An overview of deep learning architectures, libraries and its applications areas

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***Abstract*— In today's world, a massive amount of data is available through various fields in the form of text, images and audio. All this data can be a vast repository of information when analysed to find some patterns, trends and predictions. Extracting features from a corpus using traditional statistical methods was a challenging task and then prediction algorithm or clustering was applied on data to find useful information. Now the scenario has changed with the involvement of deep learning. Using deep learning model can be trained, learned on complex data along with multiple levels of abstraction. This paper gives an overview of some mostly used deep learning architectures, libraries which are useful and discusses various application areas where deep learning is active.**

Keywords*— *deep learning, architectures, applications, software libraries, comparisons

I. INTRODUCTION (HEADING 1)

Deep Learning or deep structured learning or hierarchical learning is a subarea of machine learning that deals with algorithms which have an inspiration by structure and function of the brain called artificial neural network (ANN). It is an application of ANN for such problems where learning tasks require more than one hidden layer. The 'deep' word in deep learning refers to the depth of the network whereas the ANN can be very shallow [6]. It tries to learn high-level of abstraction in data with the help of hierarchical architectures.[13]

In today's world, many problems which are solvable by taking a considerable amount of time are getting solved in less time. So a drastic increase of the interest of researchers in the area of deep learning has been seen. Figure. 1 clearly shows that the performance increase with deep learning in comparison to other machine learning algorithm. The reason for the rise in deep learning area in a few years due to the vast amount of data is available along with good computation capabilities. This helps in the creation of deep neural network model having a large number of hidden layers.

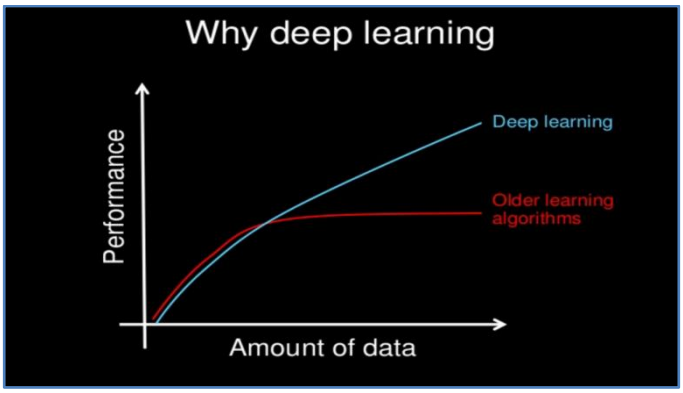

Figure 1: Performance comparison between deep learning and other traditional machine learning algorithm [1]

With the progress in processing time and hardware capabilities of a computer system, deep learning is getting applied in many fields like satellite imaging, computer vision, sentiment analysis from text & voice, video, object detection, semantic segmentation, human pose prediction etc.. If we take healthcare as an example, it can be applied to drug discovery for patients based on his medical history, Medical imaging for detecting life-threatening diseases through MRI scans, CT scans, ECG etc, Insurance fraud predictions in future and ,detection of Alzheimer's disease, understanding genome to help patient's for likely diseases in future [16]. In the areas of Internet of things (IOT), as per ABI research, it is estimated that over 30 billion devices are going to get connected through wireless communication to the Internet of things by 2020 [14]. This interconnection of devices generates big data which is a key factor for many smart IOT devices & applications. Deep learning techniques can be applied for extracting higher level information & analysis of such data [15]. A lot of work has been done using deep learning and has achieved better performance than traditional machine learning methods. For example - In [17], the author has used the stacked auto-encoder (SAE) deep learning model for traffic flow prediction, the performance of the proposed method is superior that Back-Propagation neural network, random walk, support vector machine, radial basis function neural network. In [18], the author has used Convolutional neural network (CNN) as deep learning model for classifying the quality of wood boards on the basis of their images. In this case, the performance of deep

ISBN: 978-1-5386-4119-4/18/$31.00 ©2018 IEEE

learning model for image processing tasks is superior than other traditional classification techniques.

