Deep Learning: A Predictive Iot Data Analytics Method

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Abstract *- IoT provides a platform for sensor devices enabling information sharing across the platforms. IoT allows these devices to communicate without any interruption within a smart environment in convenient manner. In this digital era, correlation of data and Internet of Things (IoT) is red-hot area for data analysts. Amalgamation of Big data analytics with machine learning concepts has engendered interest of many researchers. Any IoT framework produces gigantic amount of data. This data is of no use if not analyzed and reviewed properly. This study is focusing on predictive analytics techniques that can be used in an IoT enabled environment. Paper sheds light on various data analytical methodologies. Brief introduction to architecture of deep learning is given. There are different intelligent machine learning algorithms elucidated in this study and deep learning is also one of them. Deep Learning is considered as the advanced artificial intelligence technology, which can be used in analytics and learning process of IoT data. It expounds the reasons of using deep learning for predictive IoT data analytics. Besides, introducing readers to different algorithms of deep learning which can be helpful in predictive analytics, it also elaborates their working in detail with the help of their architectures.*

Keywords: *Deep Learning, Internet of Things (IoT), Machine Learning, Neural Networks, Predictive analytics.*

I. INTRODUCTION

Internet of Things (IoT) is a prominent technology these days.[40] IoT are made up of a network of different types of things which are connected to the internet such as sensors, devices etc which can be controlled, monitored and detected. IoT technology is being very popular in different domains such as transportation healthcare, agriculture, security, retail, smart cities and education [5]. In IoT system different sensors are used to collect different amount of data for particular type of machine. This collected data is huge which is analyzed with the help of big data mining techniques.

Data analytics can be achieved with help of various approaches, various tools and technologies. It seems machine learning is considered as a primary module of data analytics.[3] The analysis of different parameters in IoT based systems are very challenging research scope to merge with big data handling capabilities.

Large amount of IoT data being released due to different sort of devices in different sectors like healthcare, retail, smart-cities, agriculture, weather forecasting etc. and this data is going to increase with high growth rate in near future.[45] This IoT data is needed to be stored, managed, processed and analyzed. To do this analytical process on large IoT dataset an intelligent learning mechanism is needed which is deep learning. [4] Deep learning has become widely accepted machine learning algorithm regarding IoT based Big Data analysis. Deep learning has become an important methodology for different informatics fields. It is a strong analytical tool for large amount of data such as real world IoT sensor data. Now-a-days, Deep learning instigate many tasks related to IoT. [47]

Gartner's hype cycle is a way of representing the maturity and adoption of a technologies and applications with the help of a graph. Gartner hype cycle gives a view of how different technologies and applications will evolve in near future. Figure 1 shows the Gartner's Hype Cycle for artificial intelligence 2019. Deep learning is at the peak of the graph which means that deep learning will be the burning topic for next 2 to 5 years.

Here in this paper various data analytical methodologies and how these analytical processes can be achieved with the help of deep learning is being studied [46]. The rest of the paper is divided into different sections: In Section 2 related research work of deep learning in different field has been discussed. Section 3 discuss about the different steps to process the data used for prediction. Section 4 introduce with Deep learning and its different characteristics. Section 5 gives the architecture of deep learning. Section 6 give details of different types of deep learning algorithms.

