Comprehensive and Comparative Analysis of Neural Network

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Abstract

History of science has taken a great turn after the evolution of Artificial Intelligence. Whole world is taken part in Artificial Intelligence through different languages like Python, Java, R, C++, C, JavaScript, Scala, Julia, etc. Machine learning is a part of artificial intelligence that helps in training of machines for the interaction with human. Man machine interaction starts from a smallest level of neural network that is Perceptron. Perceptron is the single layer neural network which is trained using machine learning. The interconnection of different layers forms a neural network. There are different types of neural networks which are used for different purposes. The objective of the paper is to find out which neural network fits best for face recognition or natural language processing or any other task. Output with the diagram will make the decision more clear about the objective.

Keyword: Artificial Intelligence, Python, Machine Learning, Neural Network, Perceptron.

I. INTRODUCTION

Human has the natural intelligence called the brain. Brain is a highly complex, non-linear and parallel computer. Humans naturally have this intelligence that's why called the natural intelligence [11]. The intelligence given to machine or demonstrated by machine is called Artificial or Machine intelligence. It is a very complicated task. Learning is one the goal of AI. Learning is the ability to improve behavior based on experience. Humans have this learning ability and to teach the machine how to learn is called Machine Learning. Machine Learning is one of the most important applications of Artificial Intelligence. Machine Learning explores algorithms that learn from data or build model from data. This model is used for prediction, decision making or solving task. There are various applications of Machine Learning such as Medicine, Computer vision, Robot control, Natural Language Processing, Financial stock rise or fall, fraud detection, understand consumer sentiments, etc. Artificial Neural Network [2][14][15] is one of the applications of Machine Learning.

In the paper we focused on the Artificial Neural Network. There are different types of artificial neural networks developed for different purposes. For example CNN neural network [1] used for face recognition, Recurrent neural network used for Natural Language Processing, etc. The paper shows the comparison of different artificial neural networks with their respective diagram and output.

Neural Network inspired by human brain, human beings are very intelligent and can do certain tasks extremely well and this inspired people to try to understand how human brain

works. Human brain contains 10 billions of neurons which are highly connected and these individual neurons are simple conducting units but together they perform very complex task. There are certain characteristics of neurons which have been incorporated while trying to form the architecture of neural network. So, these characteristics are:

1. Massive Parallelism
2. Connectionism
3. Distributed Associative Memory

The basic unit in the neural network is called Perceptron [17]. Frank Rosenblatt invented perceptron in 1957 at the Cornell Aeronautical Laborator [17]. To learn the binary classifier perceptron algorithm is used. It is also termed as single-layer perceptron. It is the simple feed forward neural network [3]. Feedback neural network is an artificial neural network where connection between the units doesn't form a cycle. It is the first and simplest type of Artificial Neural Network derived. It is a type of linear classifier. Linear classifier makes the classification decision on the basis of linear combination of features. In contrast there is a classifier called non linear classifier. KNN is an example of non-linear classifier. Basically there are two types of learning supervised and unsupervised learning. Perceptron algorithm is used for supervised learning. In supervised learning label means output dataset is provided whereas in unsupervised learning no label or output dataset is provided; only input is given in unsupervised learning. It is also called clustering.

II. HISTORY

A simplified history is shown in table below:

TABLE 1 NEURAL NETWORK HISTORY [2][11]

YEAR	SCIENTIST NAME	WORK DONE
1943	Warren McCulloch and Walter Pitts	They had taken the first step toward Artificial Neural Network. They wrote a paper on how neurons work and modeled a simple neural network on electrical circuit.
1949	Donald Hebb	Wrote the book "Organization of behavior".
1950s	Nathanial Rochester	He first time simulate a neural network.
1956	Dartmouth	Simulate research on both AI and Neural Network.
1957	Frank Rosenblatt	Develop Perceptron
1959	Bernard Widrow and Marcian Hoff	Develops model called ADALINE and MADALINE. MADALINE was the first neural network to be applied to a real world problem.
1962	Widrow & Hoff	Examine the value before weight adjusts.
1972	Kohonen and Anderson	developed a network independently of one another.
1975		first multilayered network was developed, an unsupervised network.

III. PERCEPTRON [17]

The basic unit of neural network is Perceptron. It is the most basic form of neural network. Perceptron algorithm is used to learn the binary classifier. As per the classification rule, binomial classifier classifies the dataset into two groups.

