The Performance of Data Mining Techniques in Prediction of Yarn Quality

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***Abstract*—The data mining techniques such as Artificial Neural network algorithm (ANN) and support vector machine (SVM) based models are utilized in this study. Three different kernel functions were used as SVM kernel functions which are polynomial, Radial Basis Function (RBF), and Pearson VII function-based Universal Kernel (PUK). The SVM models based on these three kernel functions and ANN model were used in forecasting the quality of ring and compact spinning yarn such as yarn unevenness, hairiness, yarn tenacity, and yarn elongation. The comparison of results indicates that the SVM models based on RBF and PUK Performs yarn properties forecasts more accurately than ANN model.**

***Index Terms*—Data mining, artificial neural network (ANN), support vector machine (SVM), kernel functions, yarn properties**.

I. Introduction

In recent years there has been a significant increase in application of data mining techniques or machine learning in textile engineering especially in forecasting the quality of yarn spinning. The corresponding increase in forecasting yarn spinning quality became an important part of this field of application because of the relation between fiber and yarn properties are still more complex and nonlinearly. Therefore, modeling of yarn properties which is an indicator to yarn spinning quality and the relationship between fiber and yarn properties are widely studied in textile engineering [1]-[8]. In this paper, we investigate on the study of the forecasting quality of yarn spinning that are made from the common types of yarn spinning such as ring and compact spinning and focusing on their properties such as yarn unevenness, hairiness, yarn tenacity, and yarn elongation, using the Multilayer Perceptron artificial neural network and support vector machine based models.

II. Methods

A. ANN

Artificial neural network (ANN) is suitable for modeling nonlinear relationship. It is a powerful data modeling tool that is able to capture and represent any kind of input – output relationships. The theory of ANN and application in textile engineering exactly in spinning process and modeling yarn properties studies are extensively discussed in many reviews [1], [9]-[12].

The ANN employed in this study was a three layer Back-Propagation Multilayer Perceptron network, the input layer, one hidden layer, and the output layer. The Multilayer Perception artificial neural network (MLP) is the most popular and widely used nonlinear network for solving many practical problems in applied sciences, including textile engineering.

The reason for the popularity of the (MLP) network is that it is very flexible and can be trained to assume the shape of the patterns in the data, regardless of the complexity of these patterns [13]. More presented details on the theory of MLP neural networks can be found in [13]. Fig. 1 shows the structure of MLP neural network.

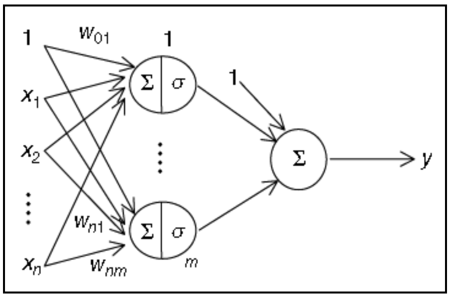

Fig. 1. MLP network with three layers (input, one hidden layer, and output).

B. SVM

Support vector machines (SVM) was originally developed for the classification problem by Vapnik and co-workers [14]. This technique was built on the structural risk minimization principle. Now, with the introduction of ε-insensitive loss function, SVM has been extended to solve nonlinear regression estimation. By using the kernel function, SVM plays role to map the data to high dimensional feature space and then find a linear separating hyperplane with the maximal margin in that high dimensional space.

The technique has demonstrated much success in prediction studies in textile engineering exactly in fiber and yarn relationship area, and gives a powerful accuracy with good performance in many studies [15]-[17]. However, detailed description of SVM theory has been discussed in the reviews [14], [18] and [19]. In this paper we used support vector machine for regression (SVMR) with the commonly kernel function, i.e., polynomial and (radial basis function (RBF)) in addition to Pearson VII Universal Kernel which was applied as a kernel function of SVM in [20] , and referred to as PUK.

The parameters of support vector machine for regression (SVM) such as the complexity parameter C, and the value of ε-insensitive loss function , and the kernel parameters such as the degree d of polynomial kernel, the width of RBF kernel function γ, and PUK kernel parameters (ω and σ) were optimized by using Grid search approach using 10 fold

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cross validation. The errors that were used as an indicator of the predictive performance of the models were Root mean-squared error (RMSE) and Correlation coefficient (R). For implementation and carry out our experiments, the SVM and ANN models were executed by using Rapid Miner (Rapid-5) software program, a well known, Java Based optimization software for hard optimization and machine learning.

III. The Experiments

A. The Data

The cotton fiber properties and corresponding yarn properties data were collected from spinning mill in Xuchang, Henan Province, China. The data collected contain 21 and 23 datasets of fibers and yarn properties for ring and compact yarn, respectively. The cotton fiber properties were measured by Uster AFIS. The fiber properties used as input data were fiber length UHML (mm), Short Fiber Content SFC (%), maturity, fineness, neps, seed coat neps and trash. The yarn properties of corresponding yarn such as unevenness%, hairiness, tenacity (cN/tex), and elongation % were used as the output data and the target. The statistical description of ring and compact yarn are shown in Tables I and II respectively.

B. Optimization of Ann Model

The optimization of the Multilayer Perceptron ANN model was done with 10 fold cross validation. The ANN optimized parameters such as the optimal learning rate, the momentum coefficient, and the number of epochs were selected lonely according to each target and depending on smaller RMSE the best results were selected.

