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ARTIFICIAL NEURAL NETWORK APPROACH FOR THE PREDICITION OF THE CORN (*ZEA MAYS* L.) LEAF AREA

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Abstract

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This research investigates the artificial neural networks utilization in improving leaf area forecasting at corn leaves (*Zea mays* L.). Best fitting results were obtained with 2 input nodes (leaf length and leaf width), 2 hidden layers and one output (leaf area). Artificial neural network model performance was tested successfully to describe the relationship between actual leaf area and predicted leaf area. R^2 of leaf area was 0.98. Artificial neural networks model produced satisfied correlation between measured and predicted value and minimum inspection error.

Key words: Artificial neural network, Corn, Leaf area, Modeling, *Zea mays* L.

Abbreviations: ANNs-Artificial neural networks, L- leaf length, LA-Leaf area, W-leaf width

Introduction

Leaf area has been measured in experiments concerning some physiological phenomenon such as light, photosynthesis, respiration, plant water consumption and transpiration (Centritto et al., 2000). In addition, leaf number and area of a plant have an important role in some cultural practices such as training, pruning, irrigation, fertilisation, etc. The leaf area estimation models aiming to predict leaf area non-destructively can provide researches with many advantages in agricultural experiments. Moreover, these kinds of models enable researchers to carry out leaf area measurements on the same plants over the course of a study, resulting in reduced experimental variability. Leaf area can be measured by using expensive instruments and/or predictive models (Oner et al., 2011).

Maize or corn is a cereal crop that is grown widely throughout the world in a range of agroecological environments. More maize is produced annually than any other grain. About 50 species exist and consist of different colors, textures and grain shapes and sizes. White, yellow and red are the most common types. Most people depending on the region prefer the white and yellow varieties. The characterize and predict the development process of maize (*Zea mays* L.) leaf area by separating the process into time of appearance of each mature leaf (leaf stage) and leaf area of each mature leaf.

Artificial neural network (ANN) is the simulation of biological neural system in a mathematical or computational model. It focused on identifying and modeling data in different forms and in different areas such as engineering, medicine, statistics, economy and meteorology. ANN approach offers more powerful solutions in cases where conventional methods are not sufficient. In the agricultural sciences, software implementations of artificial neural networks approach has been inspired and largely abandoned for a more practical approach based on statistics (Dunea and Moise, 2008).

ANNs are non-linear data driven self-adaptive approaches, and they can identify and learn correlated patterns between input data sets and corresponding target values, even when the underlying data relationship is unknown. Through the system training, ANNs can be used to predict the outcome of new independent input data.

ANNs can imitate the learning process of the human brain and process problems involving non-linear and complex data even if the data are imprecise and noisy. Recent-

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ly, ANNs combined with image processing techniques have been widely used to model complex and non-linear agricultural data (Xing-mei et al., 2010).

In this study, rapid calculating of leaf area estimation using artificial neural networks with minimum error and a different approach to the work of Plant Physiology are intended.

Results and Discussion

Advantages of neural computing techniques relied on faster computation, learning ability and noise rejection. Utilization of precision agriculture technology is essential as an optimization method in the production system to increase quality of agricultural products. Plant leaves are one of essential indicators of its quality degradation. In this study, samples of Corn leaves were used.

Leaf area is routinely measured in experiments interesting crops where some physiological phenomenon such as light, photosynthesis, respiration, plant water consumption and transpiration is being studied (Centritto et al., 2000). In addition, leaf number and area of a plant are important in terms of cultural practices such as training, pruning, irrigation, fertilization etc. The leaf area estimation models that aim to predict leaf area non-destructively can provide researches with many advantages in agricultural experiments. Moreover, these kinds of models enable researchers to carry out leaf area measurements on the same plants over the course of a study, resulting in reduced experimental variability. Leaf area can be determined by using expensive instruments and/or predictive models. Recently, new instruments, tools and machines such as hand scanners and laser optic apparatuses have been developed for leaf and fruit measurements. These are very expensive and complex devices for both basic and simple studies. Furthermore, non-destructive estimation of leaf area saves time as compared with geometric measurements. For this reason, several leaf area prediction models were produced for some plant species in previous studies.

