A DISTRIBUTED SYSTEMS APPROACH TO KNOWLEDGE-BASED SYSTEMS FOR THE UTILISATION OF SOUTH AFRICAN WOOL

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Abstract:

Potential and present investors in the South African (S.A.) wool industry need up-to-date information on the production and properties of the wool they need for the particular end-products they manufacture or intend to manufacture. This article describes the concept and development of a knowledge-based advisory system on the utilisation of South African wool for the benefit of present and potential investors and other interested parties. The architecture of the system encompasses the concept of distributed systems and the related advantages in its general architecture and within its internal components. It marries both expert and general knowledge-based systems.

Key words:

Knowledge-based system, distributed system, expert system, utilisation of wool, South African wool

1. Introduction

Wool is a natural animal fibre produced in varying quantities around the world. The wool fibre is far from homogenous; its type and quality depend on the breed of sheep and the environmental conditions it encounters during its life. The bulk of wool is produced in the Southern Hemisphere and it is then exported to the main wool processing and consuming countries in North America, Europe, Japan and China. This means that a high proportion of the greasy wool produced in countries like South Africa is subsequently exported in its raw state. Wool is used in a variety of end uses, ranging from fine worsted suiting, to hand knitting yarn, carpets, blankets and aircraft upholstery (Piercy, 1987).

The wool industry is one of the oldest agricultural industries in South Africa. It plays an important economic role as an earner of foreign exchange, and provides income to some 100 000 people, also making South Africa self-sufficient in terms of its consumption of apparel wool. Wool is produced in many parts of South Africa under extensive, semi-extensive or intensive conditions. South African wool is often referred to as Cape Wool and is largely an export commodity in processed, semi-processed and unprocessed form. It is produced and traded in a sophisticated free market business environment into the international market place, where supply and demand forces determine price levels.

Exporting wool in semi-processed and unprocessed form detrimentally affects employment, foreign exchange and income-generating opportunities. Value-addition to wool before export would net more. For instance, cost elements (value addition) in the retail price of a man's wool worsted suit is made up of some 56% - retailing, 25% - making up, 6% - dyeing and finishing, 5% - weaving, 2% - spinning, 1.5% - scouring and top-making and 4.5% - fibre.

To reduce the amount of wool exported in unprocessed or semi-processed form wool-processing enterprises need to be established to produce marketable end products from wool. At present some 90% of South African wool is exported in an unprocessed or semi-processed state. Therefore South Africa needs to attract investors into the wool sector, who will set up manufacturing mills in an economically sustainable manner. To encourage investment, investors should have easy access to information on the production statistics, processing and characteristics of the wool they need for the kind of products and markets they wish to target.

In order to ensure accessibility to such continuously updated information it is essential to develop an integrated computer-based system. This is necessitated by:

- communication difficulties between potential investors and the investment sector,

- scarcity of experts to provide such information to potential investors,
- increasing investment opportunities,
- taking advantage of information technologies (IT) in the wool industry,
- absence of databases that house such information,
- easy and continuous updating of such a system.

It is with this in mind that a knowledge-based system on the utilisation of wool has been developed. The architecture of the system encompasses the concepts of distributed systems. It consists of a combination of an ordinary knowledge-based system (KBS) that can be queried for information and an expert system that provides advice to users.

KBS are defined as computer systems that are programmed to imitate human problem-solving by referencing databases of knowledge on a particular subject. Expert systems are a type of KBS. They are computer models of human expertise in a specific domain of work. They are capable of offering advice and decision-support related to specific problem-solving in a well-defined knowledge domain. An expert system acts like an expert consultant, asking for information, applying this information to the rules it has learned, and drawing conclusions (Ignizio, 1991).