TABLE I: The Statistical Description of Ring Spinning Dataset

The attributes	Range	Mean	SD	CV%
Fiber properties				
UHML (mm)	31.68 – 33.54	33.060	0.433	14.15
SFC %	8.4 – 10.2	9.128	0.538	5.89
Fineness	158 - 168	163.095	2.914	1.79
Maturity	0.880 – 0.920	0.902	0.01	1.11
Neps	211 - 279	254.048	17.296	6.81
SCNep	15 - 22	18.571	1.535	8.27
Trash	371- 631	462.095	76.713	16.6
Yarn properties				
Unevenness	13.06 – 13.73	13.439	0.194	1.44
Hairiness	0.65 – 1.61	1.098	0.285	25.96
Tenacity	16.5 – 19.7	17.961	0.814	4.53
Elongation	4.7 – 6.2	5.226	0.367	7.02

TABLE II: The Statistical Description of Compact Spinning

The attributes	Range	Mean	SD	CV%
Fiber properties				
UHML (mm)	30.86 – 32.34	31.7	0.496	1.57
SFC %	4.8 – 7.8	6.274	0.857	13.59
Fineness	162 - 173	167.217	3.261	1.95
Maturity	0.88 – 0.92	0.898	0.01	1.11
Neps	151 - 205	174.174	12.727	7.31
SCNep	14 - 23	18.913	2.334	12.34
Trash	300 - 718	456.391	92.809	20.34
Yarn properties				
Unevenness	13.06 – 13.73	13.439	0.194	1.44
Hairiness	0.65 – 1.61	1.098	0.285	25.96
Tenacity	16.5 – 19.7	17.961	0.814	4.53
Elongation	4.7 – 6.2	5.226	0.367	7.02

C. Optimization of Svm Models

The optimization of SVM parameters was performed by using Grid search approach in the data using 10 fold cross validation and depending on smallest RMSR error we selected the optimal parameters of the model. The optimized parameters of SVM based models are shown in Table III.

TABLE III: The Optimal Parameters of SVM Based Models for Carded and Combed Ring Yarn

Yarn Type	Properties	Optimal parameters of SVM based model									
		Polynomial			RBF			PUK			
		σ	ε	C	γ	ε	C	ω	σ	ε	C
Ring yarn	Unevenness %	3.0	0.1	40.96	0.02	0.001	40.96	105.0	12.1	0.001	40.96
	Hairiness	3.0	0.008	1.0	0.04	0.002	360.64	1.0	1.0	0.001	360.64
	Tenacity	3.0	0.1	90.91	0.02	0.001	40.96	125.0	12.1	0.001	40.96
	Elongation %	3.0	0.001	160.84	0.01	0.01	90.91	1.0	1.0	0.001	10.99
Compact yarn	Unevenness %	3.0	0.1	1000	0.02	0.001	1.0	1.0	1.0	0.1	810.19
	Hairiness	3.0	0.008	1.0	0.04	0.001	810.19	45.0	9.1	0.001	10.99
	Tenacity	3.0	0.1	250.75	0.01	0.02	490.51	95.0	19.1	0.1	490.51
	Elongation %	3.0	0.001	1.0	0.04	0.001	360.64	85.0	7.1	0.001	160.84

TABLE IV: Comparisons of Prediction between ANN and SVM Models for Ring Yarn

Yarn properties	Errors	ANN	SVM		
			Polynomial	**RBF**	**PUK**
Unevenness %	RMSE	0.321	0.210	0.195	0.194
	R	0.600	0.597	0.699	0.699
Hairiness	RMSE	1.877	1.192	1.184	1.040
	R	0.437	0.567	0.499	0.599
Tenacity	RMSE	1.133	1.599	0.640	0.638
	R	0.600	0.432	0.800	0.798
Elongation %	RMSE	0.498	0.446	0.336	0.314
	R	0.462	0.785	0.561	0.641

D. Results and Comparisons

The goal of this part of research is to compare the prediction results provided by SVM based on polynomial, Gaussian radial basis (RBF) and PUK kernels function as well as the ANN model in forecasting of the quality of spinning yarn such as ring yarn and compact yarn.

TABLE V: Comparisons of Prediction between ANN and SVM Models for Compact Yarn

Yarn properties	Errors	ANN	SVM		
			Polynomial	**RBF**	**PUK**
Unevenness %	RMSE	0.223	0.212	0.155	0.144
	R	0.416	0.398	0.568	0.607
Hairiness	RMSE	0.305	0.299	0.247	0.246
	R	0.500	0.407	0.657	0.673
Tenacity	RMSE	0.572	0.676	0.497	0.482
	R	0.805	0.766	0.808	0.805
Elongation %	RMSE	0.341	0.284	0.230	0.222
	R	0.395	0.461	0.754	0.794

The Errors that were used as an indicator of the predictive performance are used to compare the predictive power of the SVM-based and ANN based models in prediction of ring and compact yarn properties and the results are summarized in Tables IV and V, respectively.

It can be seen from Tables IV and V that the values of RMSE and R which provided by SVM based on polynomial kernel indicate to the generalization performance of SVM based on polynomial kernel is bad. Therefore, this model does not fit the data well.

The RMSE of SVM based on PUK kernel were lower than that of SVM based on RBK kernel. The R values provided by SVM based on PUK kernel were higher than that of SVM based on RBK kernel.

As it can be observed from these results in Tables IV and V that the SVM models based on RBK and PUK kernels gives smallest RMSE and biggest value of R errors in comparison with ANN models. This result indicates that support vector machines based on RBK and PUK kernels outperforms artificial neural networks, therefore, the SVM models based on RBF and PUK Performs yarn properties forecasts more accurately than artificial neural network approach.

IV. Conclusions

In this paper a Multilayer Perceptron artificial neural network (ANN) and support vector machine based models are presented and applied for predicting ring and compact yarn properties. The ANN was compared with SVM model based on on polynomial, Gaussian radial basis (RBF) and PUK kernels function. The comparison of the four models indicates that SVM based on RBK and PUK kernels outperforms ANN model, therefore, the SVM models based on RBF and PUK Performs yarn properties forecasts more accurately than artificial neural network approach.

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