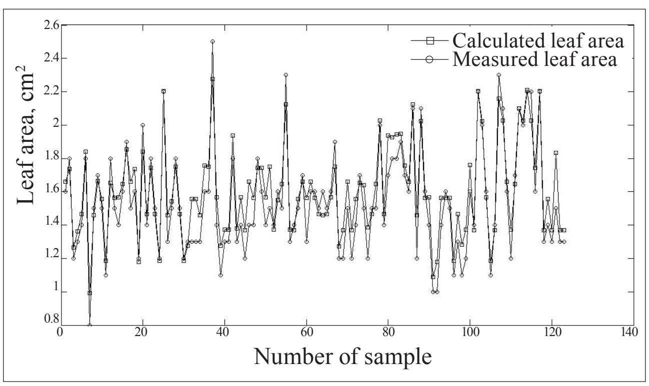

Fig. 1. Relationship between ANN output and measured leaf area values

In this study, the individual leaf area was well correlated with leaf length and leaf width, with high R^2 value. The shape of a leaf was a significant factor in the estimation of leaf area. Non-destructive and rapid estimation of leaf area, many methods have been applied. Artificial neural network was rapid and relatively accurate. There is a high accuracy between calculated leaf area and measured leaf area values (Figure 1).

According to the results of the current study, corn leaf area was estimated by artificial neural network including leaf length and leaf width.

Material and Methods

Plant Material and Experimental Conditions

Corn seeds were sown in May 2009 according to a randomized complete block design with 3 replications. Plot size was 22.4 m^2 and every plot consisted of 4 ear-to-row progenies 70 cm apart and 8 m long. Fertilizer equivalent to 60-120-150 kg ha^{-1} of N-P_2O_5-K_2O, was applied according to cultivars.

Model Construction

Leaf samples (50 leaves for each cultivars) were collected. Thus, total of 500 leaves were processed at the same day as they were collected in the following manner. At first, they were placed on the photocopier desktop by holding flat and secure and copied on A3 sheet (at 1:1 ratio). Then, Placom Digital Planimeter (*Sokkisha Planimeter Inc., model KP-90,* Japan) was used to measure actual leaf area of the copy. Selection of leaf dimensions for measurement was governed by variation in leaf characteristics (*e.g*., size, shape, and symmetry) and practical constraints (*e.g*., ease and accuracy of measurements under field conditions). Considering these factors, maximum leaf width (W) and length (L) were selected to correlate with leaf area. W was measured from tip to tip at the widest part of the lamina and L from lamina tip to the point of petiole intersection along the midrib. The leaf positions were selected with regard to points that could be easily identified and used to facilitate the measurement of L and W.

Introduction to Neural Network

In modern software implementations of artificial neural networks, the approach inspired by biology has been largely abandoned for a more practical approach based on statistics and signal processing. While the more general approach of such adaptive systems is more suitable for real-world problem solving, it has far less to do with the traditional artificial intelligence connectionist models. What they do have in common, however, is the principle of non-linear, distributed, parallel and local processing and adaptation. The word network in the term 'artificial neural network' refers to the inter–connections between the neurons in the different layers of each system (Halici, 2011).

The neuron model shown in (Figure 2) is the one that widely used in artificial neural networks.

The artificial neuron given in this figure has n input, denoted as u1, u2,…un. Each line connecting these inputs to the neuron is assigned a weight, which are denoted a w1, w2,.., wn respectively. Weights in the artificial model correspond to the synaptic connectionsin biological neurons. The threshold in artificial neuron is usually represented by θ and the activation corresponding to the graded potential is given by the formula Eq.(1):