The rest of the paper is as follows: Section 2 covers wool production statistics in South Africa. Section 3 covers the end uses of the wool fibre versus the diameter of the fibre. Section 4 discusses the basic components of knowledge-based systems. Section 5 considers the advantages of distributed architectures. Section 6 shows the flow of processes in a wool utilization system and Section 7 reviews related work. Section 8 describes the architecture of the proposed expert system. Section 9 contains the analysis and conclusions.

2. Wool production statistics

The South African wool clip is predominantly merino, but coarse and coloured types are also produced and marketed on a limited scale. Some 67% of the clip comprises fleece wool, 8% lambs wool, 12% bellies and 13% locks (Cape Wools, 2000/2001). Almost 60% qualifies for the most sought after styles, namely good top-making, best top-making and spinners styles. In 2005/2006 the style distribution of fleece wools was as follows: spinners - 3.6%, best - 12%, good - 42.2%, average - 30.6%, inferior - 10.9%, and other - 0.7% (Cape Wools, 2005/2006).

The percentage of the total wool production by region is as follows: South West Cape - >12%, Transkei 4-8%, Midlands 10-12%, Northern Cape 0-2%, North Eastern Cape 10-12%, Northern Karoo 4-8%, North Western Cape 2-4%, Southern Coastal Region 2-4%, Southern Karoo 2-4%, North and Western Free State 10-12%, Eastern Free State 4-8%, Southern Free State 8-10%, North and Eastern Transvaal 0-2%, Eastern Transvaal 8-10% and Natal 2-4% (Cape Wools, 2000/2001).

The percentage wool production by province in 2005/2006 the production by province was: Eastern Cape - 24.7%, Free State - 24.7%, Western Cape - 18.3%, Northern Cape - 15.4%, Mpumalanga - 10.3%, KwaZulu Natal - 5.1% and the rest of South Africa - 1.5% (Cape Wools, 2005/2006).

The fibre diameter of S.A. wools ranges from about 18 to 27 micron, with more than 80% of the clip finer that 24 micron. Long wools (60mm and above) normally comprise more than 65% of the clip. The micron/ length distribution of Cape Wools is as shown in Table 1 (Cape Wools, 2000/2001).

Table 1. Micron/length distribution of Cape Wools.

Cape Wools distribution	MICRONS (% of clip)							
	<19	19-20	20-21	21-22	22-23	23-24	24-25	>25
Long (60-90mm)	1	4	11	23	21.5	12	4	1
Medium (40-60mm)	0.5	1.3	8	6	4.5	13.5	0.5	0.5
Short (<40mm)	0.5	0.2	1	1	1	1	0.5	0.5
TOTAL	2	5.5	20	30	27	26.5	5	2

The clip micron distribution in 2005/2006 was as follows: >24 microns - 3%, <20 microns - 25%, 22-24 microns - 19% and 20-22 microns - 53% (Cape Wools, 2005/2006). S.A. wools have excellent colour characteristics, and fleeces normally measure between 60 and 69 Y-units on the brightness scale. Corresponding yellowness values (Y-Z) are very low, varying between 0 and 2 units(Cape Wools, 2000/2001).

Table 2. Average colour spectrum of Cape Wools.

Wools style	Brightness (Y)	Yellowness (Y-Z)
Spinners	60-66.5	0-0.9
Best	60-65.5	0-1
Good	60-64	0-1.1
Average	60-61.5	0-1.4

S.A. wools are high yielding, with more than 60% of the clip yielding at least 60% clean. Clean yield distribution statistics for South African wools is as follows: 13 % of the wool has a clean yield of <50%, 46% has 50-60%, 23% has 60-70% and 18% has a clean yield of >70% or more (Cape Wools, 2005/ 2006). Almost 64% of fleece wools on offer during the 2005/ 2006 season was of good top-making style or better (Cape Wools, 2005/2006).

Seed contamination is limited, with more than 80% of the clip normally exhibiting very low levels (2% or less). The vegetable matter (VM) fault content for South African wools is as follows: 59% have a VM fault of 0.5-2%, 24% have a VM fault of <0.5% and 15% have a VM fault of 2-4%, 2% have a VM fault > 4 (Cape Wools, 2005/2006).

