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A Knowledge-Based System for Spinning Management

ROSA MARIA VASCONCELOS

Departamento de Engenharia Têxtil, Escola de Engenharia, Universidade do Minho, Portugal

ABSTRACT

This paper describes the development of a knowledge-based system to support and improve the spinning process. It is divided in three parts. The first part describes a statistical study using sixteen raw cottons and three kinds of yarn. A set of mathematical models describes the relationships between cotton fiber and yarn properties. Eighteen different models have been identified according to different control processes (HVI motion control and Spinlab and individual instruments) and different production processes (ring and rotor spinning, OE RU 14 Spincomat and Autocoro 117). The second part details the implementation of the knowledge-based system using the programming languages PROLOG and C. The knowledge base uses a framework shell (*flex* or forward logical expert systems) that interfaces with PROLOG. This prototype can be used either to predict the characteristics of the yarn according to those of the available raw materials, or to select the raw materials adequate to produce yarn with specific characteristics. The last section presents some conclusions of the work.

The use of optimal raw materials to produce requisite yarn properties has always been the main goal of spinners. Several studies [3, 5–7, 9, 11–13, 20] tried to correlate yarn properties with raw material characteristics, but the opposite relationship has not been explored. For this reason, knowledge of what yarn properties will be obtained with the raw material used is very important economically. In previous work [16], we have shown that the cost of raw materials is extremely important in determining the final yarn cost, its contribution being nearly 70%. The meaning of this component in final yarn cost motivated the development of this system.

The main objectives of the knowledge-based system [15, 19] are to help the textile manager select the raw material to produce a yarn with well known characteristics, and predict the yarn properties obtained with known characteristics of the raw material. The system also provides the manager with a data base where he can update historical spinning data, such as raw material characteristics, yarn characteristics produced and the raw material that produced them, and information about suppliers. With the Spinning support system, we can minimize the training and the time of decision making and improve the results.

Methodology

STATISTICAL ANALYSIS

Before discussing the structure of the knowledge-based system to select or predict raw material and yarn properties, it is necessary to provide models to solve those problems. The solutions require statistical analyses [2] to obtain models that are going to support the system.

We studied sixteen kinds of raw cotton and three different yarns with an average count of 26 to 29 tex. We determined the properties that characterized the raw cotton using two kinds of control techniques: individual instruments and high volume instrumentation [1].

We used Spinlab and Motion Control for the raw material characterizations. Depending on the method used in the control, the numbers of the parameters obtained were different. For individual instruments we had seven, while for Spinlab and Motion Control, we had nine and ten, respectively.

As far as the yarns are concerned, the differences were in the spinning process used. One yarn was produced on the ring spinning frame, while the other two were spun on two kinds of open-end machines: OE1 was produced on a OE RU 14 Spincomat and OE2 was made on an Autocoro 117. Tables I and II list the properties of the yarns and raw materials in the study as they relate to the defined parameters in the mathematical models.

Table III shows the mean, minimum, and maximum raw characteristics values use in this study. Table IV shows the mean, minimum, and maximum yarn property values.

The mathematical models were developed with SPSS [8]. After determining the correlation matrix, because

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TABLE I. Definition of raw material parameters.

Raw material properties	
Strength, cN/Tex	x1
Elongation, %	x2
2.5% Span length,	x3
Length uniformity index, %	x4
Micronaire	x5
Reflectance, %*Rd*	x6
Yellowness, +*b*	x7
Color Index 1	x8
Color Index 2	x9
Leaf	x10
Short fiber content, %	w1
Nonlint content, %	w3

TABLE II. Definition of yarn parameters.

Yarn properties	
Alfa tex	y1
Yarn count, tex	y2
Yarn count coefficient of variation	y3
Strength, g	y4
Strength coefficient of variation	y5
Elongation, %	y6
Elongation coefficient of variation	y7
Uster CV	y8
Thin places/1000 m	y9
Thick places/1000 m	y10
Neps/100 m	y11
Hairiness	y12

TABLE III. Raw characteristics values.

	Mean	Min.	Max.
I			
x1	25.17	22.37	27.60
x2	5.70	4.93	6.87
x3	1.0	0.89	1.09
x4	45.41	43.20	47.20
w1	5.49	1.95	8.26
x5	3.77	2.95	4.33
w3	2.61	0.90	5.57
MC			
x1	25.98	22.75	29.75
x2	5.85	5.28	6.35
x3	1.02	0.94	1.11
x4	79.78	76.50	84.00
x5	3.80	2.95	4.35
x6	75.56	70.00	82.40
x7	8.13	6.60	9.70
x8	34	11	41
x9	2	1	4
x10	32	20	60
SP			
x1	25.73	21.60	29.70
x2	5.67	5.00	6.30
x3	1.04	0.95	1.14
x4	78.81	72.00	85.00
x5	3.84	2.90	4.50
x6	75.91	70.80	82.00
x7	8.61	7.40	10.30
x8	32	11	41
x9	2	1	4

of the great number of variables in the study, we adopted a backward elimination procedure [1, 2].