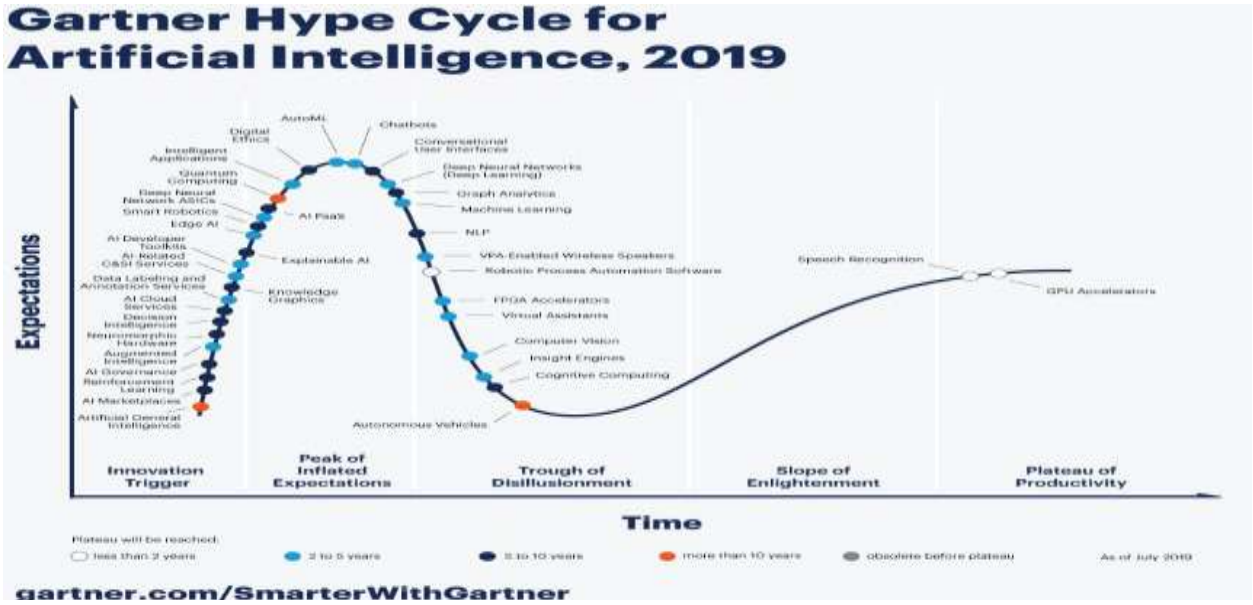


Figure 1: Gartner's hype cycle *[**Source:** https://www.forbes.com/sites/louiscolumbus/2019/09/25/whats-new-in-gartners-hype-cycle-for-ai-2019/#590eff7e547b]*

II. RELATED WORK

He Li*et al.* introduced Edge Computing with the help of deep learning in IoT. Deep learning is considered as a analytical tool for big data. Edge computing helps in unloading computational jobs. Jobs are moved from centralized cloud to the edge near IoT devices. When intermediate data size is smaller than input data size, in that case edge computing performs best. Multilayered Deep learning network can be used to scale down the intermediate data until enough features are found. Deep learning applications are used besides edge computing technology to achieve maximum efficiency of IoT. They also have designed a novel offloading strategy.[7]

Fengxiao Tang *et al.* uses deep learning for traffic load prediction. Now-a-days sensing data is increasing more and more over the network. They propose a algorithm for traffic predictive analytics using deep learning which helps in finding future load and congestion of the network. Two type of Deep learning structures to train the data for predictions i.e. Deep Belief Architecture (DBA) and Deep Convolution Neural Network (DCNN). Both use forward and backward propagation techniques to train the data. The forward propagation is used to construct the structure and activate output, while the back propagation is used to adapt the structure. However, size of input data is large and spatially high dimensional in CNN than that of DBA. [8]

T. T. Chhowa *et al.* performed the IoT based medical data analysis with the help of deep learning. They come up with the facts that for medical sector deep learning is a better option for analytics as compared to machine learning because of their manual feature extraction and less accuracy factors. They made a comparative study on already existing deep learning strategies.[9]

Justin Ker *et al.* made a review on machine learning algorithms especially deep learning when applied to medical image analysis. They try to cover different analytical areas for medical image classification, localization, detection, segmentation, and registration. They focused on Convolution Neural Networks (CNN).[10]

P. Li *et al.* uses CNN as one of the technique of deep learning for hierarchical feature learning on Big Data in IoT. In it Deep Convolution Computational Model (DCCM) is used which is an extended version of CNN using tensor representation. [11] This DCCM is then further applied on three types of datasets to check its performance. Datasets used for this purpose are CUAVE, SNAE2, STL-10.[11] CUAVE is a heterogeneous dataset containing audio and image form of information [12]. SNAE2 is a collection from YouTube which is perfect to facilitate heterogeneous data feature learning research [13]. STL-10 is basically an image data set which contains more than 1300 images. [14]

M. P. Hosseini *et al.* explained how seizure can be predicted using deep learning and EEG Big Data via IoT. In medical sector, the Brain-computer interface (BCI) is used for controlling epilepsy with the help of seizure prediction techniques provided by deep learning. They deploy process of seizure prediction done by BCI. After this, they localize EEG (electroencephalographic) scalp and ECoG

(electrocorticographic) big data by taking leverage of deep learning [15].W. Zhang*et al.* discussed the meaningful feature and pattern extraction from EEG big data for data analysis and querying [16]. M. Abavisani *et al.* considers deep learning as a advanced computational method for data processing [17]. M.-P. Hosseini *et al.* finds out that deep learning structures uses multilevel hierarchical learning approach to extract features from raw data [18].

