Analysis of Hopfield Autoassociative Memory in the Character Recognition

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Abstract: *This paper aims that analyzing neural network method in pattern recognition. A neural network is a processing device, whose design was inspired by the design and functioning of human brain and their components. The proposed solutions focus on applying Hopfield Autoassociative memory model for pattern recognition. The Hopfield network is an associative memory. The primary function of which is to retrieve in a pattern stored in memory, when an incomplete or noisy version of that pattern is presented. An associative memory is a storehouse of associated patterns that are encoded in some form. In auto-association, an input pattern is associated with itself and the states of input and output units coincide. When the storehouse is incited with a given distorted or partial pattern, the associated pattern pair stored in its perfect form is recalled. Pattern recognition techniques are associated a symbolic identity with the image of the pattern. This problem of replication of patterns by machines (computers) involves the machine printed patterns. There is no idle memory containing data and programmed, but each neuron is programmed and continuously active.*

Keywords: Neural network, machine printed character, pattern recognition.

1. Introduction

An Artificial Neural Network (ANN) is an information processing paradigm that is inspired by the biological nervous systems, such as the brain. It is composed of a large number of highly interconnected processing elements (neurons) working in unison to solve specific problems. A Neural Network is configured for pattern recognition or data classification, through a learning process. In biological systems, Learning involves adjustments to the synaptic connections that exist between the neurons. Neural networks process information in a similar way the human brain does. The network is composed of a large number of highly interconnected processing elements working in parallel to solve a specific problem. Neural networks learn by example. A neuron has many inputs and one output. The neuron has two modes of operation (i) the training mode and (ii) the using mode. In the training mode, the neuron can be trained for particular input patterns. In the using mode, when a taught input pattern is detected at the input, its associated output becomes the current output. If the input pattern does not belong in the taught list of input patterns, the training rule is used. Neural network has many applications. The most likely applications for the neural networks are (1) Classification (2) Association and (3) Reasoning. An important application of neural networks is pattern recognition. Pattern recognition can be implemented by using a feed-forward neural network that has been trained accordingly. During training, the network is trained to associate outputs with input patterns. When the network is used, it identifies the input pattern and tries to output the associated output pattern. Four significant approaches to PR have evolved. These are [5].

Statistical pattern recognition: Here, the problem is posed as one of composite hypothesis testing, each hypothesis pertaining to the premise, of the datum having originated from a particular class; or as one of regression from the space of measurements to the space of classes. The statistical methods for solving the same involve the computation other class conditional probability densities, which remains the main hurdle in this approach. The statistical approach is one of the oldest, and still widely used [8].

Syntactic pattern recognition: In syntactic pattern recognition, each pattern is assumed to be composed of sub-pattern or primitives strung together in accordance with the generation rules of a grammar characteristic of the associated class. Class identifications accomplished by way of parsing operations using automata corresponding to the various grammars [15, 16]. Parser design and grammatical inference are two difficult issues associated with this approach to PR and are responsible for its somewhat limited applicability.

Knowledge-based pattern recognition: This approach to PR [17] is evolved from advances in rule-based system in artificial intelligence (AI). Each rule is in form of a clause that reflects evidence about the presence of a particular class. The sub-problems spawned by the methodology are:-

1. How the rule-based may be constructed, and
2. What mechanism might be used to integrate the evidence yielded by the invoked rules?

Neural Pattern Recognition: Artificial Neural Network (ANN) provides an emerging paradigm in pattern recognition. The field of ANN encompasses a large variety of models [18], all of which have two important characteristics:

1. They are composed of a large number of structurally and functionally similar units called neurons usually connected various configurations by weighted links.
2. The Ann's model parameters are derived from supplied I/O paired data sets by an estimation process called training.

2. Methodology

Different neural network algorithms are used for recognizing the pattern. Various algorithms differ in their learning mechanism. Information is stored in the weight matrix of a neural network. Learning is the determination of the weights. All learning methods used for adaptive neural networks can be classified into two major categories: supervised learning and unsupervised learning.

Supervised learning incorporates an external teacher. After training the network, we should get the response equal to target response. During the learning process, global information may be required. The aim is to determine a set of weights, which minimizes the error.

Unsupervised learning uses no external teacher and is based on clustering of input data. There is no prior information about input's membership in a particular class. The characteristics of the patterns and a history of training are used to assist the network in defining classes. It self-organizes data presented to the network and detects their emergent collective properties.

The characteristics of the neurons and initial weights are specified based upon the training method of the network. The pattern sets is applied to the network during the training. The pattern to be recognized are in the form of vector whose elements is obtained from a pattern grid. The elements are either 0 and 1 or -1 and 1. In some of the algorithms, weights are calculated from the pattern presented to the network and in some algorithms, weights are initialized. The network acquires the knowledge from the environment. The network stores the patterns presented during the training in another way it extracts the features of pattern. As a result of this, the information can be retrieved later.

3. Problem Statement

The aim of the paper is that neural network has demonstrated its capability for solving complex pattern recognition problems. Commonly solved problems of pattern have limited scope. Single neural network architecture can recognize only few patterns. Relative performance of various neural network algorithms has not been reported in the literature.

The thesis discusses on various neural network algorithms with their implementation details for solving pattern recognition problems. The relative performance evaluation of these algorithms has been carried out. The comparisons of algorithms have been performed based on following criteria:

(1) Noise in weights
(2) Noise in inputs
(3) Loss of connections
(4) Missing information and adding information.