Exports of greasy wool for the 2005/2006 season stood at 23.4 million kilogrammes. The main export destinations were Italy - 20.8%, China - 20.7%, Czech Republic - 17.9%, Germany - 11.0%, Bulgaria - 5.5%, Spain - 4.8%, UK - 4.1% and India 4.0% (Cape Wools, 2000/2001).

3. End uses of wool

Because of its wide range of microns and staple lengths, S.A. wools can be processed into a large and diverse range of fine wool apparel products on either the worsted, semi-worsted or woollen systems. Fibre diameter and length are the primary measurements which determine the “quality” of the wool. Diameter is measured in micrometres which is equal to one millionth of a metre. Wool is generally classified under the following groups: 19 microns and finer - superfine, 20-24 microns - merino, 25 - 28 microns - fine crossbred, 29-32 mi-

Table 3. End uses of wool.

Product	Full micron range	Full micron range description	Concentrated micron	Concentrated micron description
Apparel products				
Men's woven outwear	20-31 microns	Merino to medium	22-27 microns	Merino to fine
Women's woven outwear	19-30 microns	Superfine to medium	20-26 microns	Merino to fine breed
Knitwear	19-33 microns	Superfine to strong	19-22microns and 26-30 microns	Superfine to merino and fine to medium
Underwear	19-23 microns	Superfine to merino	19.5-22 microns	Superfine to merino
Socks	21-32 microns	Merino to medium	23-28 microns	Merino to fine
Hand knitting yarn	25-34 microns	Fine to strong	25-26 microns and 30-32 microns	Fine and medium to strong
Non-apparel products				
Pressed felts	19.5-31.5 microns	Superfine to medium	22-31 microns	Merino to medium
Quilt fillings	25-37.5	Fine to strong	28-33	Fine to medium
Furnishings	27-37	Fine to strong	28-34	Fine to strong
Carpets	30-39	Medium to strong	34-36	Strong
Mattress Fillings	30-39	Medium to strong	33-37.5	Strong
Blankets	20-36	Merino to strong	27-34	Fine to medium

crons - medium crossbred and 33 microns and stronger, strong wool. The wool fibre diameter range for products is as shown in Table 3 (Piercy, 1987)

Some two-thirds of global wool consumption goes into apparel, with the remaining one-third consumed in other textile products, such as carpets, blankets, felts and upholstery. The virgin wool consumption by main end-use in apparel products is approximately 23% in men's wear, 30% women's wear, 25% knitwear and 25% other products. For non-apparel products, 74% goes to carpets and 26% to other products (Piercy, 1987).

4. Knowledge-based systems

A knowledge base (KB) is a centralized repository of information. It is used to optimize information collection, organization and retrieval. It is not a static collection of information, but a dynamic resource that may itself have the capacity to learn as part of artificial intelligence.

There are several definitions of knowledge-based systems (KBS). A KBS is constructed to input, manipulate, edit, store and execute existing information. They are systems that use knowledge-based techniques to support human-decision-making, learning and action.

Elements of knowledge-based systems are:

- techniques for acquiring knowledge,
- ways of representing knowledge internally,
- search procedures for working with the internally stored knowledge,
- inference mechanisms for deducing solutions to problems from stored knowledge.

An expert system is a type of knowledge-based system. The typical expert system receives input describing a problem in its field of expertise, and then uses its inferencing technique to extract appropriate information from its knowledge base to produce an answer, diagnosis or description of a solution. Such systems have been used to interpret medical test results, diagnose car problems and determine the causes of telephone line failures (Buchanan, 1988), Giarratano, 2003) and (Ignizio,1991).

The components of an expert system include the knowledge base, inference engine, knowledge acquisition component, and explanation system as illustrated in Figure 1.

