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CATI : APPLICATION OF IMAGE ANALYSIS SYSTEMS FOR SEED COAT FRAGMENT DETECTION AND ON OTHER FIBRE CHARACTERIZATION

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Abstract

Research conducted by Cirad in the 1990s focussed on reducing the number of seed coat fragments (SCF) in cotton lint. Technologies were therefore developed to characterize cotton samples and the TRASHCAM project was initiated to develop a sample preparation technique and the software for counting and sizing SCF in cotton webs. Various CATI software systems were produced to analyse images captured on a grey scale (256 grey levels). This technology was then showed to be effective for SCF in breeding programmes, but was dependent upon the preparation technique, which involved using a mini-card that is assumed to remove everything in the lint but SCF.

Other preparation devices were tested, but impurities remained in the cotton web together with the SCF. To overcome this problem, software was developed that took into account the colour of the foreign matter in the lint.

This software, called CATI, proved to be effective and thanks to its versatility was considered as potentially of interest for determining the number of dark or stained wool fibres in wool webs.
Results obtained with this software in the measurement of dark and stained fibres in wool webs are presented in this paper.

Introduction: Seed-coat fragments, an impurity that can lead to quality and productivity problems

Seed-coat fragments (SCF) are created during ginning when the fibres are separated from the seeds (). Some weak parts of the seed-coat, e.g. the chalaza, are separated or broken. SCF often carry fibres or linters, and this makes them difficult to remove during the spinning process. These fragments end up in the yarn and in the fabric where they constitute a major source of defects (Krifa, 2002). In short, the SCF originate in the field (variety, environmental and growing conditions, Bachelier 1998), are revealed during ginning and remain in the fibres through out downstream processing steps.

This contamination has economic repercussions: 1/ during ginning, where more intense cleaning operations are required, with the risk of reducing fibre technological characteristics; 2/ during spinning, by reducing yarn yield and quality; 3/ during fabric processing, by increasing costs.

Figure 1: Chalaza torn off the seed (credit B. Bachelier).

TRASHCAM: a tool to count and size seed coat fragments

The TRASHCAM project led to the development of a rapid method used to evaluate the seed coat fragment (SCF) potential of new cotton cultivars. A camera is used to acquire an image of the fibre web and this is then analysed by image processing (Gourlot, 1995, 1997). CATI (Counting Apparatus of some Types of Impurities), the latest versions of the product, have improved image quality by using a scanner for image acquisition (Giner, 1998).

TRASHCAM is a test device that avoids the requirement to manufacture yarn then analyse this yarn on an evenness tester for trash particles (Frydrych 1989). The TRASHCAM also analyses an image of the card web prepared in the following manner: about 10 grams of cotton are mixed on a laboratory opener. The fibre web is rolled around a cylinder on leaving the opener. This web is cut into four parts, which are placed one on top of the other on entering a laboratory mini-card (Shirley Platt). Four layers of fibre web are rolled around the cylinder to form the test web. The TRASHCAM then acquires the images. Two or three images are taken of each web and are then analysed. An algorithm is employed to analyse each image and the results obtained are transferred to the Windows interface which can present these results in 3 forms (histogram of size distribution, image of the SCF detected, ASCII files). The CATI software processes the image so as to compare the ‘colour’ information of every single pixel in the image to its close neighbour and highlights the pixels that are significantly different on the basis of fixed thresholds.

The effects of SCF on yarn quality

Cirad designed measuring tools such as the TRASHCAM/CATI to evaluate the negative effects of SCF on yarn characteristics (namely evenness and strength). An experiment where samples with or without SCF (SCF removed using tweezers) were spun to measure their yarn strength (Krifa, 2001 and 2002,) demonstrated that the higher the quality of the fibres, the more negative the effects of SCF.

