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Prediction of soil temperature using artificial neural networks

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ABSTRACT

Artificial neural networks are distributed and parallel computational algorithms, which have been efficiently used, in various practical problems. The relationship between air temperatures at 1-meter height above ground and surface soil temperatures recorded at Land Surface Process Experiment (LASPEX) held at Anand during the year 1997 was studied using a multi layer perceptron neural network. Here the input set is air temperature recorded at every minute and output is the corresponding soil temperature. The effect of air temperature on soil temperature is modelled by a network, which is trained by back propagation algorithm with a momentum term. The Network is capable of predicting the soil temperature for a given air temperature.

Key words : Neural network, Soil temperature prediction.

The soil temperature is an important weather element and is highly influenced by air temperatures and vice versa due to energy exchange. Many researchers have studied the problem of prediction of soil temperature (Bocock *et.al*, 1974; Krishnan and Kushwaha, 1972; Liakatas,1994; Parton and Logan,1981) , due to its importance in cropping. The basic tools used for soil temperature study are the harmonic analysis or other statistical methods (Conard and Pollock,1950; Hann,1977; Panofsky and Brier,1958.) Often, enormous quantity of data is used in the prediction problems. In this situation, the matrices to be inverted by using harmonic analysis methods or statistical methods are of very large size. Even with availability of modern computers with large memories, it is often difficult or impossible to invert such huge matrices.

The artificial neural network algorithms have now become established as alternatives for tackling these data problems (Goswami and Srividya, 1996), due to their features like parallel distributed computing and freedom from a predefined analytical or stochastic model. Such algorithms do not depend upon inversion of huge matrices and are very efficient in detecting the inherent dynamics of a system from the data provided. To model a real life problem having known inputs and outputs, neural network approach is considered effective and does not require a preassigned model. An attempt has been made here to make use of artificial neural networks algorithm for prediction of soil temperature with respect to time and air temperature.

MATERIAL AND METHODS

The soil temperature data for the month of December 1997 of LASPEX site of Anand station and air temperatures at different heights viz. 1 and 2 meter have been used to predict the soil temperature at different depths using artificial neural network.

Artificial neural network approach

An artificial neural network is a parallel-distributed computational algorithm imitating the working of brain cells (neurons). It is also a model free estimator for the approximation of the functional relationship between a set of input and output data of a given system. It learns from experience and it has the ability of generalization. Any continuous function mapping n-dimensional Euclidian space to m dimensional Euclidian space could be approximated by means of a neural network having a single hidden layer. This result is the natural generalization of the Weirstrass theorem any continuous function on a compact set can be approximated by polynomials (Hecht-Nielsen, 1987; Kolmogorove, 1957). Artificial neural networks have some more advantages like, filtering of noised data for weather prediction and for modelling and simulation etc.

There are various types of architectures for neural networks (Richard, 1987; Werner, 1994; Zurada, 1998.). The multilayered Feed forward Networks in which neurons are arranged in three layers viz. input layer, hidden layer and output layer was employed in the present analysis. The hidden one is the layer in which the nodes are not connected directly to the input or output of the system. Fig. 1 shows a multi-layer feed forward network with a single hidden layer. It has n-inputs x_1, x_2,....... x_n, represented by n input neurons which are connected to each of the m neurons in the hidden layer with each association having a real weight . Each of the neurons in the hidden layer is also connected to each of the k neurons. The weights of various connections in the Neural Network are initially chosen randomly. Then the weighted sum of the inputs is calculated for each processing neuron. This sum is passed through a transfer function f(x), to generate the output of the neuron, given by

$$f(x) = \frac{1}{1+\eta e^{-kx}},$$

where is known as the learning rate. The output of the neurons in the output layer thus calculated is compared with the actual output and the difference is computed as error.

A learning algorithm is used to modify iteratively the weights of the connections to minimize the total error in the approximation. There are several algorithms to compute this weight updations. The back propagation-learning algorithm with a momentum term was used to find out the weights. Weight update rule in back propagation algorithm is given by (Haykin, 1999)

$$Wji^{(l)}(n+1) = Wji^{(l)}(n) + \alpha[Wji^{(l)}(n-1)] + \eta\, \delta j^{(l)}(n)\, yi^{(l-1)}(n)$$

where α is the momentum which is constant, η the learning rate, l the layer index and $\delta^{(l)}$ the local gradient at the l^{th} layer and $Wji^{(l)}$ is the weights of the neuron.

First, a set of input and actual output data has been taken for the training of the network. After this trained networks which can predict the soil temperature at a given time point and for a given air temperature, is obtained.