Perceptron is also called single layer neural network.

Fig. 1. Single Layer Perceptron [17]

$X_1, X_2, \dots, X_n$ are the inputs.

b is the bias.

Y is the output.

$$Y = \text{sgn}(W_1X_1 + W_2X_2 + \dots + W_nX_n + b)$$

Sgn function value varies from 1 to -1.

If greater than 0 then 1,

Else -1.

This is the simplest output function. This function is used to classify linearly separable pattern.

Fig. 2. Linearly Separable [2][16][17]

The above figure divides the space into two classes + and -. This is called linearly separable. Single layer Perceptron is used to classify this type of dataset.

Single layer perceptron is applied on iris dataset. Iris is a flower dataset. In the paper two classes Setosa and Versicolor are used. If the range varies from -1 to 1 then it comes under Setosa class otherwise Versicolor class.

Fig. 3. Single Layer Perceptron Output

Red color shows Setosa,
 Blue color shows Versicolor, and
 Yellow color shows target.

IV. ARTIFICIAL NEURAL NETWORK(ANN)

ANN is based on the human brain. Human has naturally thinking power known as Natural Intelligence whereas when we applied the intelligence to the machine called Machine Intelligence.

Human brain is consist of multiple neurons. These nerons are connect together with link and interact with each other by transferring data/signal. Similarly, ANN is composed of multiple nodes. These nodes are connect with each other by link. The node takes input data, perform operation and passed output to other node. In this way all the nodes are connecting and interacting with each other parallelly. It makes ANN architecture Massive Parallelism, Connectionism, and Distributed Associative Memory. The Activation function is used at the output of each node. This function defines the node output on the basis of the input or set of inputs. And the link between each node is associated with weight. Due to this weight ANN is capable of learning. Learning happens by altering weight.

Simple layer neural network is consists of Inputs, Outputs and a single Hidden layer. If a neural network has more than one Hidden layer called multilayer neural network.

Fig. 4. Single Layer Neural Network [2][16]

A. Types of Neural Network

Classification of neural network is done on the basics of Learning.

1. Supervised Learning
2. Unsupervised Learning
3. Deep Learning

Supervised neural network

a) Feedforward Neural Network

A feedforward neural network is a simple type of artificial neural network where the units do not form a cycle between the connections of the units[3]. It is different from recurrent neural networks [4]. Basically feedforward neural network was the first and simplest type of artificial neural network comes [16].

Fig. 5. Feedforward Neural Network [3][4][16]

```

Python 3.6.3 Shell
File Edit Shell Debug Options Window Help
2 [1, 0] [0.8453921]
TRUE
3 [0, 0] [0.73825]
4 [1, 0] [0.83895067]
TRUE
5 [0, 0] [0.72918474]
6 [0, 1] [0.7733785]
7 [0, 0] [0.72111545]
8 [1, 0] [0.82628511]
TRUE
9 [0, 0] [0.71170185]
10 [0, 0] [0.69949933]
11 [1, 0] [0.81000047]
TRUE
12 [0, 0] [0.68979602]
13 [0, 0] [0.67675498]
14 [0, 0] [0.66326616]
15 [0, 0] [0.64935634]
16 [0, 0] [0.63505898]
17 [1, 0] [0.75967283]
18 [0, 1] [0.69309517]
19 [0, 0] [0.63245196]
20 [0, 0] [0.61774439]
21 [0, 1] [0.67321319]
22 [0, 0] [0.61064973]
23 [0, 1] [0.66729307]
24 [1, 0] [0.74731499]
25 [0, 1] [0.68048697]
26 [0, 0] [0.61709387]
27 [0, 0] [0.60207025]
28 [0, 1] [0.66071441]
29 [0, 1] [0.66899824]

```

Fig. 6. Feedforward Neural Network Output

b) Radial Basic Neural Network

A Radial Basis Function Network is a type of artificial neural network. In this type radial basis functions is used as the activation functions [9]. The output of the network is a linear combination of radial basis functions of the inputs and neuron parameters [10]. Radial basis function networks have many uses, including function approximation, time series prediction, classification, and system control.

