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Comfort characteristics of textiles - Objective evaluation and prediction by soft computing techniques

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ABSTRACT: *Comfort characteristics along with the aesthetic appeal of textile structures for varied applications like next to skin layer, sportswear and active wear are of paramount importance for today's consumer demanding comfort as well as latest trends. Comfort although a subjective term can be objectively evaluated to determine the suitability and end use requirements of apparel fabrics. The effects of different fibre, yarn and fabric parameters on physical, thermal, mechanical and moisture management properties of textile structures can not only be objectively and subjectively determined but the properties can be predicted using soft computing techniques like artificial neural networks with high degree of accuracy. Nonlinear relationship of different fabric parameters with the comfort properties of textiles and close relationship of parameters with each other pauses problems in statistical modeling. Neural networks provide an effective tool for prediction of thermal, moisture management and hand values of textile structures. Another advantage of ANN is its stability and suitability for a variety of fabric types and an opportunity to generate database of fabric properties and eventually in development and engineering of new fabrics or updating the existing fabrics to keep pace with fashion. The present paper discusses the objective evaluation and prediction of thermal properties of textiles using the artificial neural network with emphasis on the structure and training of neural network using multi-layer perceptron (MLP).*
Keywords: *Comfort, Neural network, Soft computing, Textile, Thermal.*

I. Introduction

Clothing being worn merely for self-adornment in the past has evolved over the years to be functionally adaptive to meet the ever challenging demands of climatic adversities and consumers preferences. One of the prime requirements of clothing is of course to provide protection from extremes of climatic conditions and in so doing it acts as a barrier betweenhuman body and the external environment. Clothing comfort can be defined as absence of displeasure or discomfort experienced by the wearer. Clothing comfort includes three main considerations:thermo-physiological, sensorial and psychological [1, 2]. Thermo-physiological comfort is crucial for sportswear and next to skin applications where rapid heat transfer, moisture vapor and liquid moisture transfer from skin to the outer fabric surface is required. Heat transfer mechanism operative in clothing systems are conduction by solid material of fibres, conduction by intervening air, thermal radiation, convection and heat loss provided by evaporation [3,4]. Fig. 1 shows the different mechanisms of heat transfer from the human skin to external environment [5]. Thermal properties of fabrics can be determined by several experimental methods like Alambeta and thermal mannequins which are discussed in details in the next section. The thermal properties of textiles are affected by a gamut of fibre, yarn and fabric parameters which show a close relationship with each other. Non- linear relationship of different fabric parameters with thermal properties pauses problems in statistical modeling. Therefore, it becomes difficult to study the effect of some parameters without varying the other parameters. Soft computing techniques like artificial neural networks are widely being used for prediction of comfort properties of textiles owing to the high degree of accuracy of prediction along with simplicity and suitability of simulators for different fabric types and textile markets [6].

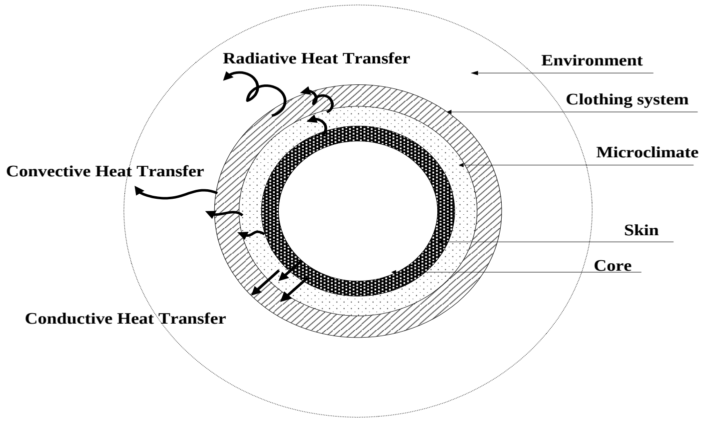

Fig.1. Human- Clothing – Environment system [5]

II. Objective evaluation of thermal properties

Thermal comfort of textile structures can be characterized by three properties: thermal conductivity, thermal resistance and thermal absorptivity [3, 4, 5].

