Dual Nature Hidden Layers Neural Networks
"A Novel Paradigm of Neural Network Architecture"

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ABSTRACT

We present here a new scheme to construct a neural network architecture based on the physiological properties biological neuron for enhancing its performance. The new scheme divides every hidden layer into two parts to facilitate the processing of 0 and 1 separately and reduces the total number of interconnections considerably. The first part consist of units that receives signals only from '1 state' units of the immediately lower layer and are responsible for producing excitation units in the output layer i.e. the '1 state' and the second part consist of units that also receives signals only '1 state' units from the immediately lower layer are responsible for producing inhibition of the units in the output layer i.e. the '0 states'.

The resulting architecture converges fast, produces more reliable results and reduces the computational burden considerably when compared to fully connected neural networks.

1 Introduction

The success of solving the problems using neural networks is primarily dependent upon the architecture of the neural network and learning strategy used to train the neural networks. The functioning of the biological neuron is known, but the functioning of the network of biological neuron is still remains as a mystery. The basic aim of the artificial neural network research is to reveal the functioning networks of neuron in the human brain. The number of the input units and the number of output units of a neural network for solving a given problem are chosen according to the size of the preprocessed input and target output pattern respectively. The performance of a neural network is solely dependent upon the nature processing take place in the hidden layers. We proposed a Novel Paradigm of Neural Network Architecture, which has new type of the hidden layer based on physiological properties of biological neuron.

2 Biological Background

Nerve cells are encased in a semi-permeable membrane that permits some substances to pass through the membrane, while others are kept out. As the consequence, there are more number negative ions are inside than outside the cell membrane resulting in a membrane potential. This membrane potential is called the resting potential of the cell. A cell in the resting state is said to be polarized.

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When a section of the cell membrane is excited by the flow of ionic current or by some form of externally applied energy. The membrane changes its characteristics and begins to allow some of the sodium ions to enter this movement of sodium ions into the cell. As a result, the cell has a slightly positive potential on inside due to the imbalance of potassium ions. This potential is known as the action potential. A cell that has been excited and that displays an action potential is said to be depolarized; the process of changing from the resting state to the action potential is called depolarization.

Once the rush of sodium ions through the cell membrane has stopped, the ionic current that lowered the barrier to sodium ions are no longer present and the membrane reverts back to its original, selectively permeable condition, where in the passage of sodium ions from the outside to the inside of the cell is again blocked. A resting potential is restored back after a long time. this is done by an active process called sodium potassium pump. The process of changing the depolarized to polarized state is called repolarization.

Regardless of the method by which a cell is excited or the intensity of stimulus, the action potential is always the same for any given cell. This is known as the all or nothing law. Following the generation of an action potential, there is a brief period of time during which the cell can not respond to any new stimulus. This period is called the absolute refractory period and last about 1 msec. in nerve cells. A relative refractory period occurs following the absolute refractory period, during this relative refractory period another action potential can be triggered by much stronger stimulation. In nerve cells, the relative refractory period lasts several milliseconds. [Lesile Cromwell et al., 1980]

2.1 Propagation of Action Potential

When a cell is excited and generates an action potential ionic currents begin to flow. This process can, in turn, excite neighbouring cells or adjacent areas of the same cell. In nature, nerve cells are excited only near their input end. As the action potential travels down the fiber, it can not re-excite the portion of the fiber immediately upstream, because of the refractory period that follows the action potential. The rate of which an action potential moves down a fiber is called the propagation rate. In nerve fibers the propagation rate is is from 20 to 140 meters per second.

3 Motivation

The physiology of nerve cells indicate that there are three states for neuron namely

I. Resting State,
II. Excitory State and
III. Inhibitory State.

One option is the design of neural network architecture based on the above information by assigning three different values to each of the three different states of a processing unit. This tri-logic architecture ends with huge calculation during the training phase of the neural network. The results obtained as well as the performance of the neural network are not very satisfactory.

This drawback made us to think about alternative formalism to implement the three different states for neural network units. In our proposed new neural network architecture we maintain the binary states for each unit in the neural network with values 0 and 1. But 1 state represents the excitory state which happen when weighted sum of all inputs from 1 state units of the immediately lower layer to a particular unit exceeds the threshold value determined by an activation function and the 0 state represents either resting state or inhibitory states. The inhibitory and not the resting state contribute to neural network processing. Our proposed novel neural network architecture incorporate inhibitory state mechanism.

4 Dual Nature Hidden Layer Neural Networks

Our new experimental model employs three layers topology and this technique can be extended to multiple hidden layers. The bottom layer of units is the input layer - the only units in the network that receive external input. The top layer is the output layer. The middle layer is divided into two parts. The first part consist of units that are responsible for excitation units in the output layer i.e. the 1 state and the second part consist of units that are responsible for inhibition of the units in the output layer i.e. the 0 states. These three layers are interconnected as shown in the fig. 1. Each processing unit in the input layer is connected separately to every processing unit in the inhibitory part and excitory part of the hidden layer. Similarly every units in the inhibitory part and excitory part of the hidden layer are connected to all the units in the output layer. The units are not connected to other units in the same layer The straight line links indicates the connections responsible for producing the 1 state in the output layer and dotted line links indicates the connection responsible for producing the 0 state in the output layer. A significant change in this model is that the separate processing unit for producing one and zero states of the output layer units.

