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Computational Analysis of Optical Neural Network Models to Weather Forecasting

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Abstract

Neural networks have been in use in numerous meteorological applications including weather forecasting. They are found to be more powerful than any traditional expert system in the classification of meteorological patterns, in performing pattern classification tasks as they learn from examples without explicitly stating the rules and being non linear they solve complex problems more than linear techniques. A weather forecasting problem – rain fall estimation has been experimented using different neural network architectures namely Electronic Neural Network (ENN) model and opto-electronic neural network model. The percentage of correctness of the rainfall estimation of the neural network models and the meteorological experts are compared. The results of the ENN are compared with the results of the opto-electronic neural network for the estimation of rainfall.

Keywords - Back propagation, convergence, neural network, opto-electronic neural network, rainfall estimation.

1. Introduction

Rain is one of the nature's greatest gifts for countries. It is a major concern to identify any trends for rainfall to deviate from its periodicity, which would disrupt the economy of the country. In the present study rainfall is estimated based on the temperature, air pressure, humidity, cloudiness, precipitation, wind direction, wind speed, etc., consolidated from meteorological experts and documents [1,2].

Electronic Neural Networks have shown tremendous improvement over the traditional methods to handle the non-linear problems, especially in the field of weather forecasting. ENN can be considered as intermediate between statistical and structural models. These Neural Networks (NN) can be called as universal because of their ability in learning and absence of assumption based on probabilistic models. Results have shown that several statistical classifiers can be implemented using neural networks. The ENN model and opto-electronic neural network model were used for the estimation of rainfall [3]. In the design of opto-electronic neural network model, opto-electronic communication links between the layers in a neural network have been used as a means of over coming the connectivity problems associated with conventional electronic networks. The opto-electronic neural network converges quickly compared to electronic neural network.

The motivation of this paper is

(i) to study the effect of the electronic neural network model based on the opto-electronic communication links between layers in neural network

(ii) to study the effect of the neural network models based on the neurophysiology of human nervous system

(iii) to classify weather forecasting patterns particularly estimation of rainfall.

2. Electronic Neural Network

An electronic neural network is a set of very simple processing elements (neurons) with a high degree of interconnections between them. Such processing architecture is characterized by parallel processing and distributed computing, and is able to learn and adapt to better perform a specific task by modifying the strength of connections between the neurons [4]. The ENN, multilayer perceptron, trained using back propagation algorithm [5, 6] is constructed as three layered network with one hidden layer.

2. Opto–electronic Neural Network

The optical neuron, modeled using the following relations [7], is used in the neurons of opto-electronic neural network. The optical neuron architecture is shown in **Fig. 1**. The opto-electronic neural network, multilayer perceptron, trained using modified back propagation is constructed as three layered network with one hidden layer.

Light input to photo detector:

$$Linput_{ij} = Loutput_i \text{ x optical attenuation} \quad (3.1)$$

Photo detector photo current:

$$Iph_{ij} = \gamma_P \text{ x } V_{bias\ ij} \text{ x } Linput_{ij} \quad (3.2)$$

where $Linput_{ij}$ is the light input of neuron j in the hidden layer from the neuron i in the input layer.

Amplifier output:

$$I_j = \Sigma\, Iph_{ij} \frac{1}{|\gamma_p| \text{ x optical attenuation}} \quad (3.3)$$

Sigmoid output:

$$Isig_j = \frac{I_{max}}{1 + e^{-Ij/Imax}} \quad (3.4)$$

Current output:

$$Ioutput_j = \frac{1}{|\gamma_i|} \text{ x } Isig_j \quad (3.5)$$

Light output:

$$Loutput_j = \gamma_j \text{ x } Ioutput_j \quad (3.6)$$

Input layer output:

$$Loutput_i = Input_i \text{ x } (1 + \text{noise factor x random number}) \quad (3.7)$$

where $Input_i$ is the input to the input layer

Sigmoid function's output is, in the range between [0,1]. Since sigmoid function is output limiting and quasi bi-stable, it is also differentiable.

