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Teaching AI in Knitwear Education, with reference to the application of Artificial Neural Networks (ANN)

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Abstract

With the rapid advancements in knitwear and knitting technology, there is an increasing scope of teaching advanced concepts like Artificial Intelligence (AI) in the Knitwear curriculum. The scope of technical textiles has also increased and so has the need to develop more and more precise fabrics that meet certain parameters and needs thereby. This has resulted in the need to improve the fabric design procedures so that the final products conform to certain technical properties , like thermal conductivity, bursting strength, etc. The performance of the knitted fabrics is desired to be predictable right from the design phase, and this can be a very relevant and useful input for the future knitwear designers and technologists. Hence, knit fabric design is focusing on the control of its parameters, so that the requirements of the end use like sensory comfort, pilling control, handle, strength , etc. can be met. Since most of these parameters don't have a linear mathematical link with the properties as such, hence there has been an increasing need and use of Artificial Intelligence tools, especially the Artificial Neural Networks (ANN), so as to estimate, predict and classify various knitted fabric properties. Hence, this paper mainly reviews and talks about the various applications of ANN in knits , so that they may be incorporated into the Knitwear curriculum in the near future.

Keywords: ***Knitwear , Education, AI, Artificial Neural Networks, Knitted fabrics, Future***

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Introduction :

With the increasing use of knits in various categories of products, the yarn and fabric structure, appearance and the physical properties affecting its final performance are getting more and more crucial. However, the knitted structures are very complex in nature. It's not just the fabric structure that matters but also the fibre and the yarn, including various related parameters of the same. By addressing such concerns for the future of Knitwear industry, it becomes important to discuss the possibility of teaching advanced concepts like AI in the curriculum of knitwear design. If students are equipped with the knowledge and application of such concepts in knits, they can be more future ready for the industry challenges.

The performance of the knitted fabrics depends not only on the structural complexity, as well as from various parameters of the materials themselves, which present a non-linear relationship. This double non-linearity of the knitted fabrics increases the difficulty in the fabric design and manufacturing processes. The complex structure and the complexities introduced by the fibres and yarns do not allow the use of conventional mathematical models for fabric design.

As the current inputs in Knitwear education don't delve into such a scenario, there is a need to incorporate an increasing use of alternative computational models that aim at the prediction of the properties and the performance of the knitted fabrics. Various computational models have been used in order to represent the fabrics and to predict their final properties. In case of classification problems, Artificial Neural Networks (ANNs) have proved to be a very efficient tool for an efficient solution. Applications of ANNs in the textile field for classification as well as in the prediction of properties and optimization problems (Chattopadhyay & Guha, 2004) have proved to be very effective. The applications of the ANNs in the fabric classification and prediction problems have been tested effectively in the fields of fibres, yarns and fabrics as well as colour, wet processing and clothing.

Artificial Neural Networks :

Artificial Neural Networks (ANNs) are algorithmic structures derived from a simplified concept of the human brain structure (Vassiliadis et al., 2010). They belong to the Soft Computing family of methods, along with fuzzy logic / fuzzy control algorithms and genetic algorithms,(Zadeh, 1994). They all share an iterative, non- linear search for optimal or suboptimal solutions to a given problem, without the presupposition of a model of any type for the underlying system or process, (Keeler, 1992). Various different ANN types have already been successfully employed in a wide variety of application fields, (Haykin, 1998). Major ANN functionalities are :

i. Function approximation: this functionality is exploited in system input-output modelling and prediction, and

ii. Classification: this functionality is exploited in pattern recognition / classification problems, (Lippman, 1987).

• In their capacity as function approximators, ANNs have long been studied as to the required properties of the target function as well as to the structure of the ANN, in order to guarantee convergence of the – typically iterative – approximation algorithm. The first brain-inspired ANN structure was proposed by McCulloch and Pitts in 1943, along with a proof that it could approximate any deterministic function, (Hertz et. al., 1991). In light of the Cybenko theorem, (Cybenko, 1989), ANNs are recognised today as ‚universal approximators‛, i.e. they can approximate arbitrarily closely any function on a compact subset of Rn, under certain general assumptions on the function. The property was proved for a specific ANN structure (the standard multilayer feedforward network with a single hidden layer that contains a finite number of hidden neurons, with a sigmoid activation function and a linear output layer). Similar results exist for arbitrary activation functions, (Hornik, 1989) and other ANN structures, as well, (e.g., Lin, 1994). A common prerequisite for the ANN to operate as approximator is the linearity of its output node(s).

