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ASSESSMENT OF TRASH CONTENT OF COTTON USING 2D X-RAY IMAGERY

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Abstract

Trash content of raw cotton is a critical quality attribute. Therefore, its assessment is crucial for its processing and evaluation of its market value. Current technologies including gravimetric methods and surface scanners suffer from various limitations. Furthermore, worldwide the most commonly used method is still human grading. Thus, the need for implementing new technologies is growing. One of the best alternatives to aforementioned approaches is x-ray imaging since it allows a thorough analysis of contaminants in a very precise and quick manner. We have used x-ray radiographic imaging because of its real-time applicability. The segmentation of trash particles in 2D transmission images is not an easy task. We dealt with this problem by characterizing and identifying the background cotton via scale space filtering followed by a *'background normalization'* process that removes the background cotton successfully while leaving the trash particles intact. We tested our technique on 280 cotton radiographs - graded from 1 to 7 according to its trash content by expert graders - and compared the results with the existing alternatives.

Introduction

Cotton is subject to contamination from various sources, including vegetation in the field and materials used for its harvesting and handling. The accurate assessment of trash content in cotton is critical to its processing and market value. For over fifty years, research has been conducted in this area, leading to the development of many industrial tools, which can be categorized into two main groups: 1) Gravimetric Methods, and 2) Surface Scanners. Systems in the former group are based on separating the trash by mechanical means and then collecting information by weighing, counting, and measuring the size of the contaminants; while the ones in the latter group perform optical surface scanning. Unfortunately, both approaches suffer from various drawbacks. For example, the former methods require sample preparation and are slow and incapable of distinguishing between different types of trash, while the latter methods can only evaluate the trash content on the surface of the samples.

In our earlier work [1], we proposed a vision system, based on x-ray imaging, which overcomes the aforementioned shortcomings. X-ray imaging allows for the analysis of contaminants that are embedded within the samples, as well as those on the surface. Furthermore, it provides the particles' density information, which when combined with their shape and size, allows for better classification. There are two basic modes in x-ray imaging; namely, 2D radiographic and 3D tomographic imaging modes. In our complementary work, the 3D approach has successfully been applied to the detection and classification of trash particles in controlled samples. Although the 3D approach gives more accurate results, the 2D approach is more appealing in terms of real-time applicability.

In this paper, we will present our adaptation of 2D x-ray imaging to the assessment of trash content in cotton. The primary focus of this paper will be the segmentation of trash in 2D x-ray radiographs and a discussion of our preliminary results.

Methodology

The overall approach can be outlined as acquiring the x-ray image of the sample using the imaging modality that gives the maximum contrast between the trash particles and the cotton [1], and then utilizing computer vision techniques to segment and to classify the trash particles. These techniques involve a preprocessing step, including median filtering and contrast stretching, followed by the segmentation of trash particles from the background cotton through a background normalization technique, which is now briefly described.

Figure 1 shows an x-ray transmission image of a sample from ginned cotton. In general, background cotton is not uniform due to its natural lint structure and the layering formed by the gin. Moreover, there is considerable overlap between the gray-level intensities spanned by subtle trash types (e.g., leaf particles and polypropylene-based plastics) and dense cotton, which makes the segmentation problem quite difficult. To tackle this problem, a background normalization technique is designed to effectively remove the background cotton and segment the trash particles indirectly. Essentially, the idea here is to focus on the background, which is easier to characterize than the various trash types that may be encountered.

The procedure may be summarized as follows:

1) Areas that are likely to be Background Cotton are Detected

Areas in the image that are most likely to contain cotton are determined based on the fact that the intensities of the background (i.e. areas of cotton) follow a normal distribution. If independent, random samples are taken from a normal distribution, the distribution of their variances will also be approximately normal. Background regions are characterized and distinguished from the areas containing trash based on the local variations of the image. A grid is applied on the image, variances of the blocks are calculated and their distribution is analyzed to distinguish regions containing trash from the others. Variances of the regions containing background only will give rise to an approximately normal distribution, and will be located at the low-variance end of the distribution (see Figure 2). The identification of background regions equals to the separation of this low-variance, normally distributed mode of the distribution from the high-variance modes that correspond to areas involving some trash. This is achieved by analyzing its scale-space representation (SSR) of the distribution which is shown in Figure 2.