$$a=\left(\sum_{j=1}^{n}u_j w_j\right)+\theta \qquad \text{Eq. (1)}$$

The inputs and the weights are real values. A negative value for a weight indicates an inhibitory connection while a positive value indicates an excitatory one. Although in biological neurons, θ has a negative value, it may be assigned a positive value in artificial neuron models. If θ is positive, it is usually referred as bias. For its mathematical convenience we will use (+) sign in the activation formula. Sometimes, the threshold is combined for simplicity into the summation part by assuming an imaginary input u_0=+1 and a connection weight $w_0=\theta$. Hence (1) becomes Eq.(2):

$$a=\sum_{j=1}^{n}u_j w_j \qquad \text{Eq. (2)}$$

The output value of the neuron is a function of its activation in an analogy to the firing frequency of the biological neurons Eq.(3):

$$x=f(a) \qquad \text{Eq. (3)}$$

Originally the neuron output function f(a) in McCulloch Pitts model proposed *as* threshold function, however linear, ramp and sigmoid and functions (Table 1) are also widely used output functions.

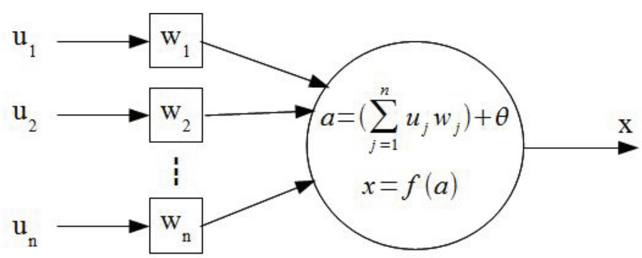

Fig. 2. Architectural graph of a neuron

According to the structure of the connections, we identify different classes of network architectures. In feed-forward neural networks, the neurons are organized in the form of layers. The neurons in a layer get input from the previous layer and feed their output to the next layer. In this kind of networks connections to the neurons in the same or previous layers are not permitted. The last layer of neurons is called the output layer and the layers between the input and output layers are called the hidden layers. The input layer is made up of special input neurons, transmitting only the applied external input to their outputs. In a network if there is only the layer of input nodes and a single layer of neurons constituting the output layer then they are called single layer network. If there are one or more hidden layers, such networks are called multilayer networks.

The structures, in which connections to the neurons of the same layer or to the previous layers are allowed, are called recurrent networks. For a feed-forward network always exists an assignment of indices to neurons resulting in a triangular weight matrix. Furthermore, if the diagonal entries are zero this indicates that there is no self-feedback on the neurons. However, in recurrent networks, due to feedback, it is not possible to obtain a triangular weight matrix with any assignment of the indices (Halici, 2011).

Table 1
Formulas of widely used neuron output functions

Function	Formula
Linear	$f(a)=\kappa a$
Treshold	$f(a)=\begin{matrix}0 & a\le 0\\ 1 & a>0\end{matrix}$
Saturating linear	$f(a)=\begin{matrix}0 & a\le 0\\ a & 0<a\le 1\\ 1 & 1<a\end{matrix}$
Symmetric saturating linear	$f(a)=\begin{matrix}-1 & a<-1\\ a & -1\le a\le 1\\ 1 & 1<a\end{matrix}$
Ramp	$f(a)=\begin{matrix}0 & a\le 0\\ a/\kappa & 0<a\le\kappa\\ 1 & a>\kappa\end{matrix}$
Sigmoid	$f(a)=\dfrac{1}{1-e^{-\kappa a}}$
Tangential sigmoid	$f(a)=\dfrac{1}{1+e^{-2a}}-1$

Neural networks can be explicitly programmed to perform a task by manually creating the topology and then setting the weights and thresholds of each link. Determination of weights and biases is called training. We need training data set for this. The training data set consists of input signals ($x_1, x_2, ..., x_n$) assigned with corresponding target (desired output) z.

The network training is an iterative process. In each iteration weights, coefficients of nodes are modified using new data from training data set. Modification is calculated using algorithm described as: Each teaching step starts with forcing both input signals from training set. After this stage, we can determine output signals values for each neuron in each network layer. For feed-forward neural networks, this method is called as back-propagation.