Deep learning [48] helps to harness large amount of data i.e. big data with little amount of engineering [19]. T. Young *et al.* helps us understanding Natural Language Processing (NLP) in co-relation with deep learning. They discussed various deep learning models that have been employed for different NLP tasks [20].

Y. Lv *et al.* used spatial and temporal correlations to predict traffic flow with the help of novel deep learning technique. They used stacked auto-encoders (SAEs) for this. Generic traffic flow feature is learned with the help of these SAEs. These SAEs are trained in a layer wise greedy fashion. They improved performance of predictive algorithm by updating model's parameters. [21]

D. Ravi *et al.* explained about the applicability of deep learning in field of healthcare and also discussed its limitations and challenges. They came to conclusion that with the help of deep learning human intervention is reduced in the process of generating features from large dataset, because now it is being done by different algorithms of deep learning. This feature has helped to solve different problems in healthcare sector. It also supports unstructured data such as medical imaging, medical informatics, and bioinformatics etc. [29]

III. PREDICTIVE ANALYTICS ON IOT DATA

Predictive analytics relies on machine learning and helps in developing models that is built using past information or data to predict the future. Predictive analytics in any framework has to go through certain steps [1]:

A. Data Gathering

Raw Big IoT data is gathered from different sensors and IoT appliances to generate a dataset. This is the step where we need to remove noises, fill the missing values and keep track the changes that are done in the database due to manipulations on it. Also considerable amount of data is reduced which is not required in prediction.

B. Data Cluster Analysis

It is a process in which data is grouped on the basis of their similarity. These groups are further used in a productive way. Data is clustered in two ways in analytical process i.e. hierarchal cluster and Partitioning cluster. Hierarchical clustering is a clustering in which we can traverse the cluster from starting note to the ending node on the basis of evidence we found. It can be done in top-down or bottom-up manner. In partitioning cluster, cluster is made by relocation of common centroid.

C. Association Rule Mining

It helps to remove irrelevant data and noises from the data. In this multiple rules are made which helps to rule out the data which is not appropriate for our analysis. It is done with the help of two steps: first, minimum support/ confidence mining and second, execution time reduction and number of rules reduction.

D. Outlier Analysis

It helps in predicting fresh and unfamiliar patterns. It can be done by two ways i.e. by looking out for left out values, or by combining the values.

E. Conclusive Statement Gathering

After the dataset is created by applying all above mentioned points we conclude the answers or predict the future. It follows the following four steps:

- Building knowledge in form of if-else ladder
- classifying facts from knowledge
- Validate the knowledge by removing multiple answering questions
- Verifying knowledge

IV. DEEP LEARNING FOR PREDICTIVE ANALYTICS ON IOT DATA

Various machine learning paradigms are there which helps in predictive analytics which are named below:

- Ensemble Learning
- Online Learning
- Lifelong Learning
- Local Learning
- Deep Learning
- Transfer Learning[3]

Here, figure 2 shows the recent Google trends of machine learning algorithms that are being used in different technology services these days. It can be seen in figure 2 that after 2016 deep learning has beaten all other machine learning techniques like Logistic Regression, Support Vector Machine (SVM), Decision Tree [46] and K Means etc. [41] in number of average searches per year.

- *Deep Learning:*

It is the advanced machine learning technique which facilitates predictive learning in IoT domain. It is a process that extracts data just like neural networks in