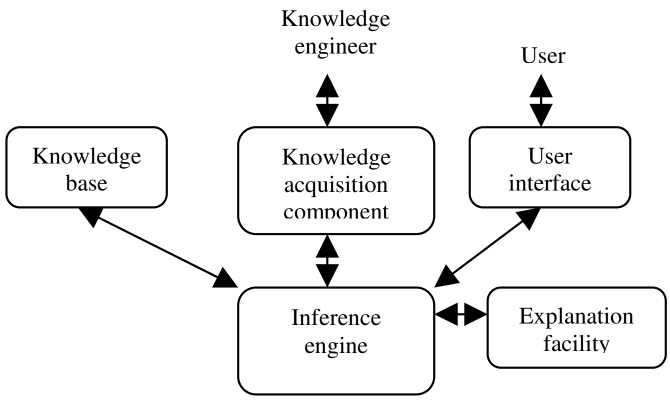

Figure 1. General structure of an expert system.

Knowledge base. The permanent knowledge of an expert system is stored in a knowledge base. It contains the information that the expert system uses to make decisions. This information represents expertise gained from top experts in the field. This knowledge comes in the form of facts and rules. Facts are minimal elements of the knowledge which must be identified before anything else. Rules consist of if....then statements, where a given set of conditions will lead to a specified set of results. If a condition is true then an action takes place.

Inferencing. The purpose of the inference engine is to seek information and form relationships from the knowledge base and provide answers. It determines which rules will be applied to a given question, and in what order, by using information in the knowledge base. The inference engine drives the system by drawing an inference from relating user-supplied facts to a knowledge-base rule and then proceeding to the next fact and rule combination (Buchanan, 1982 and 1985).
Knowledge acquisition. Most expert systems continue to