II. Overview of Deep Learning Architectures

The below mentioned are examples of deep learning architectures:

A. Deep Neural Networks

A deep neural network is a kind of artificial neural network having multiple hidden layers present in between the input and output layer. It can model a complicated non-linear relationship. The extra hidden layers present in the deep neural network (DNN) helps in the composition of features from lower layer thereby enabling the neural network to model complex data. It is typically a feed-forward network where the data flow happens from input to output layer without looping back. The challenges with the deep neural network are over-fitting and computation time. Various regularization methods can be applied to control over-fitting such as Ivakhnenko's unit pruning or weight decay or sparsity. Apart from that size of neural network such the number of hidden layer and computational units per layer, learning rate, initial weights, batching and use of graphics processing units (GPUs) may be considered for computation time.

B. Deep Belief Networks

The deep belief network is a deep multi-layer graphical model in which the various hidden layers are present. The layers are connected to each other, but the neurons or computational elements are not connected to each other in the network. These models are used for hierarchical or abstract representation for features in the data. The lowest layer is the input layer and the uppers layer gradually represents the abstraction of the feature. Also, the training of the network happens in layer-wise fashion. Figure 2 show an overview of the deep belief network.

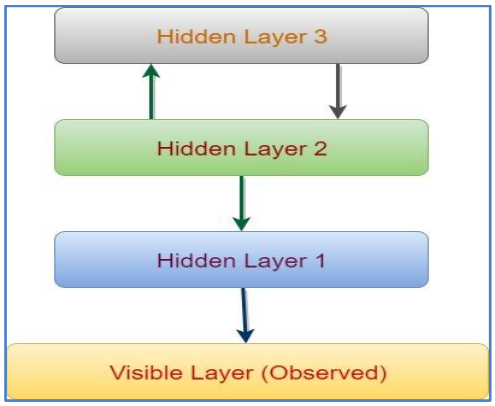

Figure 2: Overview of Deep Belief Network [3]

C. Recurrent Neural Networks

The recurrent neural network is a kind of artificial neural network which shows dynamic temporal behaviour as the computational units in ANN forms a directed cycle. These networks have loops in them which are used for persisting the information. Recurrent neural network (RNN) is capable of connecting the previous information to current tasks when the gap between them is small. In such cases, where the gap between the relevant information and the point where it is needed becomes very large then a particular kind of RNN is used which is called LSTM(Long Short-Term Memory) network and have the capability of learning long-term dependencies which means remembering the information for long term[4]. The below figure 3 take an example of weather prediction and clears the idea about LSTM-RNN. In the below figure X1, X2...Xn is the feature inputs from historical weather data, i.e. temperature, wind, rain or any other features. Now the LSTM model will learn the long-term dependencies between inputted features and based on it will predict the future weather data regarding the similar length of features and time duration.

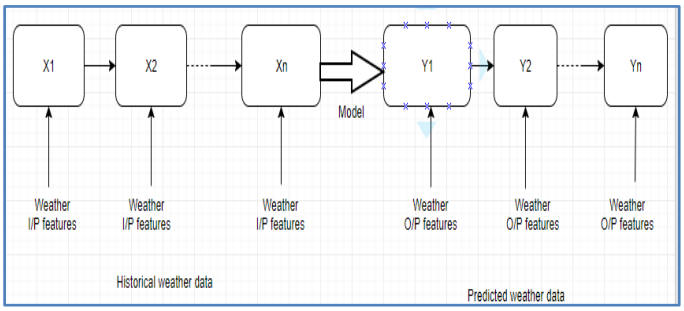

Figure 3: Showing an example for weather prediction using LSTM-RNN model

D. Boltzmann machine

A Boltzmann machine is a network of symmetrically connected, neuron-like units that make stochastic decisions about whether to be on or off [11]. Fig.4 represents a simple Boltzmann machine with 3 hidden and 4 visible units.