In a textiles context, the function approximation capacity of ANNs is of great practical interest because a variety of quantities that characterise yarns and/or fabrics depend on (i.e., are functions of) the yarn or fabric consistency, structure and weaving characteristics. Air permeability of a woven fabric, for example, depends on such parameters as warp and weft yarn density and mass per unit area. These dependencies do not always lend themselves to accurate description by an analytic mathematical function; yet, the ability to estimate or predict the value of such a quantity of interest given the yarn or fabric parameters – before actually constructing the yarn or fabricating the fabric – is highly desirable in the textiles design and production phases. Research has turned to ANNs for estimation and prediction tasks in various textile applications, (Stylios & Parsons-Moore, 1993), (Stylios & Sotomi, 1996), (Ertugul & Ucar, 2000), (Majumdar, 2004), (Lin, 2007), (Bhattacharjee & Kothari, 2007), (Gurumurthy, 2007), (Guruprasad & Behera, 2010).

• In their capacity as classifiers, on the other hand, ANNs have found extensive and successful application in virtually all pattern recognition tasks, including 1-D and 2-D signal (image) processing applications, clustering, etc. In such problems, unknown input data are classified as belonging to one of a finite number of known classes or categories. ANN structures with an output layer of nodes (neurons) of the ‚competitive ‛type are suitable for classification tasks. Individual binary outputs of the output layer nodes are vectorised in order to enumerate the class where incoming data belong, in typical classification problems. Single and multiple-layer perceptrons, self- organising maps and other types of ANN structures serve as classifiers. Among them, of practical interest are networks that compute probabilities that a given input belongs to one of the considered classes, rather than deterministic outputs. They can thus substitute multi expert decision algorithms, such as majority-voting, etc. Probabilities can subsequently be handled in a variety of ways to obtain final answers in the output. The classification capacity of ANNs in a textiles context finds extended use in classification of yarn or fabric types or other visual properties, such as color, defects, weaving / knitting pattern, percentage consistency in various materials and the like, (Guruprasad & Behera, 2010). These tasks are affordable in time and equipment investment thanks to the recent technological advances (a) in image capturing equipment of high quality and very low cost and (b) in hardware processors of increased processing power that allow for real or quasi-real time applications.

ANN applications in the textile field :

The applications of ANNs in the textile engineering field have become more and more popular since the 1990‛s. Eventually, it was shown that they can effectively address complex engineering problems. Many researchers have used ANNs in the case of a multi parameter and non-linear situation, in the absence of a straightforward analytical solution. Following paragraphs talk about various such applications of ANN in knits, which may be useful in enhancing the knitwear education inputs to a new level, for the future needs of the industry.

The properties of knitted fabrics need to meet the user requirements; hence, the prediction of their properties and the fabric performance is very important. The fabrics are complex structures, if their micro mechanical structure is considered. The structural complexity in along with the yarn complexity do not usually allow the development of conventional analytical tools for supporting the design phase, as in the the case of other engineering fields such as mechanical, electrical, etc. Therefore, a lot of effort has been given towards the development of computational models for the prediction of the behaviour of fabrics (Basu et al., 2002).

The inspection of the fabrics for faults detection is one of the crucial operations in the industry, usually carried out by skilled operators. Many efforts have been made in order to perform the inspection automatically. Hence, the task of automated defects detection is popular and many research teams have shown their interest on it, while many of them have used ANNs to perform the fault detection task, (Tsai et al., 1995; Sette & Bullard, 1996; Tilocca et al., 2002, Kumar, 2003). Using the same principles, stitch inspection can be achieved (Yuen et al., 2009).

Drapability is one of the the most complex physical property of a fabric and it is essential for many uses in fashion. The prediction of the drape has been made using ANNs (Fan et al., 2006). In parallel the engineering of the drapability of the fabrics became possible though a predictive tool (Stylios & Powel, 2003). Fabric hand is a property that combines the physical properties of a fabric with the sensory perception of the fabric by the humans when it is touched. Some complex systematic approaches for the definition of the fabric hand, which include the full set of the low stress physical properties of the fabrics. Obviously, the prediction of the fabric hand is equivalent to the prediction of the low stress physical properties of fabrics. It is a complex, highly non-linear problem and therefore an early target for the application of ANNs (Youssefi & Faez, 1999).

The data from the FAST system were used to approach the hand of the fabrics (Sang- Song & Tsung-Huang, 2007), while fuzzy logic was combined with ANN for the evaluation of the fabric hand (Park et al., 2000). ANNs and fuzzy logic have been used together in the case of the prediction of the sensory properties of the fabrics, as well (Jequirim et al., 2009). The prediction of the desirable properties of the fabrics is an essential technical requirement. ANNs have been used for the prediction of the tensile strength (Majumdar et al., 2008) and for the initial stress-strain curve of the fabrics (Hadizadeh et al., 2009). The same problem has been solved using an adaptive neuro-fuzzy system (Hadizadeh et al., 2010). The shear stiffness of the worsted fabrics (Chen et al., 2009) and their compression properties have been successfully modelled (Murthyguru, 2005; Gurumurthy, 2007). In general, the prediction of the properties of a fabric enables the support of the design phase, (Behera & Muttagi, 2004), and this can be a very useful tool for the knitwear designers in the filed of fabric/apparel design and development.