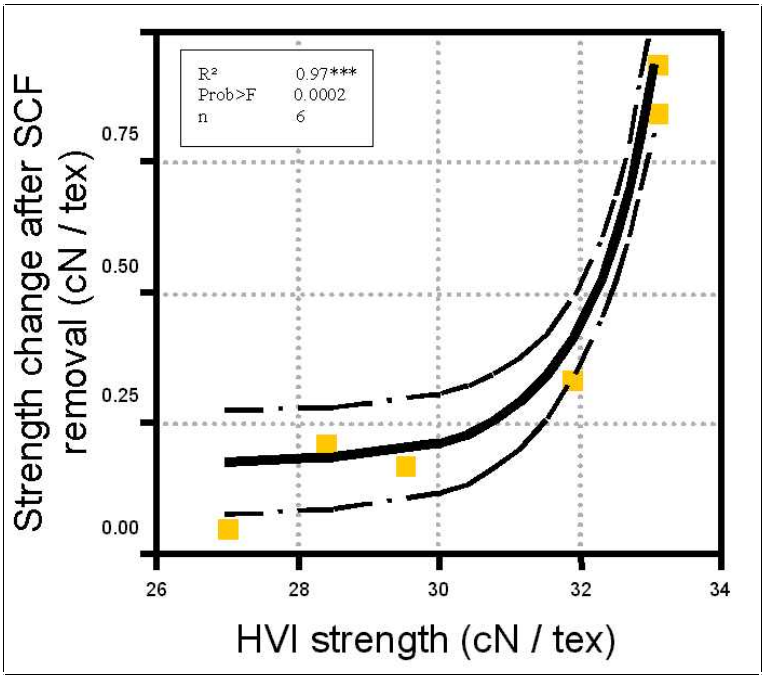

Figure 2: Yarn strength differences after removing SCF from the fibres of 6 cottons plotted against fibre strength (Krifa, 2001).

<u>Breeding is a way to reduce the number of SCF in the lint</u>

As no effective method has been found to remove SCF, Cirad used these tools in a breeding program to try to counter the SCF problem at its source. It was shown that SCF content might be reduced through breeding because this character has a significant level of heritability and a high level of variability. Varieties may therefore be bred that produce fibres with a low SCF content and suitable agricultural and technological characteristics (Bachelier, 1998,).

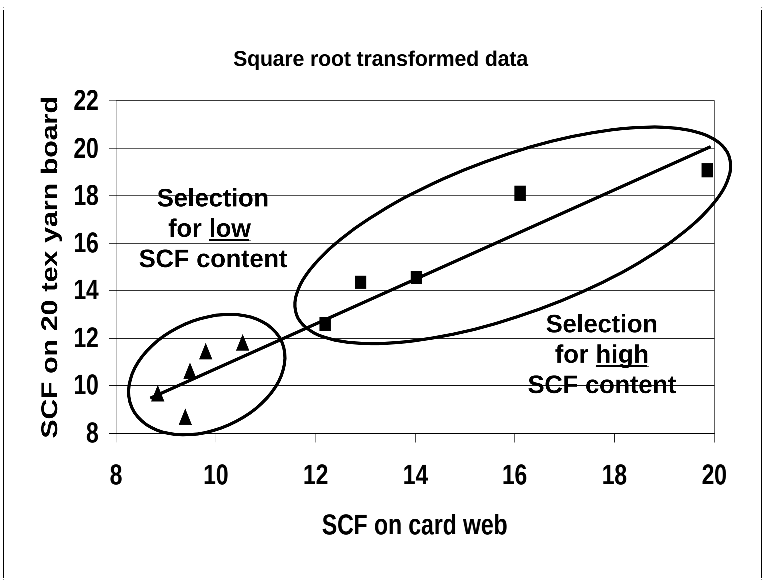

Figure 3: Breeding efficiency with regard to SCF (Bachelier, 1998).

