysed the challenges through this paper that the data scientists and researchers faced during the evolution of deep learning field. Even after two massive break downs in the deep learning research field, the deep learning enthusiasts and scientists had opened the door of effective and efficient research in DNN. We hereby conclude that deep learning is quite a promising research field and there are lots of concepts and areas related to this field which still required to be explored. We hope that new minds will associate themselves with this field to bring out more developments in both deep learning field and further human endeavours.

VI. ACKNOWLEDGMENT

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