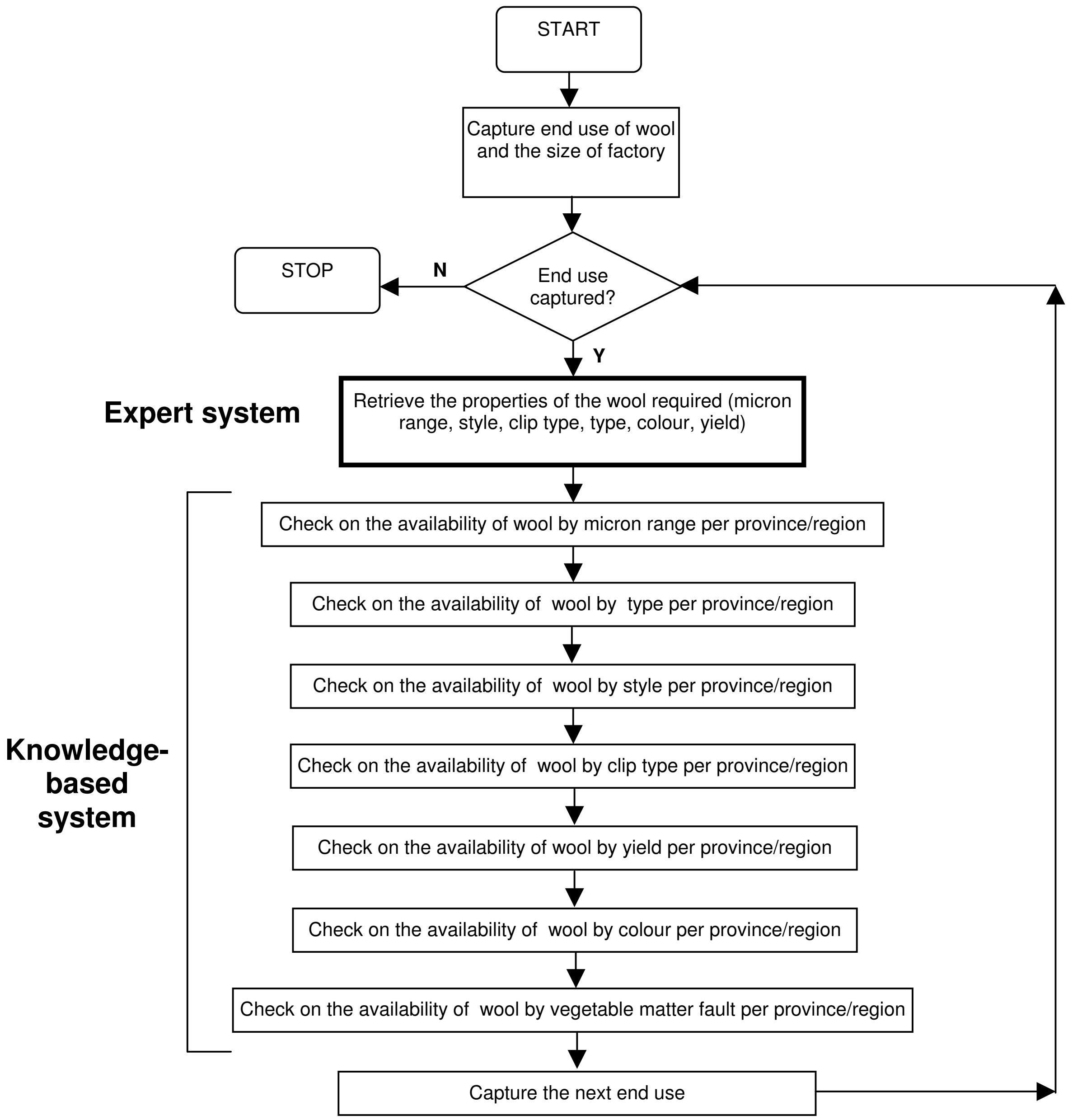

Figure 2. The flow of processes in the wool utilization process.

evolve over time. New facts and rules can be added to the knowledge base by using the knowledge acquisition subsystem.

Explanation subsystem. Another unique feature of an expert system is its ability to explain its advice or recommendations and even to justify why a certain action was recommended. The explanation subsystem enables the expert system to examine its own reasoning and explain its operations. The ability to trace responsibility for conclusions to their sources is crucial, both in the transfer of expertise and in problem solving.

User interface. The component that facilitates interaction between the user and the expert system.

5. Distributed systems

A distributed system is a collection of autonomous components that are interconnected, which enables these components to coordinate their activities and share resources of the system, so that users perceive the system as a single integrated facility.

There are a number of advantages of distributed systems (Chin, 1991) and (Mattmann, 2006). These include:

- Catering for increased capacity and growth. As the system grows, new components can be added to the distributed system without affecting the performance of the other related components.
- Improved reliability and availability of system. Even when one of the components is down, the overall system remains available in distributed processing. The remaining components continue to function. The greater accessibility enhances the reliability of the system.
- Facilitating distributed sharing. Users interested in one given component are able to access data stored in other databases and at the same time retain control over the data in their own component.
- Ensuring security of data. The distributed nature of the sys-