Preliminary work explored the relationship between raw material characteristics and yarn properties. The procedure used the yarn properties as the independent variables and the raw material as the dependent ones. We had to abandon this approach due to the low determination coefficient we obtained, so we introduced the raw material properties as independent variables.

The model used to establish the regression equation was linear, because previous work [4, 10, 12, 14, 18] used it with success. The general formula of the model is

$$Y_1 = a_0 + a_1X_1 + a_2X_2 + \ldots a_pX_p + \epsilon_1 \quad ,$$
$$Y_2 = a_0 + a_1X_1 + a_2X_2 + \ldots a_pX_p + \epsilon_2 \quad ,$$
$$Y_n = a_0 + a_1X_1 + a_2X_2 + \ldots a_pX_p + \epsilon_n \quad .$$

We obtained nine sets of equations to allow us to select

TABLE IV. Range of yarn properties.

	C			OE1			OE2		
	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.
y1	4	4	4	4.81	4.78	4.85	4.79	4.78	4.79
y2	22.37	15.77	30.67	20.42	9.76	30.49	20.75	9.74	30.86
y3	2.1	1.1	9	1.4	0.6	2.6	1.3	0.4	2.3
y4	430.5	232	937	494.6	224	980	480	219	935
y5	14.6	11.7	19.4	9.9	6.4	14.4	10.4	6.7	15.4
y6	5.69	4.73	7.21	6.10	4.78	8.26	5.86	4.11	8.65
y7	11.78	9.3	15.3	8.2	5.8	12	9.77	5.10	15.5
y8	23.75	19.01	29.45	16.98	14.27	20	16.27	13.45	20.14
y9	815	143	2186	80	4	302	74	0	326
y10	1389	463	2614	226	64	525	139	14	426
y11	485	54	1856	536	42	1879	229	6	900
y12	1181	804	1666	246	99	562	218	82	498

raw material characteristics according to yarn properties determined with the different control methods and spinning processes. A similar study predicted yarn properties using raw material characteristics, control techniques, and spinning processes.

SPINNING SUPPORT SYSTEM

Structure

Our choice of an Macintosh Apple computer to develop the system was based on the low cost of the equipment compared with others, its stable environment, and its user friendly characteristics. To develop the system, we used *flex* [17] a hybrid expert system tool kit providing features and functionality normally associated with high cost expert system shells running on dedicated AI workstations; *flex* plus PROLOG [4] provides a multi-paradigm programming system, including frames and inheritance, forward chaining, backward chaining, and data-driven programming. *Flex* has its own language, KSL or knowledge specification language. The KSL syntax for both rules and frames is rich and English-like, permitting the development of an understable and readable knowledge base. User-defined synonyms can be introduced to replace frequently occurring terms, and user-defined templates can be used to assist readability. Mathematical, Boolean, and conditional expressions and functions are supported in KSL, together with set abstractions. The SSS (spinning support system) (Figure 1) consists of the components described below.

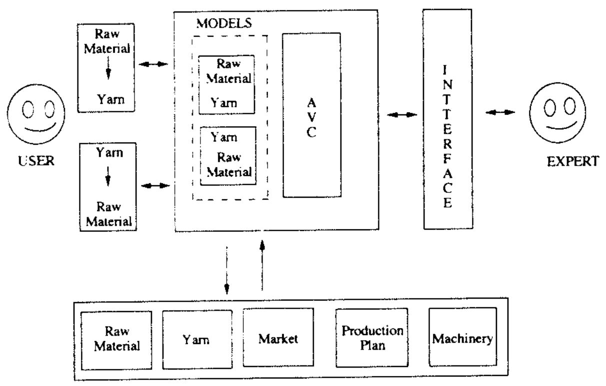

FIGURE 1. SSS main blocks.

The *data base* includes data connected with the problem to be solved. Frames and instances are used to represent all historical knowledge about raw material characteristics, yarn properties, and what kind of raw material is used in the spinning process. Information about suppliers is also available. We have used one of those instances to introduce data obtained from the user when he activates the system.

Knowledge base: in SSS, procedural knowledge is divided into three classes of rules: rules for collecting data from the user, rules for selecting the algorithm required for a solution, and rules that permit the user to choose which data are produced.

Model and algorithm base: the models are used to solve problems described by the user. The specific model selected depends upon the nature of the problem, which is reflected in the data provided by the user. Note that the knowledge required to select a specific model for a user's problem is stored in the knowledge base of SSS in the form of production rules.

Inference engine: it was not necessary to implement an inference engine, because the *flex* tool kit had already one, in this case, the forward chaining system. Forward chaining is invoked using the KSL structure ruleset. The rules, rule selection, and agenda update method used in a particular forward chaining run are specified in the ruleset.