<u>From SCF to dark wool fibre counting</u>

After a few preliminary tests, it was considered that TRASHCAM could be used to characterize wool samples by the detection of dark fibres. But, some tailor-made improvements are needed for sample preparation and image processing to meet the specific demands of the wool sector.

The basic idea was that techniques used for cotton may be applied to other fibres, and vice versa.

Objectives: modify CATI to characterize wool top samples and develop a preparation procedure for wool samples

Our overall objective was to develop an instrument and a procedure to measure the dark wool fibre content in wool tops since these are considered as a serious form of contamination by the wool industry.

The research conducted at Cirad (France) aimed therefore to adapt and modify the Cirad TRASHCAM system for the measurement of coloured fibre contamination in South Africa wool, while CSIR and UPE (South Africa) aimed to develop a sampling procedure and sample preparation system to ensure that suitable samples (wool fibre webs) were prepared for the TRASHCAM measurement.

Difference between SCF and wool contaminants

The detection of SCF relies on finding specific objects in a well contrasted image. SCF are compact and rounding shape () contrasting greatly with dark wool fibres ().

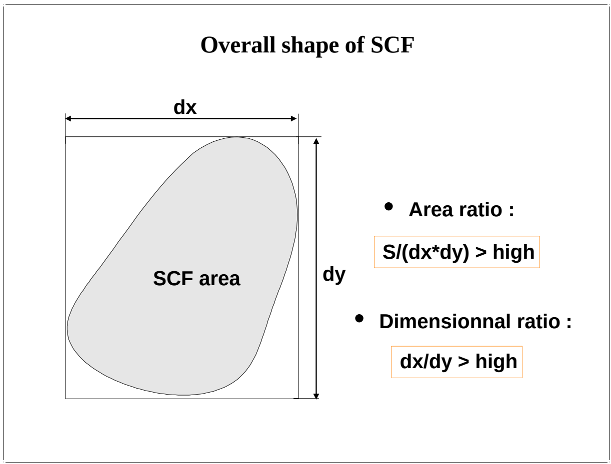

Figure 4: Appearance of a seed-coat fragment.

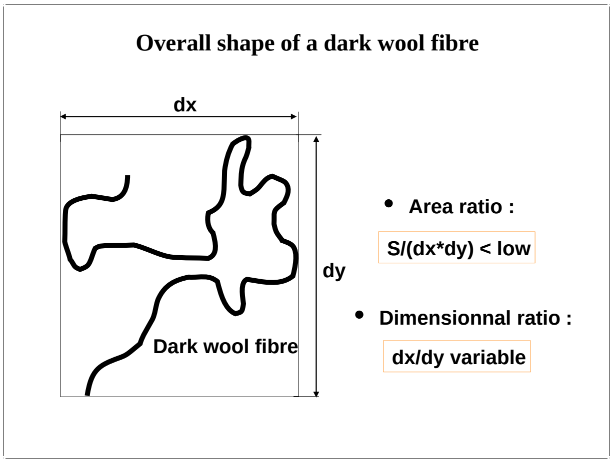

Figure 5: Appearance of a dark wool fibre.

The algorithm used for detection can be modified but rules must be followed:

- The software starts detection by comparing the grey-level of every pixel with a relative level calculated in relation to the background level; alternatively the hue level (H) of the pixel may be compared with the background.

- If this test is positive, then the pixel considered is taken into account in a new or existing impurity.
- When single pixels are detected as impurities, they can be merged to form larger objects after being tested for proximity, grey-level and/or hue.

When detecting objects using colours starting from grey levels, the software may become confused as each grey level corresponds to 65536 various colours in Red Green Blue format.
Thus, for this wool project, these constraints were taken into account for the creation of a new version of the software that can also be applied to SCF detection. This new version was then tested on two reference materials.

Constitution of a representative sample
It should be recalled that financial premiums and discounts are calculated on the basis of wool top quality parameters. If dark fibre content is to be considered as a factor in the marketing of wool then objective and precise measurements of agreed and representative samples are required. The current and agreed method is based on a standard procedure.

