SELECTION OF THE BEST COTTON BLEND: THE USE OF ADVANCED TECHNIQUES

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Abstract

This paper describes advanced techniques that can be used to select the best cotton blend, best in terms of quality and price. The first step in this is to model the spinning process, i.e. to describe the relationships between cotton blend and process conditions, and process behaviour and yarn properties. Two techniques are used for this, namely neural networks and learning classifier systems. The second step is to find the cotton blend and process conditions that allow to spin the required yarn at the best price. For this genetic algorithms have been applied. The research shows that the mentioned techniques have excellent potential to help the spinner to select the optimal cotton blend.

Introduction

When a spinner has to decide upon the fibre blend to spin a particular yarn, he has a nearly unlimited number of combinations of cotton qualities that will allow him to spin this yarn. However the price of the yarn will depend on the combination as well. Moreover the processes will run more or less smoothly depending on the quality of the blend.

At present the selection is made basically on experience. This approach allows to select a good, but not necessary the best blend. By "best" blend is meant the cheapest blend that allows to spin a yarn that meets the specifications at the highest productivity.

Several attempts have been made, but the optimisation is so complex that current techniques cannot handle the full combination of fibre properties and machine settings. Moreover optimisation is always restricted to one parameter (e.g. price), whereas price as well as processability should be considered.

In this paper, learning cognitive techniques will be evaluated.

Optimisation consists of two steps, namely:

- process modelling: determining the relationships between input (fibre properties and processing conditions) and output (yarn quality, price, processability), and
- process optimisation: developing an optimisation strategy.

Process Modelling

Before any optimisation can start, the relationships between fibre properties and processing conditions and yarn charactersitics and process behaviour must be known.

Textile processes usually are very complex, with numerous interaction between the so-called independent variables, which makes the use of statistical techniques difficult.

Two learning cognitive techniques will be considered as a tool for processing, namely neural networks and learning classifier systems.

Neural Nets

Neural Networks are models for computational systems, either in hardware or in software, which imitate the behavior of biological neurons (the human brain) by using a large number of structural interconnected artificial neurons, as is shown in Figure 1.

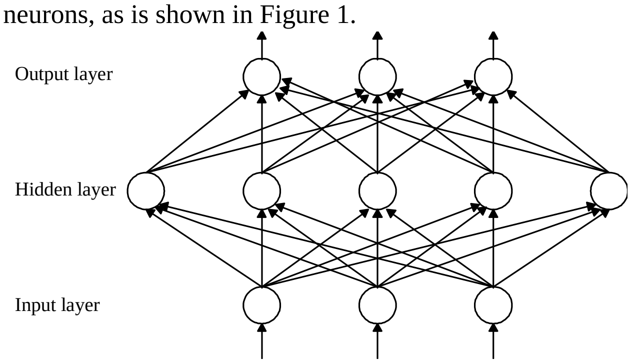

Figure 1: A Typical multi-layered Neural Network

In our case, in the input layer each node represents either a fibre property or a process condition (e.g. machine setting). The way in which a signal is being transferred from one node to another depends on its weight. N.N.'s are *learning systems*: i.e. they are trained by real-life examples, whereby the weighting factors are adapted following a certain strategy until they converge to a more or less stable steady state. After learning, the system may enter the *recall* stage, whereby unknown exemplars are presented at the input, leading by a simple computation (i.e. applying the neural network functions at each node in sequence) to an output value. Although the training phase may be very high demanding in computing power and execution time (because it is simulating in fact a highly parallel system on a sequential computer), the recall phase itself is very straightforward and fast. This characteristic makes N.N.'s very powerful and attractive.

Several textile applications have been reported.

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The results of modelling the spinning process are demonstrated in figure 2 for yarn strength. A backpropagation type network was used.

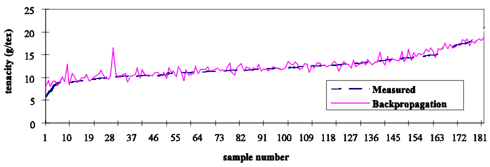

Figure 2

The average relative errors are:

- strength: 3.9%,
- elongation: 2.9%,
- CV Uster: 5.2%.

The spinnability can be predicted with an accuracy of more than 95%.

Learning Classifier Systems

Learning classifier systems (LCS) are a part of the so-called Genetic Based Machine Learning (GBML) algorithms. A classifier system is a learning system that learns syntactically simple strings in order to improve its performance in an arbitrary environment.

LCS are a kind of models between a series input and output parameters. The main difference with other modelling techniques is that the relations are no longer expressed in mathematical formulas, but in a series of rules. In essence, these rules are nothing but more or less complex IF-THEN -rules, so-called production rules, also applied in the traditional expert systems. However, where in case of the traditional expert systems the form, the number, the sequence and the contents of the rules have to be established in advance, an LCS will generate by itself the number and the contents of the rules by a learning process. The main advantage of LCS is that the rules can be linked to actual process parameters, so they have a physical meaning.

The study of Learning Classifier System (LCS) is still in its initial phase and (in the world) it is limited to a few institutes.