DEVELOPMENT AND IMPLEMENTATION

The SSS development consists of the design of its functional structure [15]. Figure 2 shows the SSS functional structure, pointing out its main modules. In the *production and control processes,* it is possible to declare or change the processes used in a work session. In the *database update* module, we can introduce new data or save the data introduced during the latest work session. The *raw simulation* module allows us to determine yarn characteristics produced with well known raw materials. The *yarn simulation* determines which raw material characteristics must be used to produce a yarn with known characteristics.

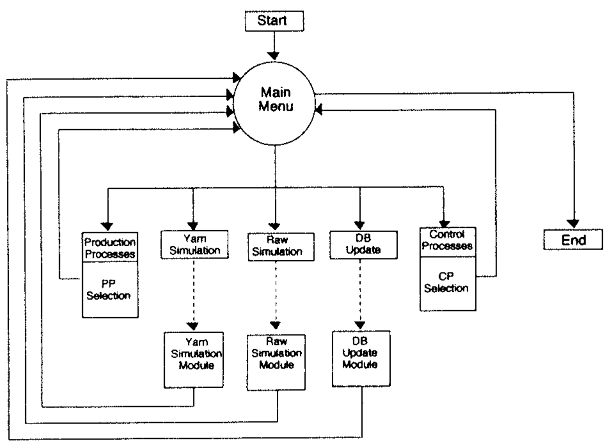

FIGURE 2. SSS functional structure.

Conclusions

With SSS, we are able to attain our objectives [15]. We can construct the mathematical models that relate yarn with raw material properties and vice-versa. We can design a knowledge base of information to support the textile manager's decisions, and we can implement a knowledge-based system with accessible computers and man/machine interfaces that is easy to operate. Our system provides insight into the spinning process using artificial intelligence-based techniques and the possibility of adapting mathematical models to particular cases.

Literature Cited

1. Chafield, C., "Statistics for Scientist & Engineers," Chapman and Hall, London.
2. Draper, N. R., and Smith, H., "Applied Regression Analysis," John Wiley & Sons, Inc.,
3. Fiber Tenacity/Yarn Strength Relationship, *Textile Topics*. **12**(9) (1984).
4. Johns, Nicky, MacPROLOG 3.0. London, Logic Programming Associates Ltd, 1990.
5. Mogahzy, Yehia E. El, Selecting Cotton Fiber Properties for Fitting Reliable Equations to HVI Data, *Textile Res. J.* **58**(7), 392–397 (1988).
6. Mogahzy, Yehia E. El, Jr., Broughton, Roy, and Lynch, W. K., A Statistical Approach for Determining the Technological Value of Cotton Using HVI Fiber Properties, *Textile Res. J.* **60**(9), 495–500 (1990).
7. Neckar, Bohuslav, Recent Research on Yarn Irregularity, *Melliand Textilber.* **70**(7), E201–E203 (1989).
8. Norusis, Marija J., SPSS/PC+, SPSS Inc., Chicago, 1985.
9. Predicting Ring Yarn Strength from Fiber Properties, *Textile Topics* **14**(4) (1986).
10. Ramey, H. H., Jr., Lawson, R., and Worley, S., Jr., Relationship of Cotton Fibers Properties to Yarn Tenacity, *Textile Res. J.* (10), 685–691 (1977).
11. Relationship of Fiber Strength to Yarn Strength, *Textile Topics* **15**(12) (1987).
12. Research on Fiber/Yarn Relationship, *Textile Topics* **11**(10) (1983).
13. Smith, Brent, A Review of the Relationship of Cotton Maturity and Dyeability, *Textile Res. J.* **61**(3), 137–145 (1991).
14. Subramanian, T. A., Ganesh, K., and Bandyopadhyay, S., A Generalized Equation for Predicting the Lea Strength of Ring-Spun Cotton Yarns, *J. Textile Inst.* **65**(6), 307–313 (1974).
15. Vasconcelos, Rosa Maria, Contribuição à Aplicação de Técnicas de Inteligência Artificial na Tecnologia da Fiação, Doctoral dissertation, Universidade do Minho, 1993.
16. Vasconcelos, Rosa Maria, Planeamento e Cálculo de Custos numa Fiação, Universidade do Minho, Provas Aptidão Pedagógica e Capacidade Cientifica, 1986.
17. Vasey, Phil, Flex Expert System Toolkit, 3 ed, Logic Programming Associates Ltd, London, 1989.
18. Virgin, W. P., and Wakeham, Helmut, Cotton Quality and Fiber Properties, Part IV: The Relation Between Single Fiber Properties and the Behavior of Bundles, Silvers, and Yarns, *Textile Res. J.* **26**(3), 177–191 (1956).
19. Waterman, Donald A., "A Guide to Expert Systems," Addison-Wesley, NY, 1988.
20. Zureck, W., Frydrych, I., and Zakrzwski, S., A Method of Predicting the Strength and Breaking Strain of Cotton Yarn, *Textile Res. J.* **57**(8), 439–444 (1987).

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