These standard samples are used to characterize various quality parameters in certified and recognized laboratories. After a visit to the relevant South African, internationally-accredited laboratory in Port Elizabeth, namely the Wool Testing Bureau, it was agreed that samples remaining after routine objective measurement tests could be used for the CATI analysis. These samples were scoured and Shirley Analysed at the Wool Testing Bureau.

Although such samples are accepted in the wool sector, determining the dark fibre content of non-greasy wool can only be considered as quantifying a rare event.

- In statistical terms, this means that, even if black or stained fibres are evenly distributed in the samples collected from these bales (this is an ideal case), the results will be highly variable because the objects counted are rare. The worst case is where the black or stained fibres are grouped together in aggregates at only certain locations in the bale. Such an occurrence may depend on farm management practices. Here it should be recalled that an economical threshold was placed at 100 dark or stained fibres per kilogram, corresponding to between 0 and 2 such fibres in an average of 12 grams.

- In practical terms, there was no certainty that black fibres would be found in the samples collected even if black or stained fibres were present in the bale from which the sample was taken. To counter this problem, it was decided that a given number of representative samples should be collected and analysed, and measurement tolerances - as well as probabilities in respect to these tolerances – should be established, discussed and accepted by the wool sector.

Development of a preparation method
For practical reasons, it was decided to begin by developing an operating method to detect very dark fibres such as pigmented fibres. Thereafter, an operating method was developed to detect more lightly coloured fibres such as stained fibres.

Detecting dark or stained wool fibres in a web requires the production of an even web (no fold, no disparity in fibre accumulation…)of homogeneous and pre-selected density, and which is very even.

In another words, such an analysis requires a homogenous wool web, for example produced using a mini-card. This is then stretched over the appropriate surface of the scanner, which is turned on just after being closed. Once the detection has been completed, the web image can be analysed by CATI software provided the relevant parameters set at appropriate levels.

It was initially specified that samples were to be prepared and measurements made under standard atmospheric conditions, namely T = 21 ± 2°C and RH = 65 ± 2%.

A mini-card (which usually works well for cotton fibres) was used to prepare the webs. The number of revolutions of the wool fibres collecting drum determined web density. It was also important that the wool sample contained only very low levels of residual grease (to avoid greasy stains on the window of the scanning device) and was free of extraneous matter, the latter being removed by the Shirley Analyser.

Webs with densities of 25, 40, 60, 68, 74 and 137 grams/m² were prepared using this technique, then tested.

Reference wool materials
Two samples were used as 'reference materials' in this project since they contained a pre-determined number of coloured fibres:

- one sample contained around 2000 dark fibres per kilogram of wool,
- the other contained around 13 dark fibres per kilogram of wool.

Another sample without any coloured fibres was also used. Coloured fibres were added to the surface of this wool or into the web to check scanner and CATI sensitivity.

Results and Discussion

Setting algorithm parameters for CATI
Both software versions were used to analyse images either as degrees of greyness (256 levels) or colour (up to 16 million levels). But grey-images were the first to be captured and analysed because they were faster to analyse and produced a smaller file for computer storage and management. These grey-level images were saved for subsequent use and to study the relationship between CatiV6 and CatiV7 results:

- CatiV6 seemed to be the most appropriate version for this project. It was therefore used to validate the feasibility of such measurements and to check progress made in preparation techniques;

- then CatiV7 was finalised and used at the end of the project, and its results were compared with those of CatiV6 on the same set of images (grey level images).

Before being brought into its routine use, all settings must be selected so as to detect target features, which in our case are black and stained wool fibres in fibre webs. This technical information is stored in 'parameters' files that are easy to load for daily and routine tests.

When used routinely, the first step for any version of CATI software is to select a 'parameters' file which contains image grabbing settings, information on where to store the data, algorithm impurity highlighting settings. Specific keys are then used to launch image acquisition and continue the process through to data storage.