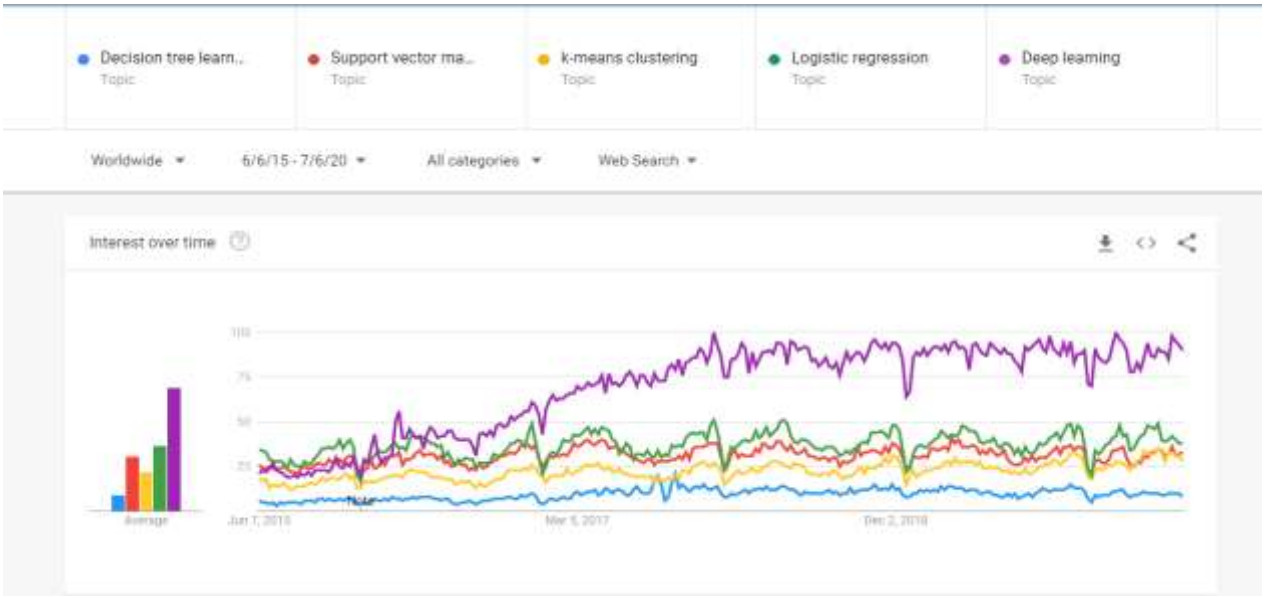


Figure 2 : Recent Google trends of different machine learning algorithms including deep learning

a hierarchical learning form. It changes data into abstract representations the helps the features to be learnt.

- *Online Learning :*

Online learning is used to bridge the gaps created by large scale Big Data. It uses data streams for training process. Unlike batch processing here, a model can grasp one instance only at a time.[42] Online processing can be regarded as alternative to batch processing [27]. It is adaptive in nature that helps to handle certain amount of noisy data and concept drift [28].

- *Local Learning :*

In global learning, a model is used to regenerate the input data based on the data underlying distribution. It is used to summarize the whole dataset. It is used for semi-parametric approximation [3] which helps in global learning. Local learning was used in 1992 by Bottou and Vapinik [29]. It is concerned with the subsets of interests only. It helps in dividing the problem into small modules, which further reduces the size of data that alleviates the curse of modularity.

- *Transfer Learning :*

In target learning, training dataset is not necessarily the same as that of the testing dataset. It is used when data size of target domain (in which learning is performed) is not sufficient or when learning task is different [30]. It can be used to improve learning in target domain [3], with the help of training models with other datasets which belong to multiple domains, called as source domain. It is used to train data from several domain. Different types of elements are transferred from source domain to target domain: instances, different feature representations, relational knowledge of different domain and model parameters. [31] [32]

- *Lifelong Learning :*

This is a type of learning which follows continuous learning process. All the knowledge collected in it is retained to solve different problems. These training processes give some outputs, that are collected and stored in topic model.[33] Lifelong learning is somewhat similar as that of online learning as both are continuous process. It also matches to transfer learning as both are able to transfer different type of information among different type of domains. It can be applied to different domains such as in e-commerce [34], network intrusion detection [35].

- *Ensemble Learning :*

Ensemble learning is a learning in which outcomes are obtained by combining outcomes of multiple learners. This overall outcome is analyzed by individual learner's voting, which may belong to same or different categories [36]. Ensemble learning can be done by two methods. First, one have different learners which a trained on the complete dataset. Second, different learners are trained on different subsets of the original dataset. Different researchers have discussed Ensemble learning with different datasets. [37] [38] [39]

A. Why Deep Learning

Characteristics of Deep Learning are described below which are well suited to address various challenges of IoT data.

- *Feature Engineering*:

Here features are learned straight from the data, hence there is no need of feature engineering.[3] Though we are studying deep learning in context of Big IoT data, by-passing the feature engineering is considered as a great advantage.