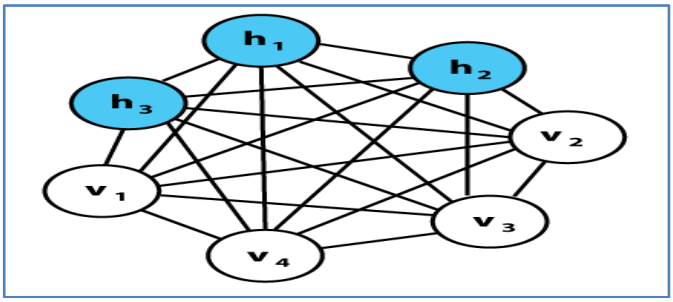

Figure 4: Boltzmann machine [7]

E. Restricted Boltzmann machine

Restricted boltzman machine is particular type of Boltzman machine consisting of a layer of visible units and a layer of hidden units with no visible-visible or hidden-hidden connection and these visible and hidden units must form a bi-partite graph. Figure 5, shows a representation of a restricted Boltzmann machine having 3 visible and 4 hidden units.

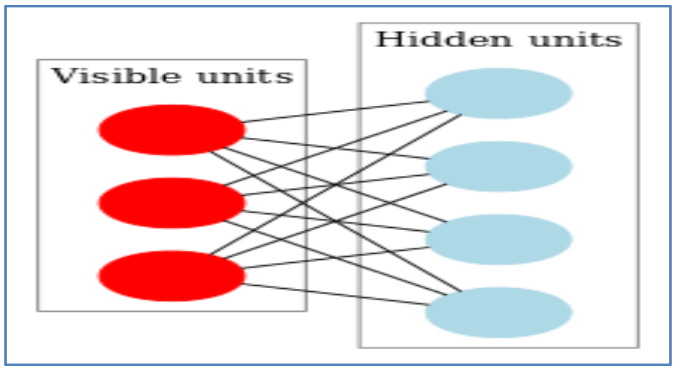

Figure 5: Graphical representation of Restricted Boltzmann machine [5]

F. Deep Autoencoder

Deep auto-encoders are a type of neural network which is composed of encoding a deep belief network and decoding deep belief network. The output layer is exactly the same as the input layer. The number of units in the hidden layer is usually less than the input layer and the output layer. The objective of putting a shallow layer in between the input and output layer so that the features of the input data can be encoded or compressed into less feature without losing the sense of information of data. This helps to identify the minimal required feature to represent the data which is known as dimensionality reduction. Again, the data with reduced features will be converted back to original data. Fig.6 represents a simple deep autoencoder.

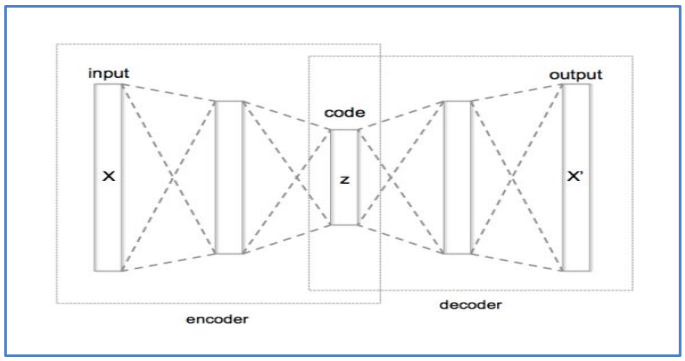

Figure 6: Graphical representation of deep auto-encoder with 3 fully connected hidden layer [8]

G. Convolutional neural network

A CNN is a kind of multi-layered feed forward deep neural network which is used mainly in the area of the image. The different layer in the network extracts different features from the image. In traditional machine learning algorithm, the features are extracted using different methodologies but in case convolutional neural network learns the filters on its own which means the network does feature extraction automatically [2,12]. Fig. 7 shows different convolutional layers for various feature extraction.