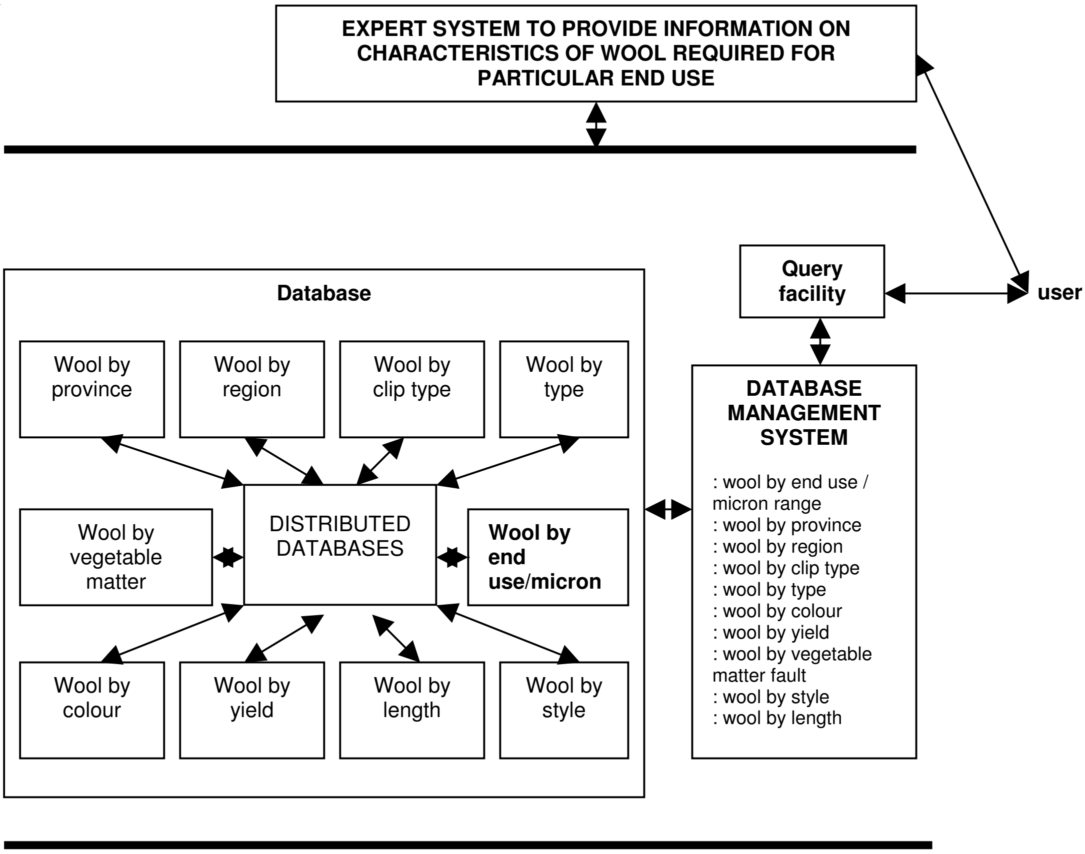

Figure 3. Architecture of wool utilization expert system

tem provides an environment for protecting information stored in the system. These advantages arise from the actual physical separation of independent information. The physical boundaries of individual components prevent errors in a particular component from spreading to the rest of the system.

- Providing room for flexibility and extendibility of system. Distributed systems have the added advantage of facilitating modification or extension of the system to adapt to changing environment without disrupting flexibility.
- Improved performance. Performance is defined in terms of response time and throughput. Response time is the period that the system takes to respond to user queries. Response time can be cut down if access is directly to the required information through distributed processing.
- Distribution. The system combines a network of independent subsystems to provide an overall whole functionality
- Transparency. The users of the system do not have to be aware of the existence of separate components of the system. Uniform access to resources is ensured.
- Concurrency. A component should be able to serve multiple requests.

6. The utilisation of wool process

The process of wool utilization involves capturing the end-use of a product and from it, retrieving the characteristics of the wool that will meet the particular end-use. The availability of the wool is then checked by region and province for each style, type, clip type, yield, colour, vegetable matter fault and micron range, in line with the statistics available in section 2 of this paper.

7. Related work

Distribution has been applied in many applications. Distributed file systems allow users of physically distributed computers to share data and storage resources by using a common file system (Levy, 1990). To achieve additional coordination of diversified computerized operations it is necessary to have database systems that can operate over a distributed network and can encompass a heterogeneous mix of computers, operating systems, communication links and local database management system (Thomas, 1990). Distribution has enabled distance education over networks (Maly, 2001), (Shang, 2001), (Virvou, 2000). Distribution is taken advantage of in publishing content on the web (Wadman, 2001). The advantages of distribution is seen in the power of sharing memory (Upfal, 1987) and sharing data (Awerbuch, 1997).