Thermal conductivity - is an intrinsic property of material that indicates its ability to conduct the heat. It is the flux(energy per unit area per unit time) divided by temperature gradient. Thermal conductivity is calculated by the following expression:

$$\lambda = \frac{Qh}{A\Delta Tt} \ldots(1)$$

Where, λ is the thermal conductivity ($Wm^{-1}K^{-1}$), Q, the amount of conducted heat (J), A, the area through which heat is conducted (m^2), t, the time of conductivity (s), ΔT, the drop of temperature(K) and h, the fabric thickness (mm).

Thermal resistance- depends on the ratio of thickness and thermal conductivity of the fabric and calculated by expression:

$$R = \frac{h}{\lambda} \ldots(2)$$

Where, R is the Thermal Resistance (Km^2W^{-1}), h, the fabric thickness (mm) andλ, the Thermal Conductivity ($Wm^{-1}K^{-1}$).

Thermal absorptivity - is the objective measurement of warm-cool feeling of fabrics.Heat exchange occurs between hand and fabric when human touches a garment at a different temperature than the skin. Thermal absorptivity can be calculated by expression:

$$b = \sqrt{\lambda \rho c} \ldots(3)$$

The thermal resistance, thermal conductivity and thermal absorptivity of fabrics can be evaluated by an instrument Alambeta (ISO ENB 1092-1994). Fig. 2 shows the schematics of Alambeta instrument. In this instrument the fabric sample is placed between two plates, one hot and the other cold. The hot plate comes in contact with the fabric sample at a pressure of 200pa. The amount of heat flow from the hot surface to cold surface through fabric is detected by heat flux sensors. Another sensor measures the fabric thickness. The values are then used to calculate thermal resistance of fabrics [3, 4, 5].

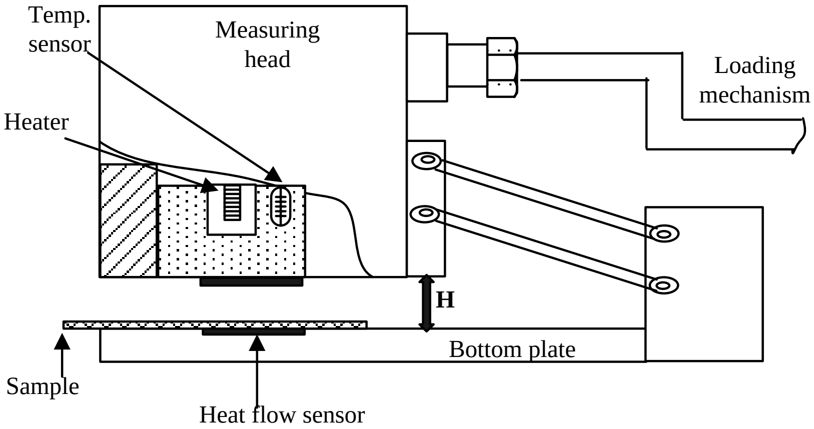

Fig.2. Schematics of Alambeta instrument for measuring thermal properties of fabrics [5]

Thermal manikins are designed for use as a repeatable measurement tool for thermal evaluation of clothing and environment. They can replace subjective and costly human testing. It is possible to safely generate data in hazardous conditions with the aid of thermal manikins and their associated software. Fig. 3 shows the thermal manikin - Newton used for evaluation of thermal properties and Fig. 4 shows the thermal manikin's software called ThermDAC.

III. ARTIFICIAL NEURAL NETWORK (ANN)

An Artificial neural network is a computational model inspired by the natural neurons. Synapses located on the dendrites or membranes of the natural neurons transmit signals to the neurons. Signal is emitted by activated neuron through the axon when the signals received by neuron are strong to surpass certain threshold. Another synapse may receive this signal and activate other neurons. Artificial neurons consist of inputs (synapses), which are multiplied by weights (strength of respective signals) and the activation of neuron is determined by computation of amathematical function. Output of the artificial neuron is computed by another function (which may be identity). Artificial neurons are combined by ANN to process the information. Neural networks are normally applied to automatic control and operating systems for solving problems related to prediction of non-linear system, where artificial neural networks show powerful learning, fault tolerance and response capabilities [7].