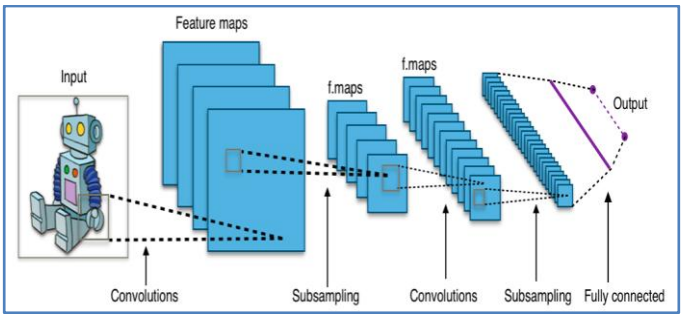

Figure 7: A typical CNN architecture [2]

III. APPLICATIONS AREAS FOR DEEP LEARNING ARCHITECTURES

In the field of deep learning, there are many deep architectures and algorithms which are used widely for extraction of the complex representation of data at the high level of abstraction [10]. Deep learning is used in various application areas as listed in Table 1.

Architecture	**Applications**
Deep belief network (DBN)	Image recognition, understanding (NLP), Information retrieval, natural language, failure prediction etc.
RNN/LSTM	Speech, handwriting, gesture (Recognition), natural language text compression, image captioning etc.
Convolutional neural network (CNN)	Image & object recognition, video analysis, Natural language processing (NLP) etc.
Restricted Boltzman machine	Enhancement in performance in speech recognition, topic-based citation recommendation etc.
Deep Autoencoder	Traffic flow prediction, speech recognition etc...

IV. SOFTWARE LIBRARIES FOR DEEP LEARNING

Details about some of the popular deep learning libraries are presented below [9]:

Library: Tensorflow
Open Source: Yes
RBM/DBM: Yes
CNN: Yes
RNN: Yes
About: Library in C++ and Python which uses data flow graph for numerical computations. It supports both CPU and GPUs.

Library: Keras
Open Source: Yes
RBM/DBM: Yes
CNN: Yes
RNN: Yes
About: Deep learning library for Python.

Library: Deeplearning4j
Open Source: Yes
RBM/DBM: Yes
CNN: Yes
RNN: Yes
About: Written for Java/C++ with LSTMs and CNN. Provides parallelism with Spark on CPUs and GPUS. From Tensorflow, Theano Keras, it imports model.

Library: Caffe
Open Source: Yes
RBM/DBM: No
CNN: Yes
RNN: Yes
About: Mainly used for image processing/computer vision.

Library: Torch
Open Source: Yes
RBM/DBM: Yes
CNN: Yes
RNN: Yes
About: Open source library based on Lua programming language and Facebook is using it.

Library: Theano
Open Source: Yes
RBM/DBM: Yes
CNN: Yes
RNN: Yes
About: Numerical computation library for Python programming language, supports CPU and GPU both.

Library: OpenNN
Open Source: Yes
RBM/DBM: No
CNN: No
RNN: No
About: Used for implementing deep neural network and gives parallelism with CPU.

Library: MXNet
Open Source: Yes
RBM/DBM: Yes
CNN: Yes
RNN: Yes
About: It's a deep learning framework for defining, training, and deploying deep neural networks.

V. CONCLUSION

In In this paper, an overview of deep learning and its related architectures along with their application areas, libraries useful for implementing various deep learning techniques. With this, we can understand that deep learning has the ability of self-learning about the model from a corpus of data in the form of text, images, audio etc. Also, this paper provides us with an insight into the process which is used in a few research areas to build/develop the model as deep learning application. In the near future, deep learning will be more successful because it has decidedly less human intervention and also along with more data, computation power it becomes more efficient and accurate.

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