4. Hopfield Autoassociative Memory

The Hopefield network is an associative memory. It has capacity limitation. The primary function of which is to retrieve in a character stored in memory, when an incomplete or noisy version of that character is presented.

In Hopefield model, each neuron has two states. The on state of neuron is denoted by the output +1; the off state is represented by -1. A pair of neurons i and j in the network are connected by weight w_{ij}, which denotes the contribution of output signal of neuron i to the potential acting on neuron j. there are two phases to the operation of the Hopefield network (i) Storage phase and (ii) Retrieval phase. In the storage phase, N-dimensional characters are stored in the memory. These characters can be retrieved during retrieval phase when these characters are presented to the network as test vectors.

5. Algorithm:

Step 1: n-dimensional vectors a_1, a_2, $a_3 \ldots a_p$ are stored in the memory with entry +1 and -1.

Step 2: Weights of the network is calculated as

$$w_{ji} = \frac{1}{n}\sum_{\mu=1}^{p} a_{\mu_{ij}} a_{\mu_{ji}} \qquad j\neq 1$$

j=1

The weights are not updated during iterations.

Step 3: n-dimensional probe vector x is presented to the network. The algorithm is initialized by,

$\mathbf{a}_j(0) = x_j$ for j=1, 2, 3, …, n

Step 4: The elements of the vector **a** (k) is updated by

$$\mathbf{a}_j(k+1) = \text{sgn}\left[\sum_{i=1}^{n} w_{ji} a_i(k)\right]$$

Step 5: During any iteration if

$$\mathbf{a}_j(k+1) = \mathbf{a}_j(k)$$

Then there is no further iteration that is vector **a** becomes stable. Otherwise, step 4 is repeated.

Step 6: The stable state $\mathbf{a}_{fixed}$ is the output vector of the network.

$Y = \mathbf{a}_{fixed}$

6. Storage Capacity:

The storage capacity of the Hopfield network is given by

$$P_{max} = \frac{n}{2\ln n}$$

Where P_{max} is the maximum numbers of fundamental memory that can be stored. n is the dimension of vector p.

7. Result:

The network has two layers. There are 49 neurons in each layer. 7×7 pattern grid is used to represent a character. With this configuration, the network is able to store and successfully recall six characters. Six characters Y, O, T, L, M, and I are stored in the network. Each is represented as 49-dimensionsal vectors with entry +1 and -1. Weight matrix is found from the stored patterns. After storage, when these characters are presented individually to the network they are recognized correctly. This has been shown in table 3.2. When A, I, L, M, X and P are stored, all these are not recognized correctly at the time of testing. I, L, M, X and P recognized correctly.

For Hopfield Autoassociative memory, the range of % increase of weights, for which does work properly is, 0.015-99.93 and the range of % increase of weight, for which there is no effect is, 0.0015-0.99.

Effect of Noise in Inputs on Algorithm

Noise is introduced in the input by adding random numbers. Hopfield network recognizes correctly all the stored characters even after introducing noise at the time of testing.

Loss of Connection

In the network, neurons are interconnected and every interconnection has some interconnecting coefficient called weight. If some of these weights are equated to zero then how it is going to effect the classification or recognition, is studied under this section. The number of connections that can be removed such that the network performance is not affected has also been found out for algorithm.
If connection of input neuron's to all the output neuron is removed, and the pixel corresponding to that neuron number is off than it makes no difference. But if that pixel is on, in the output that becomes off.

Missing Information

Missing information means some of the on pixels in pattern grid are made off. For the algorithm, how many information we can miss so that the characters can be recognized correctly varies from character to character. We cannot switch off pixel from any place. Which pixel is being switched also matters. For few characters table 1 shows the number of pixels that can be switched off for all the stored characters in algorithm.

Characters	Hopfield Autoassociative memory algorithm
I	5
L	6
M	5
O	7
T	7
Y	2

Table 1: Missing Information: No Of Pixels That Can Be Made Off In Algorithm

Adding Information

Adding information means some of the off pixels in the pattern grid are made on. In this section, the classification or recognition ability of networks after adding information is studied. Table no. 2 shows detailed description about the number of pixels that can be made on for all the characters that can be stored in networks.

Characters	Hopfield Autoassociative memory algorithm
I	11
L	5
M	14
T	9
Y	10

Table 2: Adding Information: No Of Pixels That Can Be Made On In Algorithm

8. Merits and Demerits

Hopfield network recognizes well even when an input vector that is equal to the stored patterns plus random error is presented. The Hopfield Network demonstrates the power of recurrent neural processing within a parallel architecture. The recurrences through the thresholding layer of neurons eliminated the noise added to the initializing input vector [19-20].

Hopfield associative memory has capacity limitations. Capacity limitation causes convergence to spurious states. Spurious states represent stable states of the network that are different from the stored pattern or fundamental memories of the network [21]. It also causes difficulty with recovery of stored patterns if the patterns are closed to each other in the hamming distance.

9. Conclusion:

A Hopfield Autoassociative memory has been performed for the pattern recognition for the English alphabets (A-Z).

When Weights Are varied randomly, when random numbers are added in the weight matrix, the characters are not recognized at all. Only dots appear for every character. When 100 divide random numbers then all the 6 characters are recognized correctly.

By adding constant number to all the weight of network, When 0.0065 is added to all the weights, characters stored in the network are recognized correctly.

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