Training and Simulation

In general, multi-layered, feed forward, fully connected ANNs are preferred. In this work, same approach is adopted. ANN system has four layers of neurons: input layer, two hidden layers and an output layer. The neurons or units of the network are connected by the weights. The input layer consists of all the input factors, information from the input layer is then processed through two hidden layers and following output vector is computed in the output layer. First hidden layer consists of 4 cells with pure symmetric saturating linear transfer function and second hidden layer consists of tangential sigmoid function. The scheme of ANN used in this work is shown in Figure 3.

Back propagation, which is one of the most famous training algorithms for multi-layer perceptions, is a gradient descent technique to minimize the error for particular training pattern. Input and output vectors have been consists of 935 measurement data. 632 of them are used for training and 303 of them are used for testing. ANN model of Corn Leaves Area is constructed with two input stages (W and L inputs), one output stage (LA) and two hidden layers. Gradient descent momentum and an adaptive learning rate are used to train network.

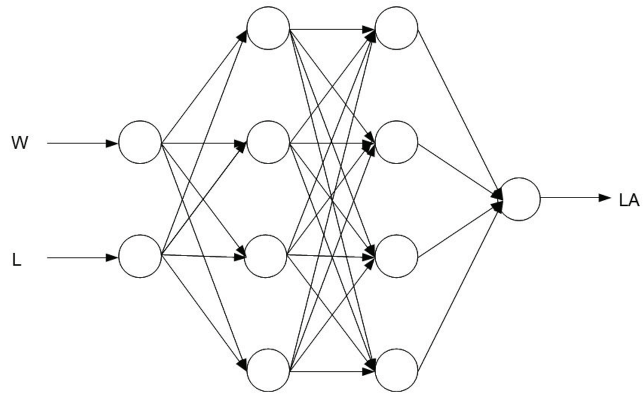

Fig. 3. Scheme of artificial neural network

Conclusions

From this research, it can be concluded that the ANN is potentially an efficient and feasible tool for modelling of corn leaf area. This approach is much simpler than adopting a high dimensional polynomial regression since no prespecified parameters, i.e. degree of polynomial and number of terms, are needed. The order of polynomial increases due to accuracy and the number of terms in polynomial increases exponentially according to its degree. The degree of accuracy obtained from both polynomial regression and the neural network still depends upon the number of data used to compute the coefficients of the polynomial and weights in the neural network. However, in case of the neural network, the network can be easily trained with those additional data to improve the degree of accuracy. Other factors can be directly included into relevant consideration with little modification of the network, allowing for iterative adjustment as new biological data becomes available (Keeratipibul et al., 2011).

References

Centritto, M., F. Loreto, A. Massacci, F. Pietrini, M. C. Villani and M. Zacchine, 2000. Improved growth and water use efficiency of cherry saplings under reduced light intensity. *Ecol. Res.,* **15**: 385–392.

Dunea, D. and V. Moise, 2008. Artificial Neural Networks as Support for Leaf Area Modelling in Crop Canopies. Proceedings of The 12th Wseas International Conference on Computers Pts 1-3: New Aspects of Computers **Book Series:** *Recent Advances in Computer Engineering***: p.** 440.

Halici, U., 2011. Lecture Notes on Artificial Neural Networks Chapter 1, Available online at: http://www.metu.edu.tr/~halici/courses/543LectureNotes/lecturenotes-pdf/ch1.pdf

Keeratipibul, S., A. Phewpan and C. Lursinsap, 2011. Prediction of coliforms and Escherichia coli on tomato fruits and lettuce leaves after sanitizing by using Artificial Neural Networks LWT. *Food Science and Technology*, **44**: 130-138.

Oner, F., M. S. Odabas, I. Sezer and F. Odabas, 2011. Leaf area prediction for corn (*Zea mays* L.) cultivars with multiregression analysis. *Photosynthetica,* **49** (4): 637-640.

Xing-Mei, S., J. Ying-Tao, Y. Mei, L. Shao-Kun, W. Ke-Rum and W. Chong-Tao, 2010. Artificial Neural Network to Predict Leaf Population Chlorophyll Content from Cotton Plant Images. *Agricultural Sciences in China,* **9** (1): 38-45.

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