Fig. 7. Radial Basic Neural Network [9][10][16]

Above diagram detects epileptiform artefacts in EEG recording using Radial Basis Neural Network

```

Python 3.6.3 Shell
File Edit Shell Debug Options Window Help
Performing k-fold cross validation using RBF network...
Cross validation complete.
Optimal beta and validation accuracy for optimal beta 140 93.9
training...
testing...
Comparing predicted labels to actual labels:
label predicted
0 0.0 0.0
1 0.0 0.0
2 0.0 0.0
3 0.0 0.0
4 0.0 0.0
5 0.0 8.0
6 0.0 0.0
7 0.0 0.0
8 0.0 0.0
9 0.0 0.0
10 0.0 0.0
11 0.0 0.0
12 0.0 0.0
13 0.0 0.0
14 0.0 0.0
15 0.0 0.0
16 0.0 0.0
17 0.0 0.0
18 0.0 0.0
19 0.0 0.0
20 0.0 0.0
21 0.0 0.0
22 0.0 0.0
23 0.0 0.0
24 0.0 0.0

```

Fig. 8. Radial Basic Neural Network output (part 1)

25	0.0	0.0
26	0.0	0.0
27	0.0	0.0
28	0.0	0.0
29	0.0	0.0
...	...	...
970	9.0	9.0
971	9.0	9.0
972	9.0	8.0
973	9.0	9.0
974	9.0	9.0
975	9.0	9.0
976	9.0	9.0
977	9.0	9.0
978	9.0	9.0
979	9.0	9.0
980	9.0	9.0
981	9.0	9.0
982	9.0	9.0
983	9.0	9.0
984	9.0	7.0
985	9.0	9.0
986	9.0	9.0
987	9.0	9.0
988	9.0	9.0
989	9.0	9.0
990	9.0	9.0
991	9.0	9.0
992	9.0	9.0
993	9.0	9.0
994	9.0	9.0
995	9.0	9.0
...	...	...

Fig. 9. Radial Basic Neural Network output (part 2)

Unsupervised Network

a) Self Organizing Neural Network

Fig. 10. Self Organizing Neural Network [7][8][9][16]

It is used to produce a low-dimensional (mostly two-dimensional), discretized representation of input sample space of the training samples[7][8] and therefore it is a method to do dimensionality reduction [9]. They applied on competitive learning as opposed to error-correction learning (backpropagation with gradient descent) to preserve the topological properties of the input space[16].

Fig. 11. Self Organizing Neural Network

Deep Learning

a) Recurrent neural network(RNN) or Long Short Term Memory(LSTM)

They are designed to capture information from sequence/ time series data

$$S_t = F_w (S_{t-1}, X_t)$$

Where

X_t = input at time step t

S_t = state at time step t

F_w = recursive function

It uses the above equation [5][6][16] to solve the problem

The LSTM cell is a specifically designed unit of logic that will help reduce the vanishing gradient problem sufficiently to make recurrent neural networks more useful for long-term memory tasks i.e. text sequence predictions[5][16]. The way it does so is by creating an internal memory state which is simply *added* to the processed input, which greatly reduces the multiplicative effect of small gradients[16]. It is used to Natural Language processing [16].

Fig. 12. Recurrent neural network(RNN) or Long Short Term Memory(LSTM) [5][6][16]

```

Python 3.6.3 Shell
File Edit Shell Debug Options Window Help
Error:[3.45638663]
Pred:[0 0 0 0 0 0 1]
True:[0 1 0 0 1 0 1]
9 + 60 = 1
-----
Error:[3.63389116]
Pred:[1 1 1 1 1 1 1]
True:[0 0 1 1 1 1 1]
28 + 35 = 255
-----
Error:[3.91366595]
Pred:[0 1 0 0 1 0 0]
True:[1 0 1 0 0 0 0]
116 + 44 = 72
-----
Error:[3.72191702]
Pred:[1 1 0 1 1 1 1]
True:[0 1 0 0 1 1 0]
4 + 73 = 223
-----
Error:[3.5852713]
Pred:[0 0 0 0 1 0 0]
True:[0 1 0 1 0 0 1]
71 + 11 = 8
-----
Error:[2.53352328]
Pred:[1 0 1 0 0 0 1]
True:[1 1 0 0 0 1 0]
81 + 113 = 162
-----
Error:[0.57691441]
Pred:[0 1 0 1 0 0 1]
    
```

Fig. 13. Recurrent neural network(RNN) or Long Short Term Memory(LSTM) output

B. Usefulness and Capabilities of Neural Network [2]

1. Non linearity

Neural Network is the interconnection of non-linear neurons. Non linearity is distributed throughout the machine/brain.