The prediction of bursting using ANNs for knitted fabrics (Ertugrul & Ucar, 2000) as well as for woven fabrics (Vassiliadis et al., 2010) has been achieved with satisfactory results. The permeability of the woven fabrics has been modelled using ANNs as well (Tokarska, 2004; Çay et al., 2007). The pilling nature of the fabrics has been predicted (Beltran et al., 2005) and the pilling of the fabrics has been evaluated (Chen & Huang, 2004), while the presence of fuzz fibres has been modeled. Prediction of the spirality of the relaxed knitted fabrics (Murrells et al., 2009) as well as knit global quality (Slah et al., 2006) and subjective assessment of the knit fabrics (Ju & Ryu, 2006) have been implemented.

Prediction of the thermal resistance and the thermal conductivity of the textile fabrics has been realised with the help of ANNs (Bhattacharjee & Kothari, 2007; Fayala et al., 2008). Moisture and heat transfer in knitted fabrics has been also studied similarly (Yazdi et al., 2009). Engineering of fabrics used in safety and protection applications is supported by ANNs (Keshavaraj et al., 1995; Ramaiah et al., 2010). Prediction of the fabrics end use is also possible via the same method (Chen et al., 2001). Optimisation of the application of a repellent coating has also been approached by the ANN model (Allan et al., 2002). Such applications can be very handy for the knitwear technologists , especially to think and apply at the knitted fabric stage.

ANN in the field of Knits :

A. Bursting strength prediction:

The bursting strength of knitted fabrics was predicted before manufacturing using intelligent techniques of neural network and neuro-fuzzy approaches in a research ((Ertugrul & Ucar, 2000). Among many parameters that affect fabric bursting strength, fabric weight, yarn breaking strength, and yarn breaking elongation were the input elements used .In this research, both the multi-layer feed-forward neural network and adaptive network based fuzzy inference system, a combination of a radial basis neural network and the Sugeno-Takagi fuzzy system, were analysed. Both systems showed the ability to learn training data successfully, and testing errors were found to be small enough to give an approximate knowledge of the bursting strength of the fabric to be knitted.

In another study (Jamshaid et al., 2012) , the aim was to compare the response surface regression and adaptive neuro-fuzzy models for predicting the bursting strength of plain knitted fabrics. The prediction models were based on the experimental data comprising yarn tenacity, knitting stitch length and fabric GSM as input variables and fabric bursting strength as output variable. The models quantitatively characterise the non-linear relationship and interactions between the input and output variables exhibiting very good prediction ability and accuracy, with ANFIS model being slightly better in performance than the regression model.

B. Apparent Quality of weft knitted fabric

In a research (Semnani et al., 2005) , it was attempted to present a novel definition for apparent quality of weft knitted fabrics with reference to the yarns, using the image analysis method, which are calculated by neural networks. First, standard boards of yarn were analysed using the image analysis method and Artificial Neural Networks. Then, samples of plain, cross-miss and plain pique fabrics and their used yarns were tested for appearance. The results showed that the correlation between apparent quality of knitted fabrics and their yarns was very strong. The ANOVA test confirmed that there was a strong influence of yarn type and fabric structure on fabric apparent quality. Although the yarn type has a strong effect on fabric appearance, the effect of fabric structure on its appearance was not significant.

C. Pilling propensity of knitted fabrics

Fabric pilling is affected by various interacting factors. This study (Beltran et al., 2005) used Artificial Neural Networks to model the multi-linear relationships between fiber, yarn and fabric properties and their effect on the pilling propensity of pure wool knitted fabrics. This tool enabled the user to gauge the expected pilling performance of a fabric from various inputs. It provided a means of improving current products by offering alternative material specification and/or selection. In addition to having the capability to predict pilling performance, the model also allowed for clarification of major fiber, yarn and fabric attributes that affect fabric pilling.

The findings from this study suggested that the prediction of pilling propensity is achievable using an Artificial Neural Network modelling technique. One of the limitations was the limited number of data sets used to train the network, which can be reduced by additional data. Optimisation of network parameter settings and pre- processing should also further improve the accuracy of the predictions. The capacity to predict the propensity of a fabric to pill, the interactions between key parameters could be realised and therefore ultimately controlled to minimise pilling behaviour of the fabric.