- *Heterogeneous Data:*

It release on the abstract data representation. So, Output of any learning process does not depends on any sort of heterogeneous data or its sources.[3]

- *Learning method:*

Deep Learning can be used on any type of learning methods i.e. supervised learning or unsupervised learning method because it can be used to extract global relationships and patterns from the data.

- *Veracity challenge:*

Deep learning can overcome the Big data V's challenge of veracity as it is less sensitive to the dirt, noise and uncertain data.

- *Non-linearity:*

Deep learning works on multiple layers which can easily address the challenges of non linear datasets.

V. ARCHITECTURE OF DEEP LEARNING

Deep Learning consists of three types of layers, namely: an input layer, several hidden layer and an output layer. Every layer have neurons in it which performs weighted summations over the input values and then on the result some activation function is applied which gives the actual output. During training process every neuron's bias is optimized.

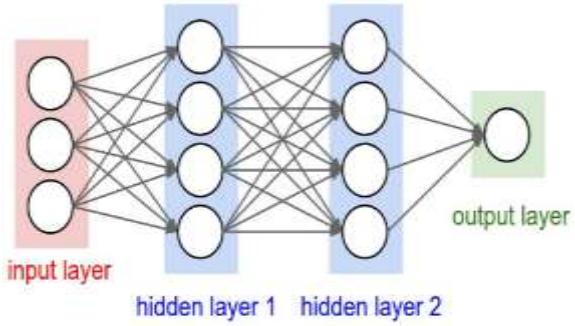


Figure 3 : Deep Learning architecture.

Input layer assigns weights to the input layer training data in a random way and then move it to next layer called hidden layer.[4] Every successive layer assigns the weights in the same random way as that of input layer and then, produces outputs. Output layer describes the predicted output. Then a loss function is also used to determine the correctness of the prediction made by the output layer. Figure 3 depicts the architecture of deep learning.

VI. DIFFERENT METHODS OF DEEP LEARNING

Deep learning is a technique which is based on different number of layers of artificial neural networks. It is both supervised as well as unsupervised kind of learning method. Some of Deep Neural Network (DNNs) methods are given below [4]:

A. Recurrent Neural Networks (RNN)

RNNs is used to classify as well as analyze the sequence of inputs given to the model but unlike feed forward network, it can be used to set up correlation between the input and output layers in time series problem or sequential problems. In this neural network, every neuron in an RNN layers should have an internal memory. This internal memory will hold the facts that are computed from previous input. Backpropagation algorithm known as backpropagation Through Time (BPTT) is used for training the network. Figure 4 shows the RNNs diagrammatically.

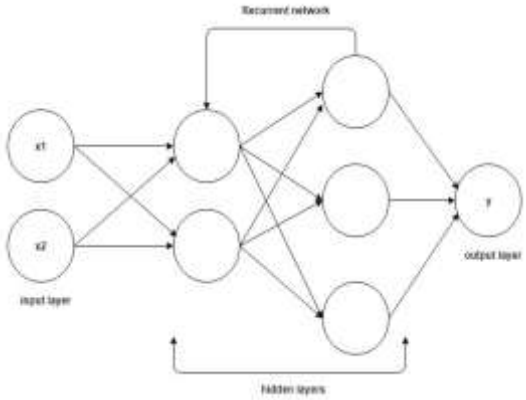


Figure 4 : Recurrent neural networks [Img. Source : https://hackernoon.com/rnn-or-recurrent-neural-network-for-noobs-a9afbb00e860]

B. Convolution Neural networks (CNNs)

CNNs have a input layer which takes the input as 2-D (images etc.) and then pass it to the hidden layers. Hidden layer have the convolution layer which have filters. These filters help in extraction of high level features from the input. While training the data set, filter present in each convolution layer calculates the product of inner input and the filter. Pooling layers are also the building blocks of CNNs. Max Pooling are the popular approach to partition the input space.

C. Long Short Term Memory (LSTM)

It is considered as a extended version of RNNs. LSTM uses the gates concept for every unit. On the basis of the input given to these gates, a value between 0 and 1 is computed. These gates can use different types of functions like sigmoid or tanh function. Every neuron have a feedback loop, forget gate, read gate and write gate which helps to control the access to neurons(or memory cell in this case). Figure 5 shows the LSTM pictorially.