One textile application has been studied with success by the Textile Department. The set of rules describes the relationships between fibre properties and machine settings, and spinnability. The result is a set of approximately 30 rules that describe whether a set of fibre and machine parameters will result in favourable conditions for spinning. An accuracy of 95% can be obtained.

A rule in this application looks as follows:

rule:	0x	xx	xx	1	xx	1	0
contents:	fibre strength	yarn count	twist level	navel	breaker speed	rotor speed	**output: spinnability**

where x means "don't care", and 0 and 1 are digital representations of the parameters.

This particular rule actually means:

> *"if fibre strength is very low (00) or low (01), and a carved navel is used, as well as high rotor speed, then yarn count, twist level and breaker speed don't matter, you will not be able to spin a yarn".*

Some of the rules are quite obvious, such as the one shown above, are quite comprehensive. Other rules are more difficult to interpret.

The main advantage of this technique is that the set of rules covers all relationships, general as well as exceptions. Other techniques, including neural networks, will try to find relationships that match for the majority of the cases, not taking into account special cases.

The main disadvantage is that the input classes are quite strict. This may cause problems in that measuring errors on fibre properties for instance, cause fibre qualities to fall in the wrong class, leading to false results. Fuzzy logic, which allows to specify in which degree values belong to one or more classes may overcome to this.

Optimisation Using Genetic Algorithms (GAs)[12]

Genetic algorithms (GA) make it possible to find an optimum solution for a certain problem.

One starts with an arbitrary series of possible solutions, called population. Every solution more or less satisfies the criteria set to define the best solution. The whole of these criteria and their importance are described by means of the so-called fitness function. Every solution has a so-called fitness.

From the (original arbitrarily chosen) population, a second generation is generated, in a way analogous to the evolution of living matter : a generation produces a following generation, where the properties of the new generation are a consequence of reproduction, cross-over and mutation of the properties of the previous generation. The transfer from one population to the other happens on the basis of coincidence, where the probability is determined by the fitness. This means that especially the elements from a population that are a "good" solution (i.e. that have a high fitness), have more chances to be kept in the next generation ("survival of the fittest").

Reproduction, cross-over and mutation are also the three types of basic operators used in the GAs to obtain better series of solutions, generation after generation.

By means of an example, the tenacity and elongation of a set of yarns are represented in figure 3:

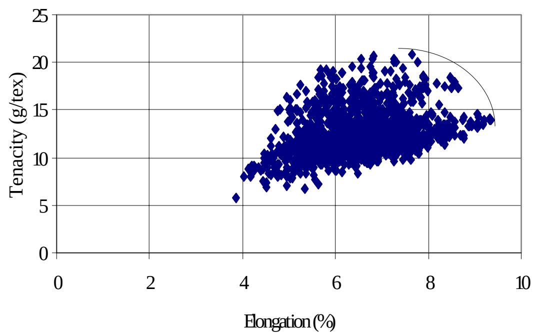

Figure 3. Strength and Elongation for a Set of Yarns

This figure shows that it is difficult to specify THE best yarn. Only one statement can be made, and that is the set of possible best yarns is represented by the curve above the collection of points. It represents all yarns that have either maximum strength or elongation, or a combination of both. This line can be determined accurately using genetic algorithms. With this technique fibre properties and spinning conditions that allow to spin any yarn on this line can be calculated. The major source of error is not the optimisation itself, but the error of prediction of the model used, or discontinuity of process conditions (e.g. possible machine settings).

A second example of optimisation is based on the same experiment. Apart from tenacity and elongation, price of the blend is taken into account as well. The result is given in figure 4.

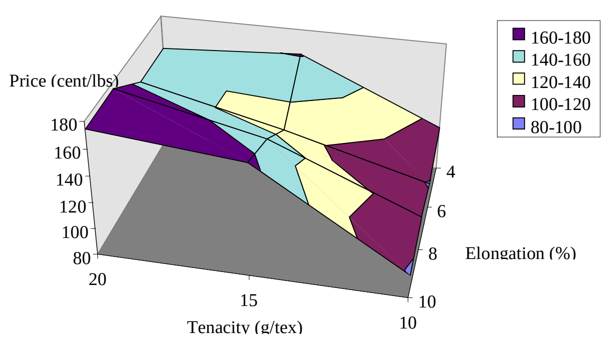

Figure 4 - Price of yarns as a function of its strength and elongation.

This graph shows that sometimes a yarn can be spun with better strength and elongation at a lower price.

On the other hand GAs allow to specify how to spin a yarn with a certain strength and elongation (or higher) at the lowest price. More criteria, such as regularity, can be added to the optimisation process, as far as good yarn models are available.

Conclusions

The results of the research that has been described in this paper shows that learning cognitive systems have the potential to calculate the best cotton blend that allows to spin the required yarn at the best price. The critical parameter in this optimisation process is the yarn model, that describes the relationship between fibre properties and spinning conditions, and yarn properties and process behaviour. Neural networks can be used for this, provided an extended set of data is available for a spinning mill. Learning classifier systems are promising, but there is quite some way to go before they will reach the stage of industrial applicability.

Once the yarn model is available, genetic algorithms can be applied with a very high accuracy to find the optimal fibre properties and spinning conditions.

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