$$\text{Sigmoid function} = 1/(l + e^{-x}) \quad (3.8)$$

Where, x is the input to sigmoid function

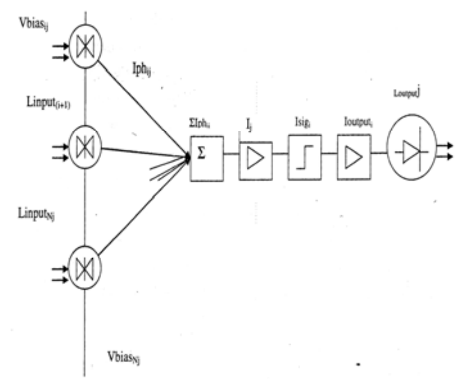

Fig. 1. Optical Neuron Architecture

3. Methodology

The basic input data for classification needs preprocessing [8]. This procedure helps in the incorporation of temperature, air pressure, humidity, cloudiness, precipitation, wind direction, wind speed, etc., in weather forecasting for ENN and opto-electronic neural network based classification. The factors: temperature, air pressure, humidity, cloudiness, precipitation, wind direction, wind speed, etc., of weather forecasting areconsolidated from meteorological experts and documents. The inputs to the ENN and opto-electronic neural network are, in the form of 1 or 0 based on the presence or absence of the factors. The different types of weather forecasting are the output of the ENN and opto-electronic neural network, in the form of 1 or 0, based on presence or absence of the types of rainfall.

The electronic neural network and opto-electronic neural network model are trained with twenty seven inputs- temperature, air pressure, humidity, cloudiness, precipitation, wind direction, wind speed, etc., and three outputs – heavy rain, moderate rain and no rain. The ENN and opto-electronic neural models are trained with samples of one seventy one patterns. The number of inputs are limited and outputs are selected based on the advice of metrological experts and documents.

4. Results and Discussion

Improvement of classification accuracy in weather forecasting is an important issue. The trained neural networks were tested with samples and validated for the accuracy of the models. The test data were analyzed with two metrological experts for its accuracy. The percentage of correct weather forecasting was tabulated in **table 1** and **Fig. 2**.

Table 1. Performance Classification

Weather Forecasting	No. of patterns	Percentage of correct classification			
		Expert I	Expert II	Electronic Neural Network	Opto-electronic Neural Network
No rain	12	83	75	83	75
Moderate Rain	12	75	58	58	76
Heavy rain	12	75	92	92	92
Over all percentage		77	75	78	81

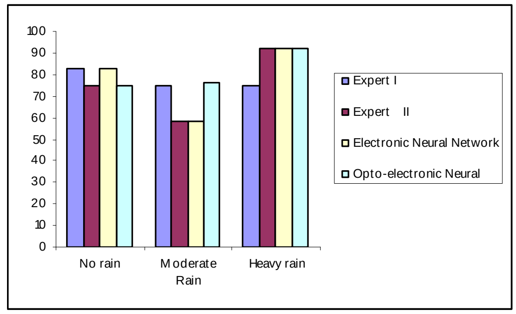

Fig. 2 Performance Classification

If the generality of neural network for classification of weather forecasting is achieved, the training would be a one time affair, and the so trained network could be used for weather forecasting. The performance of the electronic neural network is compared with the performance of the optoelectronic neural network for whether forecasting. In ENN, the training was terminated in eight thousand and thirty six iterations [9]. In the opto- electronic neural network, the training was terminated in one hundred and sixteen iterations. The training of opto-electronic neural network is fast compared to ANN. It is represented in **Fig 3**. The accuracy of opto-electronic neural network is as good as ENN.

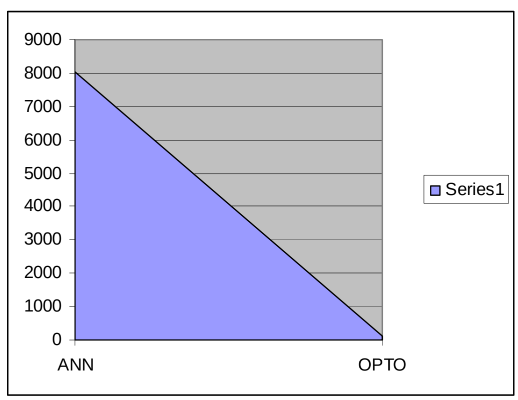

Fig. 3 Performance Neural Network Training

5. Conclusion

The weather forecasting has been experimented successfully using ENN and opto-electronic neural network models. The accuracy of the results, obtained using ENN and opto-electronic neural network models, is compared with two metrological experts. The performance of opto-electronic neural network, which is better than the performance of ENN, is reported. This study will encourage researchers to use neural network models for weather forecasting. Efforts are in progress to reduce the time consumed by back propagation training algorithm of neural networks. As new models emerge and their sophistication increase, it is expected that optical implementations of these models will continue to show advantages over other approaches. Dynamic inclusion of new factors may be incorporated to improve its adaptability.

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Bibliography

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