Fig.3. Thermal Manikin [5]

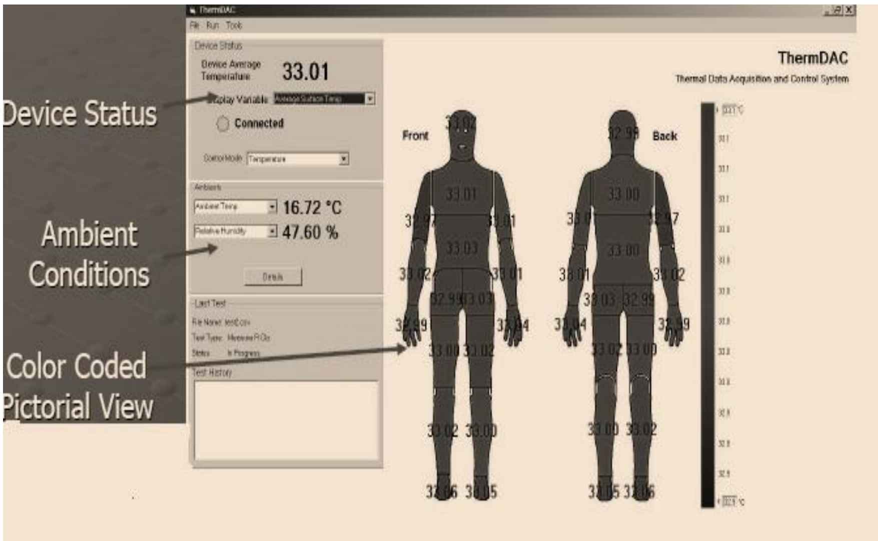

Fig.4. Thermal Manikin's software ThermDAC Principle of ANN

The basic principle of ANN is that numerical inputs (training data) are transferred into desired outputs. The input and output nodes are connected to the outside world and to the other nodes within the network. Weight strength and bias both determines the output of each node. Non linear weighing function transforms the weighed sum of all the inputs which determine the outputs. The predictive model finds its application in comfort aspects of textiles owing to the training of the system. Training the networks is possible by presenting known inputs and outputs and modifying the connection weights and biases between the nodes. The process continues till the output nodes of the networks matches the desired output with high level of accuracy. Fig. 5 shows the input, weight, bias and output in a single input neuron. Fig. 6 shows the input, hidden and output layers of artificial neural network. The input layer corresponds to the selected variables (fibre, yarn and fabric parameters) affecting the fabric properties. The output layer corresponds to the property under consideration (thermal properties). Artificial neural network with three layers is the multilayer perceptron (MLP) and is a kind of learning by updating errors called the back-propagation algorithm [6, 7, 8].

3.1 Training of Neural network

Sigmoid functions of the form $f(x) = \frac{1}{1+e^{-x}}$ can be used for non linear transformation with range of input (0,1). Margin between target value and prediction output can be reduced by learning network.The quality of learning is evaluated by using energy function (E) as follows:

$$E = \frac{1}{2}\sum (D_j - Y_j)^2 \quad ...(4)$$

Where, Dj is the output layer target value and Yj, the output layer prediction value.

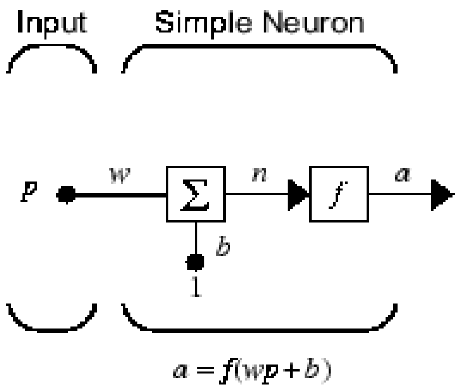

Fig.5. Single input neuron [8]

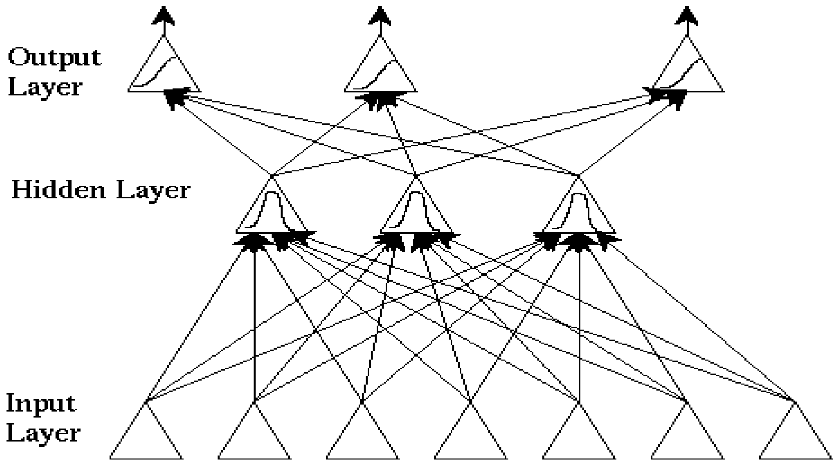

Fig.6. Three layers of ANN [8]