Textiles expert systems have been applied in dyeing recipe determination (Convert, 1997, (Convert, 2000) and (Hussain, 2005), for the selection of fluorescent whiteners (Aspland, 1991), for three dimensional computer-aided intelligent design of garments (Liu, 2003), for fabric engineering (Ng, 1993) and (Behera, 2004) and the analysis of defects in textiles (Srinivasan, 1992).

Expert systems may incorporate other knowledge representation methods, such as frames, semantic nets, neural networks and fuzzy logic, besides rule-based and case-based reasoning. For the purposes of this paper, neural networks will be proposed. In textiles, neural networks have been applied in the identification of fabric defects (Kuo, 2003) and (Tsai, 1995), in the prediction of garment drape (Fan, 2001) fabric engineering (Doraiswamy, 2005) and classification of spliced wool combed yarn joints (Lewandowski, 2005).

8. Architecture of proposed system

The distributed nature of this architecture means that it consists of three main elements:

- The expert system to advise on the characteristics of the wool that is required for a particular end use.
- A knowledge-based system for querying on the distribution of wool of the various characteristics in South Africa.
- An expert system for the selection of the best alternative area for investment for the particular product end use.

8.1. Expert system to advise on characteristics of wool

User interface

Questions such as these are asked at the user interface:

What is the anticipated end use of the wool?
What quantities of wool are required?

The outputs at the user interface are the quantities of wool per province and region in terms of micron, style, yield, colour, type, clip type. At the very end of the system, the best alternative site for siting the manufacturing base is given.

Knowledge base

The decision tree in Figure 3 represents the relationship between end use and fibre diameter. In an expert system this knowledge is represented in the form of rules.