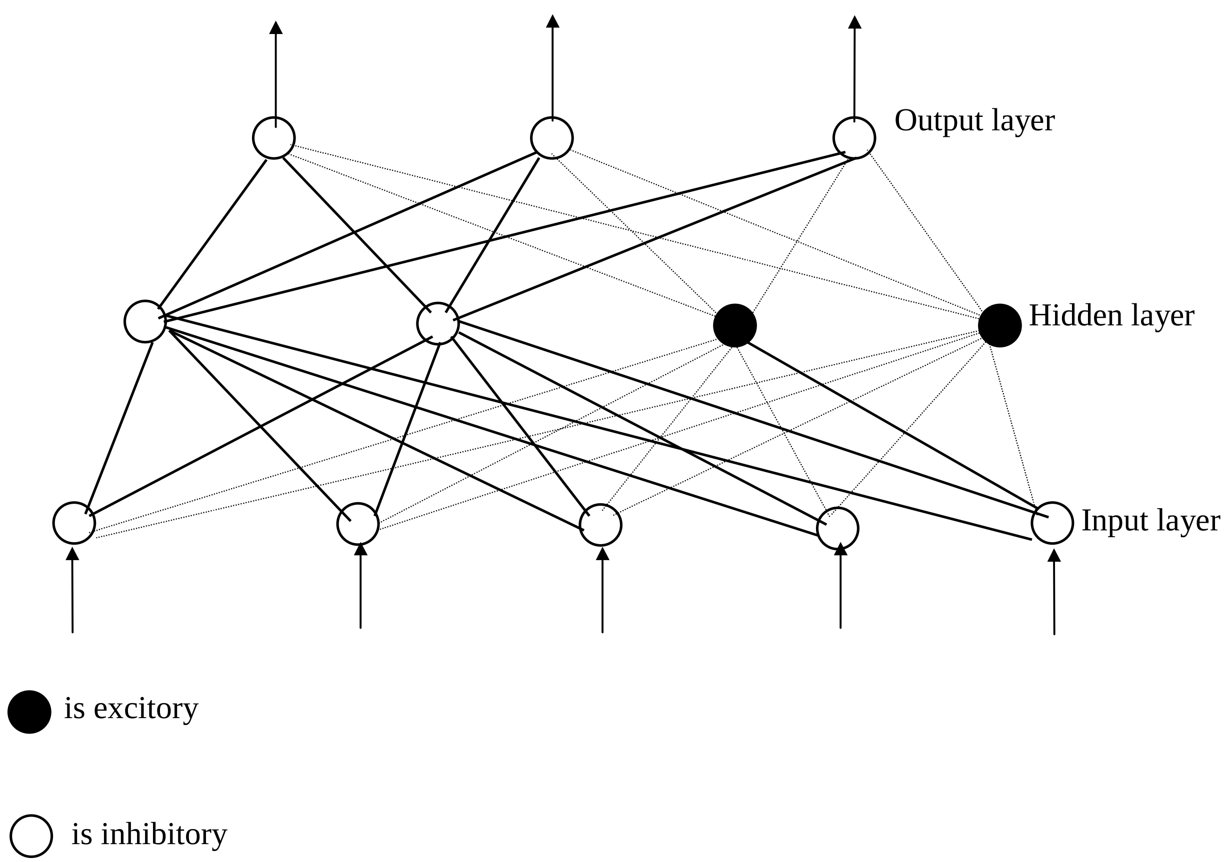

Fig. 1: The Dual Nature Hidden Layer Neural Networks.

5 Results

We constructed a few examples like ECG signal pattern classification etc and tested them with the dual nature hidden layer neural network against the fully connected back propagation three layer network. Our architecture proved to be superior than back propagation in all these cases.

Following salient features are observed:

- The number of interconnections are greatly reduced.
- The computational burden is considerably less and hence processing is faster.
- The unique special feature of this architecture is 'zeros' and 'ones' in the output layer are processed separately.
- Faster learning and the reliability of producing the correct results are very high.

7 Conclusions and discussion

In this paper, we have presented a scheme called dual nature hidden layer neural network which incorporate the inhibitory mechanism of the biological neuron. This architecture produce more reliable output which can used in medical pattern classification problems. It converges fast and show a much superior results than the three layer back propagation neural network. This network yields best results for input without having noise. For noisy inputs suitable digital filters can be used to obtain the best results. The relative proportion excitory and inhibitory unit can be determined by calculating the number of ones and zeros in all the target patterns for obtaining the best results. The total number of interconnection are greatly reduced due to division in the hidden layer. This results in faster processing.

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