Two problems were considered in this

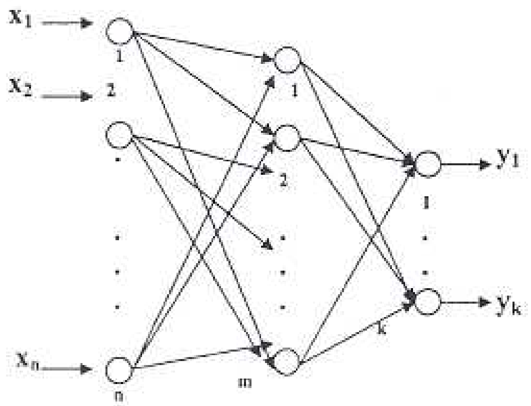

Fig. 1 : Multilayered feed forward network

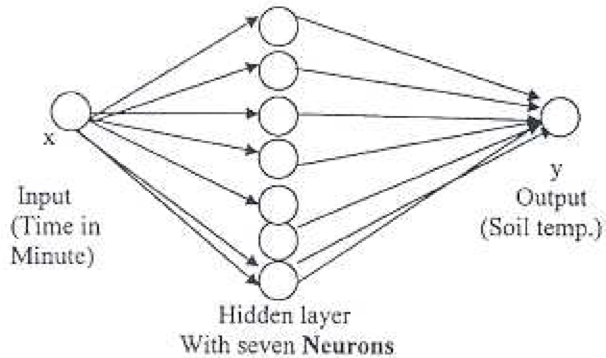

Fig.2 : Network for first problem

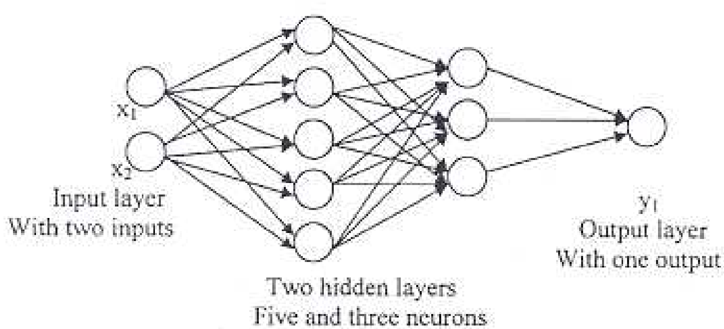

Fig.3 : Network for second problem

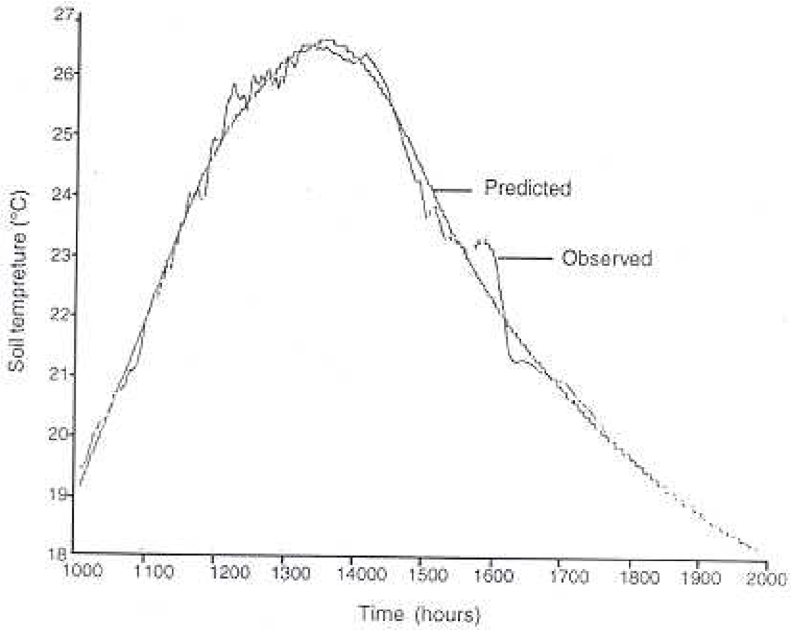

Fig.4 : Observed and predicted soil temperature at 0-5 cm depth

paper. In the first problem, prediction of soil temperature for a given time point was tried. That is, the time had been taken as input data and soil temperature as output data. In this problem a network with only one hidden layer had been considered. The architecture is shown in Fig 2. For the second problem, two sets of data viz. air temperature at 1-meter height and time were used to obtain soil temperature as output. Here, two hidden layered network was used for prediction of the soil temperature. The architecture of the network is shown in Fig. 3.

RESULTS AND DISCUSSION

The soil temperatures for 0-5 cm depth layer were calculated at different times. Network having one hidden layer with seven neurons was used for this problem (Fig. 2). To train the network the data were normalized. The learning parameters were momentum $\alpha=0.5$ and learning rate $\eta = 0.00001$. Hyperbolic tangent sigmoid function was used as transfer function. Actual data and data predicted by artificial neural network had non-significant difference.

In the second problem air temperatures at different times were used to predict soil temperature for the 0-5 cm depth of soil layer. The network having two hidden layers with five neurons in the first hidden layer and three neurons in the second layer was used for this problem (Fig. 3). For training the network, momentum α = 0.5, and learning rate, η = 0.0005 were used. Hyperbolic tangent sigmoid and linear functions were used as transfer functions. Calculated soil temperature (Fig. 4) corresponding to pertinent air temperature with time showed a smooth curve and it matched with the actual soil temperature to a large extent. These results show that artificial neural networks are very useful tools for obtaining soil temperature by measuring air temperature.

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