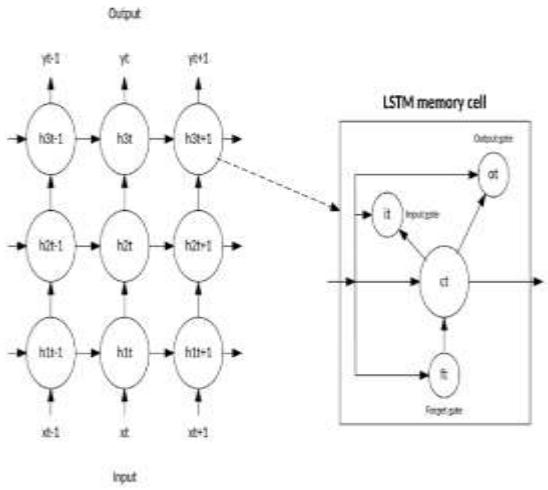


Figure 5 : Long Short Term Memory (LSTM) *[Img. Source:* **https://developer.ibm.com/technologies/artificial-intelligence/articles/cc-machine-learning-deep-learning-architectures/#:~:text=Each%20layer%20in%20a%20deep,overall%20hierarchy%20of%20the%20DSN.** *] [43]*

D. Autoencoders (AEs)

AEs have input layers, hidden layers and output layers. It has same input and output layers. Autoencoders are unsupervised algorithms. It can be used for anomaly detection. It works through backpropagation by setting their target output values as their input values, hence, to autoencoding themselves. It has two components: encoders and decoders. Encoders are those which are used to receive and input and transforming it to new representation called latent variable. Decoders are used to take these latent variables and helps in converting them the original input. Figure 6 shows the architectural view of AEs.

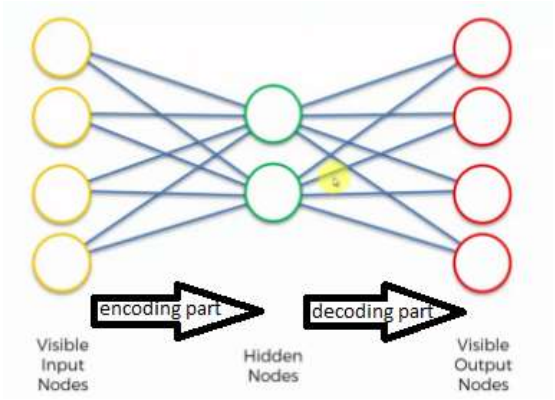
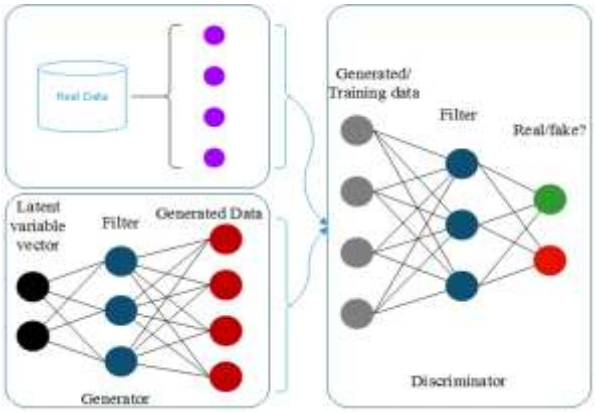


Figure 6 : Autoencoders

E. Generative Adversarial Network (GANs)

GANs results in a synthetic and high-quality data. It consists of two types of neural networks: one, which learns data distribution from a training dataset and then generates new data is called generative network. Another, which discriminates real data and fake input data called discriminative network. Figure 7 depicts these layers of GANs.



F. Restricted Boltzman Machine (RBMs)

RBMs are similar to autoencoders except they use stochastic rather than deterministic process. RBMs have two layers: Visible layer and Hidden layer. Visible layer is a layer that have input known to us and Hidden layer is a layer that contains latent variables. Connectivity of neurons of each layer is restricted by the Botzmann machine. RBMs should build a bipartite graph. The training process of dataset uses backpropagation and gradient descent algorithm for weight optimization. RBMs is shown in figure 8.