A limitation was encountered when image backgrounds were insufficiently even, as caused by poor web homogeneity. Under these conditions, CatiV6 was unable to determine the correct number of impurities as shown in . This figure shows the grey levels of an image according to the position of the pixel in the image. Background characteristics in CatiV6 are calculated by taking account of the first pixels or lines in the images (the assumption is made that the image is homogeneous in colour), and these characteristics are applied for the complete image. If the image is heterogeneous as in the case for wool samples, CatiV6 may detect impurities that are in fact only background information (bottom right square in).

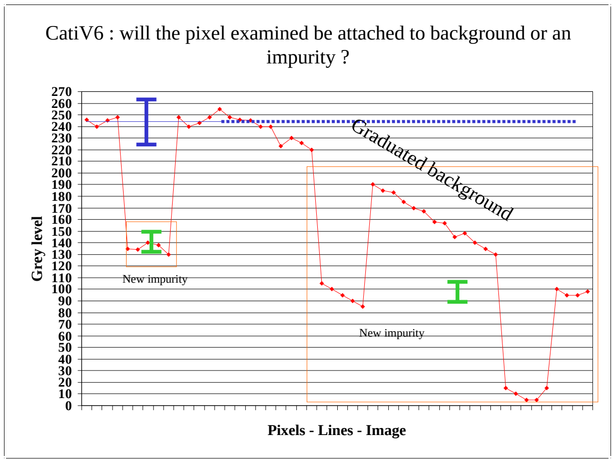

Figure 6: CatiV6 operating method.

By comparison, CatiV7 recalculates background characteristics for every pixel before it examines (pixel by pixel) the image. Under these conditions, CatiV7 is less dependent on the background colour stability of the images ().

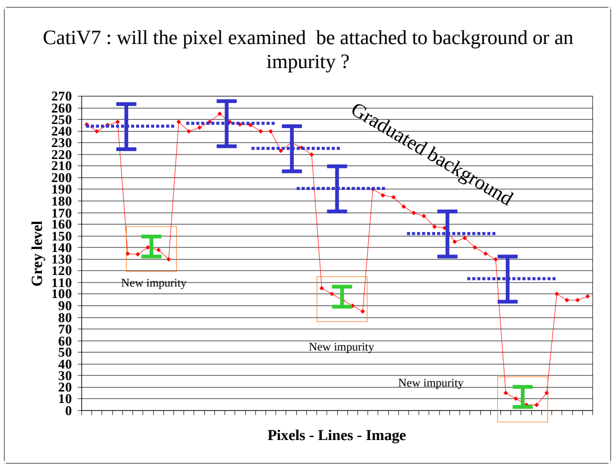

Figure 7: CatiV7 operating method.

Another technique is to detect regions as impurities by using absolute colour detection (). In this case, defects are found in the image thanks to thresholds that correspond to their typical colour.

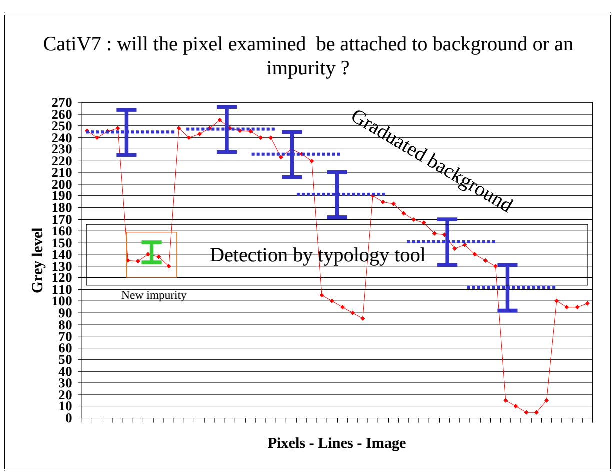

Figure 8 : CatiV7 mode of functioning when using object typology mode.