2. Input-Output Mapping
Learning with a teacher.
3. Adaptivity
It can adapt the free parameters to the changes in the surrounding environment.
4. Evidential Response
Decision with a measure of confidence.
5. Fault Tolerance
Graceful degradation.
6. Neurobiological analogy

C. Applications of Neural Network [2][16]

In general Machines are faster than Humans. For example Silicon IC's computes in some nanoseconds and Human neuron computation speed is in some milliseconds. So we can say that machines are 5 to 6 times faster than humans. But there are several tasks which are easier for human but difficult for a machine. In this field concept of machine learning or ANN comes. Following are the some important applications of ANN.

Computer vision, Robot control, Natural Language Processing, Financial stock rise or fall, fraud detection, understand consumer sentiments

1. Medical
Diseases like cancer detection, classification, and analysis. EEG and ECG analysis.
2. Speech
Conversion text to speech and vice versa, recognise and classify the speech, analyse the speech and judge the emotions.
3. Image
Recognition, classification of images. Image to text, text to image, image to speech, speech to image conversion. Also analysis of sentiments.
4. Forecasting
Forecasting or prediction widely used in business decisions, stock market, weather, etc.
ANN has a lot of other areas of applications also like in Transportation, Industry, Military, Electronics, Financial, Telecommunications, Aerospace, Time series prediction, pattern recognition, etc.

D. LIMITATIONS OF NEURAL NETWORKS [2]

1. Like with any data-driven models, they cannot be used if there is no or very little data available.
2. There are many free parameters, such as the number of hidden nodes, the learning rate, minimal error, which may greatly influence the final result.
3. Not good for arithmetic and precise calculations.
4. Neural networks do not provide explanations. If there are many nodes, then there are too many weights that are difficult to interpret (unlike the slopes in linear models, which can be seen as correlations). In some tasks, explanations are crucial (e.g. air traffic control, medical diagnosis).

V. RESULT AND DISSCUSION

TABLE 2 ANALYSIS OF NEURAL NETWORK [3][5][8][9][16]

LEARNING	NEURAL NETWORK	ACTIVATION FUNCTION	APPLICATION
Supervised	FEEDFORWARD NEURAL NETWORK	$y = f(v)$ $f(v) = a + v = a + \sum w_i x_i$	Computer Vision
	RADIAL BASIC NEURAL NETWORK	$f(x)$ $= e^{-(x-\mu)^2/2\sigma^2}$ $/\sigma\sqrt{2\pi}$ $= e^{-(x-\mu)^2/2\sigma^2}$ $/\sigma\sqrt{2\pi}$	Used in multilayer perceptron
Unsupervised	SELF ORGANIZING NEURAL NETWORK	$d_j(x) =$ $= \sum_{i=1}^D (x_i - w_{ij})$ $- w_{ij})$	Topology data analysis
Deep Learning	CONVOLUTION NEURAL NETWORK	$\sigma(x) = 1/(1+e^{-x})$ $\sigma(x) = 1/(1+e^{-x})$	analyzing visual imagery
	RECURRENT NEURAL NETWORK	$h_{t+1} = \sigma h(W h_t + U h_{t-1} + b_h)$ $y_t = \sigma y(W y_h + b_y)$	Speech Recognition, language processing

VI. CONCLUSION & FUTURE WORK

The paper explained the comprehensive study of neural network and its type with their appropriate diagrams and outputs. Neural Network applications and uses are also explained in detail. It is a very complex, detailed topic that can be used in developing a machine just like human. The machine that can think, have emotions, judgement power, prediction or forecasting ability can be developed using this technology. Neural network is not a very simple topic that can be explained in a single paper but comprehensively the paper explained maximum areas of this field. Researchers working in this area can use the paper.

In the future a new Neural Network can be developed with the appropriate Activation function. Different Neural Network uses different Activation functions which are used for different purposes. Projects like Humanoid can be done with the appropriate already present

neural network or a new neural network with different activation function and weight associated with each link. Humanoid just a robot looks like human.

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