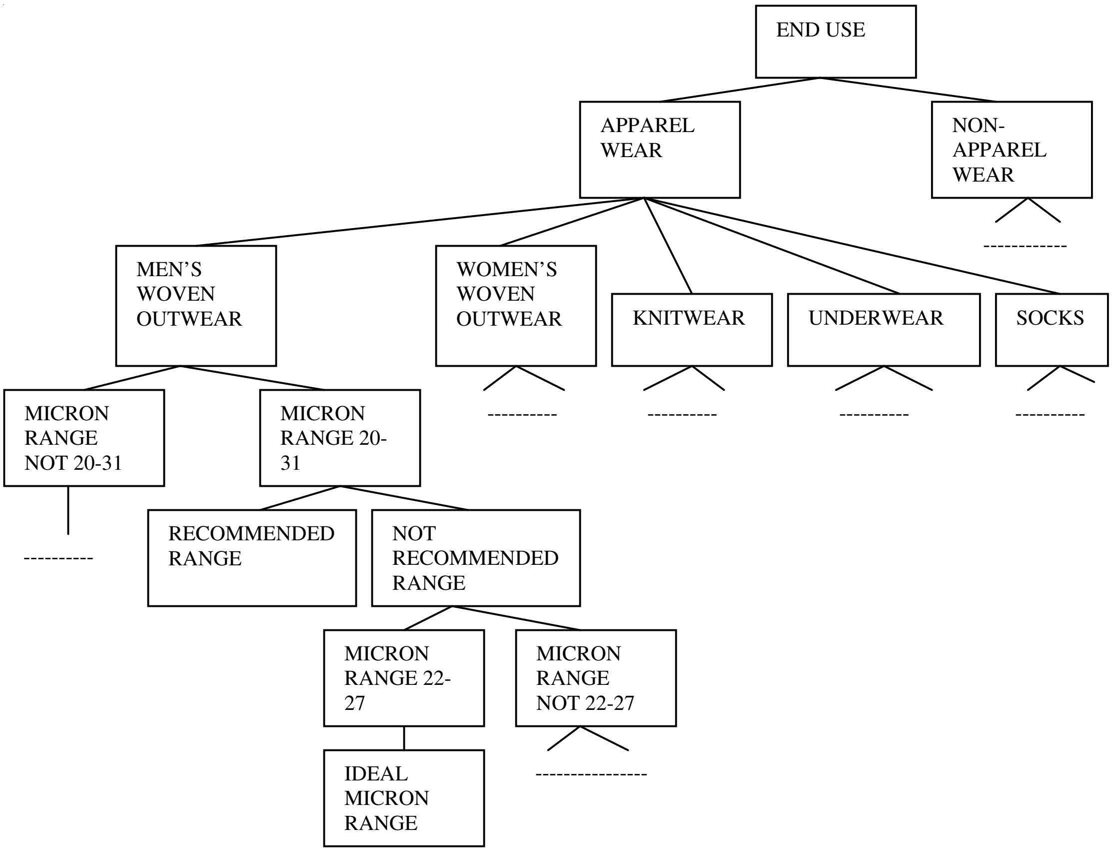

Figure 3. Decision tree to knowledge representation on micron range

The following are some of the rules that are derived from the decision tree in Figure 3 for the knowledge base.

```
IF apparel wear
AND men's-woven-outwear
AND micron range is between 20 and 31
THEN micron-range is RECOMMENDED
IF apparel wear
AND men's-woven-outwear
AND micron range is between 20 and 31
AND micron range is between 22-27
THEN micron-range is IDEAL
```

The same is repeated for all other characteristics, such as style, yield, colour, type, clip type.

Inference engine

The following is the structure of the inference engine to draw conclusions from data in the knowledge base.

```
Method END-USE
{
    If end-use in men's-woven-outerwear
    {
        Call men's-woven-outerwear-micron-method
        Call men's-woven-outerwear-style-method
        Call men's-woven-outerwear-yield-method
        Call men's-woven-outerwear-colour-method
        Call men's-woven-outerwear-type-method
        Call men's-woven-outerwear-clip-type-method
        Call men's-woven-outerwear-province-method
        Call men's-woven-outerwear-region-method
    }
If end-use is knitwear
    {
        call knitwear-micron-method
        call knitwear-style-method
        call knitwear-yield-method
        call knitwear-colour-method
        call knitwear-type-method
        call knitwear-clip-type-method
        call knitwear-province-method
        call knitwear-region-method
    }
```

The same is applied for each of the end uses as shown in Table 3.

```
}
men's-woven-outerwear-micron-method
{
    if 22<=micron<=27 then micron-range = ideal
    if 20<=micron<=31 then micron-range = recommended
    return micron-range
}

men's-woven-outerwear-province-method

{
    call men's-woven-outerwear-micron-method
    if micron-range = ideal; call ideal-provinces-method
    if micron-range = ideal; call recommended-provinces-method
}

ideal-provinces-method

{
    List all provinces and wool quantities where micron-range=ideal
    List all provinces and wool quantities where micron-
     range=recommended
}
```

8.2. Wool-knowledge-base system

The knowledge-based system should be able to provide statistics on distribution in terms of wool production by province and region for each of the following wool characteristics:

- wool production by vegetable matter fault,
- wool production by style,
- wool production by yield,
- wool production by fibre micron range,
- wool production by colour,
- wool production by clip type,
- wool production by type,
- wool production by length.

The knowledge base consists of a number of databases, each representing the various wool characteristics identified above. This represents a distributed architecture of the knowledge base. Therefore, this architecture inherits all the advantages of distributed processing systems as described in Section 5 of this paper. These knowledge bases can be queried by the user via a database management system (DBMS). A DBMS is software that manages the creation, updating, maintenance and querying of a database.

9. Analysis and conclusions

In the wool industry, the problem of unavailability of information affects investment opportunities within the sector. Therefore, knowledge-based systems can help to close the gap. In this paper an architecture of a knowledge-based system on the utilization of S.A wool to the benefit of investors is described. This architecture adopts a distributed systems approach. This approach allows not only incremental development of such systems, but also facilitates sharing of data and information.

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