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Achieving expected depth of shade in reactive dye application using artificial neural network technique

M. Senthilkumar, N. Selvakumar*

Department of Textile Technology, A.C. College of Technology, Anna University, Chennai 600025, India

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Abstract

Achieving the expected depth of shade in the production of dyed goods is a very important aspect. It requires the termination of the process at the right time in other words, correct duration of dyeing should be used. Prediction of this duration for the application of reactive HE dyes on cotton fabric using artificial neural network (ANN) is reported. The results obtained from the network gives an average training error of around 1% in the prediction of the time duration for achieving the correct depth of shade. The trained network gives the same average error % when tested with other reactive HE dyes even when the input parameters selected are beyond the range of inputs, which were used for training the network.

Keywords: Artificial neural network; Neuron; Sigmoid function; Hidden layers; Total dye fixed; Spectral reflectance curve

1. Introduction

Expected depth of shade is one of the very important qualities to be achieved in the dyed goods. In case, the depth produced is different from that of the expected, the product has to be either taken for reworking or rejected.

When goods are taken for dyeing, once the recipe and the conditions of dyeing for a given machine is fixed, the only parameter which needs attention to achieve the expected depth of shade is ‘‘the duration of the process’’. The required dyeing duration for a given situation can be predicted using statistical tools such as multiple regression analysis or computational processors such as artificial neural networks (ANN). Prediction using ANNs is claimed to have better accuracy compared to multiple regression analysis [1,2].

Neural networks are used for modelling non-linear problems and to predict the output values for a given input parameters from their training values. Most of the textile processes and the related quality assessments are non-linear in nature and hence neural networks find application in textile technology. Web density control in carding [3], prediction of yarn strength [4], ring and rotor yarn hairiness [5], total hand evaluation of knitted fabrics [6], classification of fabric [7] and dyeing [8] defects, tensile properties of needle punched non-wovens [2], quality assessment of carpets [9], dye concentrations in multiple dye mixtures [1], modelling of the H_2O_2/UV decolouration process [10], automated quality control of textile seams [11], fabric processability in garment making [12] and evaluation of seam puckering in garments [13] are some of the areas where ANNs have been attempted.

An attempt made on the prediction of dyeing time required to achieve expected depth of shade in the application of reactive HE dyes on cotton fabric using ANN is reported in this paper.

* Corresponding author. Tel.: +91 44 22203564.
E-mail address: nselva@annauniv.edu (N. Selvakumar).

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2. ANN

ANNs are typically composed of interconnected "units" which serve as model neurons. The schematic diagram of typical ANN is shown in Fig. 1. The function of the synapse is modelled by a modifiable weight, which is associated with each connection. Each unit converts the pattern of incoming activities that it reacts with into a single outgoing activity and then broadcasts it to other units. It performs this conversion in two stages. First, each incoming activity is multiplied by the weight on the connection and all these weighted inputs are added together to get a quantity called 'total input'. Secondly, an input–output function transforms the total input into an outgoing activity [14].

The commonest type of ANN consists of three groups or layers of units: (i) A layer of input units connected to (ii) a layer of hidden units, which in turn is connected to (iii) a layer of output units. The activity of the input units represents the raw information that is fed into the network. Whereas, the activity of each hidden unit is determined by the activities of the input units and the weights on the connections between the input and the hidden units. Similarly, the behaviour of the output units depends on the activity of the hidden units and the weights between the hidden and the output units.

3. Materials

The following bleached commercial cotton fabrics were used in this study.

Plain fabric with (a) EPI-80, PPI-94, $35^s \times 37^s$ and 121 gsm and (b) EPI-74, PPI-66, $37^s \times 31^s$ and 104 gsm and a twill fabric with EPI-96, PPI-56, $13^s \times 12^s$ and 291 gsm.

Three reactive HE dyes namely Procion Brilliant Red HE 3B, Procion Green HE 4BD and Procion Brilliant Red HE 7B supplied by Atul limited, Bombay, India were used in this study. Dyeing auxiliaries such as salt (NaCl) and alkali (Na_2CO_3) used were of LR grade. The soap solution used belonged to commercial grade.

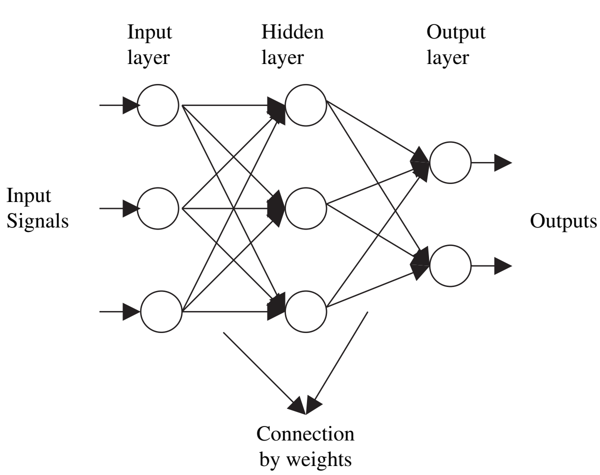

Fig. 1. Schematic diagram of typical ANN.

4. Methods

4.1. Dyeing procedure adopted

Prior to dyeing, the fabrics were pretreated using 10 g/l soap solution at boil for 1 h and washed thoroughly. The pretreated material was introduced in a bath containing the dye and the temperature was gradually raised to 80 °C. The dyeing was continued till the end of the primary exhaustion time. During this duration salt additions were made in three steps. Then, the required amount of alkali was added and dyeing was continued till the end of the fixation time. The parameters used for dyeing for the production of various samples are given in Table 1. Washing of dyed samples were carried out by using alternate cold wash with running tap water for 5 min and hot soaping at 70 °C for 5 min thrice. Finally, the samples were thoroughly washed with running tap water.

4.2. Determination of K/S value

The K/S value was calculated using the formula given below [15] from reflectance value (R) at λ_{max} (Table 2) measured using UV–vis spectrophotometer, U-3210, Hitachi, Japan.

$$K/S = \frac{(1-R)^2}{2R}$$

4.3. Determination of % total dye fixed on the fabric (T)

T of the fabric was calculated using the formula given below [16,17],

$$T = E\left(\frac{K_2}{K_1}\right)$$

where, E is the % dye bath exhaustion; K_1 is K/S value of dyed sample before soaping; K_2 is K/S value of dyed sample after soaping.

The % dye bath exhaustion was calculated using the formula given below from absorbance value at λ_{max} (Table 2) measured using UV–vis spectrophotometer, U-3210, Hitachi, Japan.

$$E = 100\left(1 - \frac{A_2}{A_1}\right)$$