Studies were conducted to determine sets of parameters for the algorithm, taking account of web densities and for grey-scale images on the basis of reference materials.

Experimental results

Results obtained between 45 and 60 g/m² so far for black fibre detection. Stained fibres can be detected between 15 and 20 g/m². This web preparation procedure now has to be validated on a routine basis.

It shows that a global background taken as the reference for highlighting impurities in images, does not allow their detection as the images having a graduated background. But when analysing the same image, CatiV7, using a local background, can efficiently highlight the fibres considered as impurities ().

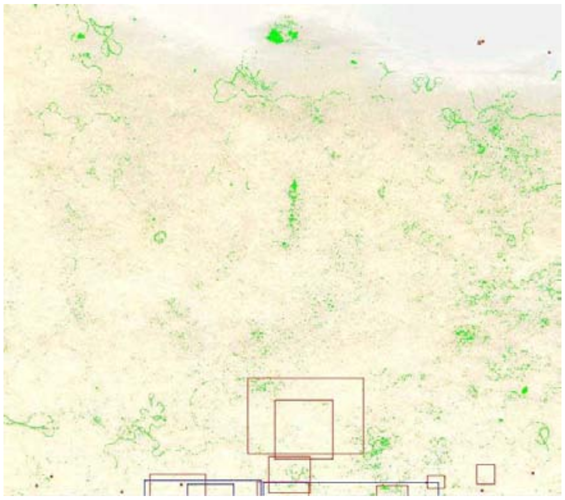

Figure 9: Global background in CatiV6 unable to detect dark fibres.

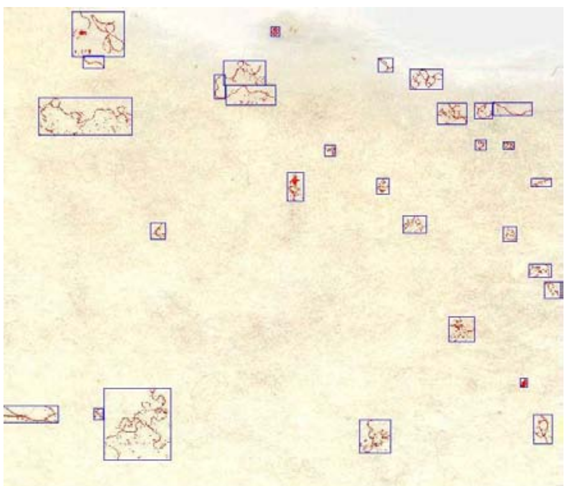

Figure 10: Local background in CatiV7 able to detect dark fibres.

We also checked that this progress made in dark wool fibre counting did not affect SCF counting in cotton webs.

Conclusion and Perspectives

The work conducted in the course of this project was used to define method for preparing wool samples for the counting of black or stained fibres on wool webs. Suitable software was also developed for this analysis operation and the preparation and analysis steps were combined as a proposal for the counting of dark or stained fibres.

But although considerable progress has been made, the following tasks remain before the method can be used for routine tests:

- Check count precision, accuracy and quality
- Check whether samples are representative of a greater mass of fibres
- Create a device for preparing wool samples
- Check the ability of CATI software to count dark and stained fibres in a single operation: as CATI software is also able to analyse colour images, it may be possible to combine the two proposed procedures to count both dark and stained fibres.
- Define confidence intervals or grades for the measurements made using these techniques (preparation + software) as prices may be defined according to these measurements.
- Standardize this technique across the wool sector through Standardization Committees.

The aim set ten years ago of creating new low-cost software has now been met though the points listed above need to be addressed before rules for routine use can be set.

This technology can detect various objects in cotton fibre webs or in yarn boards, and can be used in other media (leaf disease, counting insect eggs, sizing rice grains …).

We have also demonstrated that the basic principles of this detection are suitable for other characterizations.

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