3.2 Prediction of thermal properties using ANN

Artificial neural network offers an objective and efficient method for predicting fabric properties with rapid prototype.Textile manufacturing units can maintain their commercial expertise and experience by charactesiation of data for fabric materials.The established prediction model can serve as a guide for proper fabric designing and utilisation to fabric manufacturers and fashion designers.This approach will make fabric sourcing more realistic [6-9]. Thermal properties like thermal conductivity, thermal resistance can be predicted by Multilayer perceptron (MLP) artificial neural network by correct identification and selection of various fibre ,yarn and fabric parameters affecting the thermal properties. Fig. 7 shows the multilayer artificial neural network for prediction of thermal conductivity.Several researches have been devoted to the prediction of thethermal comfort properties, total hand value using the ANN [9].Alibi*et al.*[6] used neural network approach to predict thermal conductivity (output) of knitted structure as function of porosity, air permeability, yarn conductivity and aerial density (inputs). Networks were trained with training data set and then tested with untrained values. Thermal conductivity values obtained from network were compared to actual values obtained from instrument. Alibi *et al.*[7] studied the relationship between structural parameters and functional properties of jersey knit fabrics using the back propagation neural network algorithm. It was found that neural networks architecture with 3 hidden neurons gave better prediction performance and highest accuracy for predicting the thermal resistance of fabrics.

IV. CONCLUSION

Comfort characteristics of textiles particularly thermal properties are crucial for thermal equillibrium and well being of individual with the outside environment. The thermal properties of fabrics have been objectively and subjectively evaluated by several techniques. However, owing to non linear relationship of different fibre, yarn and fabric parameters with fabric properties, difficulty arises in the statistical modelling of textile structures. An effective soft computing technique has been introduced to predict the fabric properties (output) from parameters (input layer). Artificial neural networks can serve as an effective tool in predicting thermal properties of textile structures by validation of unseen data owing to simplicity of the simulator and ability to generate database for a gammut of innovative fabric structures.

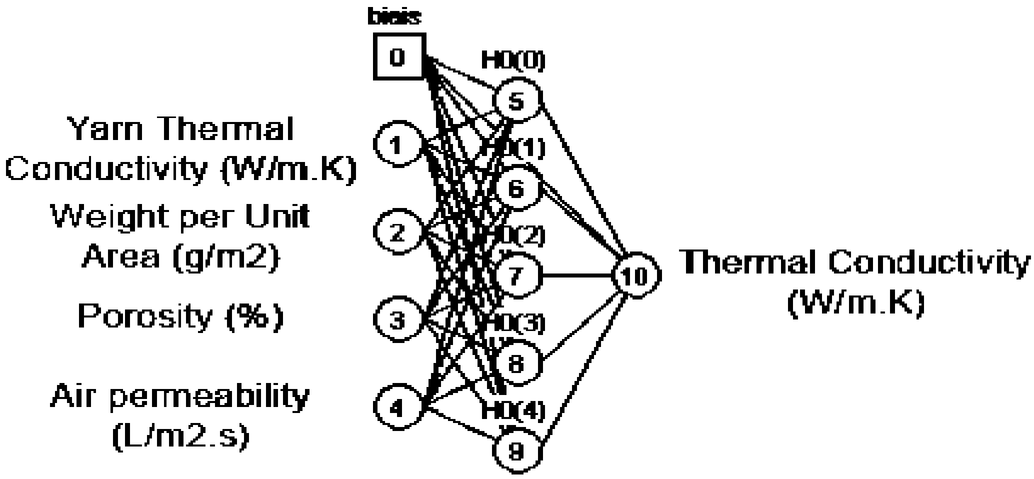

Fig.7. Multilayer artificial neural network for prediction of thermal conductivity [6]

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