D. Sensory properties prediction from process and structure parameters of knitted fabrics

In a study (Jeguirim et al., 2009) , talked about competitive market, due to which the textile industrialists intend to propose diversified products according to consumers preference. For this purpose, the integration of sensory attributes in the process parameters proved to be a useful alternative. This study provided fuzzy and neural models for the prediction of sensory properties from production parameters of knitted fabrics. The prediction accuracy of these models was tested using both the root mean square error (RMSE) and mean relative percent error (MRPE). The results revealed the models ability to predict tactile sensory attributes based on the production parameters. The comparison of the prediction performances showed that the neural models are little better than the fuzzy models.

The obtained results revealed that the neural networks and fuzzy logic provide an alternative approach to understanding and predicting tactile sensory properties from Various given parameters of knitted fabrics. The MRPE values were acceptable (<10%) and the RMSE values were lower than the mean variations of experimental values. The neural models were found to be slightly better than the fuzzy models. Therefore, both techniques were presented as a promising tool for engineering industrial products design in order to satisfy the specific needs of consumers. Also, minimal number of experiments or learning data and short cycles of product design and product development were sufficient.

E. Prediction of Thermal Conductivity

In a study (Fayala et al., 2008) , it was attempted to work on the comfort temperature for an individual or group, by means of thermal conductivity as a physical characteristic of knitted fabric. It depended on many fabric parameters and it was difficult to study the effect of one without changing the others. Also, the non-linear relationship of fabric parameters and thermal conductivity didn·t allow for mathematical modelling. So a Neural Network approach was used to predict the thermal conductivity of knitted fabric, as a function of porosity, air permeability, weight and fiber conductivity. Data on thermal conductivity was based on experiments carried out on jersey knitted fabric.

The ANN system was used to predict the thermal conductivity of knitted fabric . Many configurations of ANN were proposed and the optimal configuration was selected . The selected system was found to have four input parameters (yarn conductivity, weight per unit area, porosity and air permeability), one output (fabric thermal conductivity) and with five neurons in one layer. This system was able to predict fabric thermal conductivity with 0.913 as correlation coefficient. This model can be easily applied for industrial purposes to improve the thermal conductivity of knitted fabric.

F. Prediction of the total hand value of summer knitted T-shirts

Not only for fabrics, the ANN models have also been used for knitted apparel performance analysis. (Hasani et al., 2009) , in a study, used Weighted Euclidean Distance, for indirect determination of total hand value from the KES system parameters obtained for various summer knitted T-shirts. In this method, the weight of multivariable related to fabric hand were determined from objective measurements without any resource to subjective evaluation. Artificial Neural Network with back propagation learning algorithm and multiple linear regression algorithm have been used to construct predictive models for the determination of total hand value of summer knitted T-shirts based on fabric physical properties measured on the KES system of each sample as input and total hand value predicted by mathematical model as desired output. The predictive power of optimised models is calculated and compared. The results reveal that the Artificial Neural Network model is very effective for predicting the total hand value and has the better performance as compared to Multiple Linear Regression Model.

In this study, the feed forward neural network model with 16-16-1 architecture, i.e. sixteen input unit, sixteen neurons in hidden layer and one output neuron, was found better than the multiple linear regression model for the prediction of total hand value of summer knitted T-shirts based on five primary hand features of KES system, namely firmness, stiffness, fullness, roughness, and crispness, as input parameters. The mean square error(MSE) for predicting the testing data was found to be 0.1170 and 0.2053 for ANN and multiple linear regression models respectively. The results showed the good capability of ANN algorithm to predict total hand value of knitted summer T-shirts.

Conclusion :

Hence, attempt has been made to compile and review some of the applications of the Artificial Neural Networks (ANN) methods for the solution of textile problems , with a view to incorporate the same in the future curriculum of knitwear education. Related publications on the field have been reviewed so as to present a picture of the promising potential of Artificial Intelligence, with reference to the ANN‘s. Beginning from the the nineties, a continuously increasing number of ANN applications have provided solutions to complex and multivariable textile problems. It can be seen that the textile industry has found ANN as a powerful and efficient tool that can be used for non-linear analysis from fiber to fabric to apparel. For knits, it has proved to be an effective research tool for prediction of various fabric properties , which can lead to intelligent systems for virtual design and optimisation of the fabric properties and resources. It can be seen that ANNs will increase their level and utility of applications in the coming times, so as to solve more and more complex problems in the field of textiles and apparel. Hence, the inclusion of such concepts in the knitwear curriculum can be a promising step for the future knitwear professionals.

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