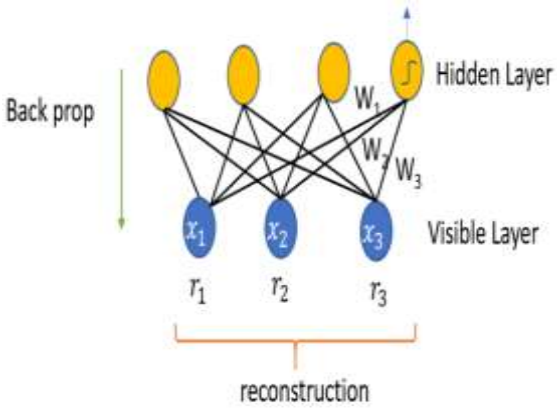


Figure 8 : Restricted Boltzman Machine (RBMs)[Img. Source: https://medium.com/datadriveninvestor/deep-learning-restricted-boltzmann-machine-b76241af7a92 *][46]*

G. Deep Belief Network (DBNs)

It has visible layer and several hidden layers. Visible layers correspond to the input and hidden layer corresponds **to the** latent variables. [4] Training of DBNs is done layer by layer. Every layer is considered as RBMs trained above the previous trained layer. It is a type of generative Artificial Neural Networks (ANNs). Deep Belief Network is shown in figure 9.

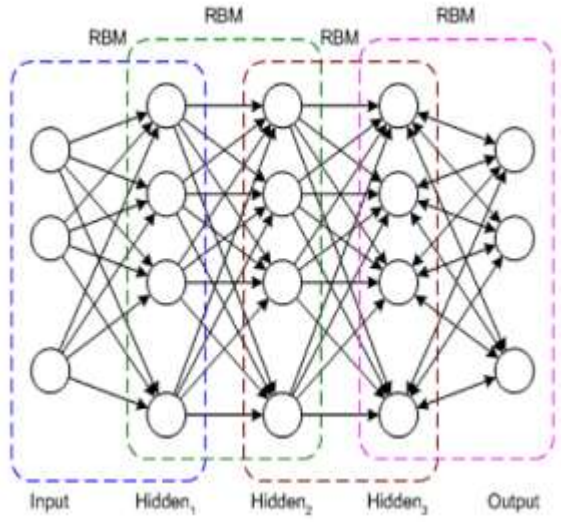


Figure 9 : Deep Belief Network (DBNs)
[Img. Source:* https://developer.ibm.com/technologies/artificial-intelligence/articles/cc-machine-learning-deep-learning-architectures/#:~:text=Each%20layer%20in%20a%20deep,overall%20hierarchy%20of%20the%20DSN.*] [43]

H. Ladder Networks

It is used to work in a semi-supervised environment. Its architecture comprises of two encoders and one decoder. Every encoder is used for normal computations as well as for adding Gaussian noise to all layers of ladder network. The decoder is used to de-noise the data that means to reconstruct the representation of each layer from the data it gets from the corrupted encoder. Its applications are handwritten digits recognition, image classification etc. Figure 10 gives the pictorial representation of Ladder Network.

VII. FUTURE SCOPE

IoT data will continue to grow more and more by the passage of time. Data analytics with IoT tends to provoke the interest of the researchers in this field. Predictive analytics can be used in every framework of IoT like in weather forecasting to predict weather, in healthcare sector to predict different disease, in agriculture sector to predict the crop yield and decide better crop sequence based on the previous crop sequence. And for predictive analytics deep learning is a best tool to analyze the data.

VIII. CONCLUSIONS

Through this study it is clear that IoT data will grow day by day and to handle it there is need of new algorithms which are intelligent in nature. Various machine learning paradigms like Ensemble Learning, Transfer Learning, Deep Learning, Local Learning, Online Learning and Lifelong Learning are explained in details which are helpful to solve this issue of data analytics.

Paper has focused on predictive data analytics for IoT environment. This purpose it served by opting Deep Learning as the most efficient method of predicting values for IoT data. This paper discussed different areas of IoT where deep learning is adopted for analytical purpose. Deep learning features helps to overcome the challenge of data uncertainty, feature engineering, heterogeneity, noisy and dirty data and non-linearity. Deep Learning and its different methods with their architectures are studied deeply so that one can conclude for which kind of prediction problem which method will fulfill the needs. Table 1 gives a quick view that what this paper adds to ones knowledge.

Table 1: What this paper adds

What is already known	What this paper adds
• Data Analytics • IoT • Data mining on IoT devices • Deep Learning	• Big IoT Data Analytics • Why deep learning • Different methods of Deep Learning with their architectures

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