This representation is obtained by convolving the histogram of variances iteratively with Gaussian distributions having successively increasing variances, and determining its local maxima and minima [2]. The essential idea here is that this representation will transform the distribution of variances to a bimodal one that can be robustly thresholded. This is due to the fact that impurities on the dominant peak are easily absorbed by smoothing if there is any, but the others (i.e., the ones that are due to the trash) are more persistent and appear as separate modes in larger scales (σ) of the SSR. The threshold shown in Figure 2 separates the low-variance modes from the high-variance modes, and it is found automatically. Figure 3 shows the final regions determined as background.

2) A Background Model is Generated

A background model is generated using the detected background regions and interpolating the remaining regions (previously containing trash). See Figure 4.

3) This Generated Model is Subtracted from the Original Image

This operation leaves the segmented trash; see Figure 5. The segmentation of the trash particles using the background normalized image is rather easy and can be done with a simple thresholding.

4) Trash Ratio of the Sample is Estimated

Since the gray value of a pixel of a transmission image is proportional to the integration of densities along the axis corresponding to that pixel. The mass percentage of the trash in the cotton is estimated as the sum of gray values of all pixels in the image:

$$\%\,\text{Trash Mass} = \frac{\sum_{all\,x,y} g(x,y)}{\sum_{all\,x,y} f(x,y)} \times 100$$

where f(x, y) and g(x, y) are the original image and the background normalized image, respectively.

5) Trash Particles are Segmented via Thresholding

Segmentation process is completed by thresholding the background normalized image. Threshold value is determined as the lowest intensity value in the region of background (that was determined in step 1).

Experimental Results

We have tested our method on x-ray transmission images of 280 cotton samples with expert-assigned grades ranging from 1 to 7 (proportional to its trash content). These 8-bit, gray-level images of size 512x736 were acquired using an x-ray scanner with tube settings of 20kV and 1 mA. The grid size is chosen as 15x15 pixels. The results, analyzed subjectively by expert graders, have been found to be satisfactory in terms of segmenting the trash particles from the cotton.

To compare the results with those of the current technologies, we have used 80 samples, consisting of 10 samples from 8 different batches. Samples that were used for x-ray scanning were used on AFIS; for Shirley Analyzer and HVI new samples from the same batches were used. The result of Shirley Analyzer is based on one determination while AFIS's, HVI's, and x-rays are the averages of 5, 10, and 10 repetitions, respectively. Figure 7 depicts the plot of results obtained. As seen from the figure, a strong concordance is observed between the proposed method and the current technologies. Discrepancies between the results are due to inaccuracies of the current technologies as well as possible mis-segmentation occurring in the x-ray approach, which may be alleviated by further elaborating on the segmentation technique.

In Figure 8, the result of x-ray approach is compared with the result obtained using AFIS. Here AFIS is taken as the reference method since for both AFIS and the X-ray approach exactly the same samples were used. The correlation coefficient between two results is calculated as 0.93. The correlation coefficient becomes 0.80 when individual repetitions (i.e. 80 data) are used, which indicates that two results are highly correlated.

Conclusions

In this work, we have devised and implemented a background normalization algorithm that is used for the detection and segmentation of trash particles in x-ray radiographs of cotton and verified its applicability experimentally. The background normalization technique developed here may also be used as a preprocessing technique for many difficult segmentation problems in which the background is non-uniform.

X-ray imaging shows potential for the comprehensive assessment of cotton contaminants. It is able to determine the particles that are embedded within the samples as well as the ones on the surface. Furthermore, it provides the particles' density information, which when combined with their shape and size information allows for distinguishing between different contaminants such as barks, leaves and seed coat fragments. Besides these, its potential for thorough analysis of contaminants, efficiency and real-time applicability makes the x-ray approach a strong candidate for the future method of cotton contamination assessment.

References

[1] A. Pai, H. Sari-Sarraf, and E. F. Hequet, "Recognition of Cotton Contaminants via X-ray Microtomographic Image Analysis", To appear in *IEEE Trans. on Industry Applications.*

[2] A. P. Witkin, "Scale Space Filtering", From pixels to predicates: recent advances in computational and robotic vision, 1986, pp. 5-19.

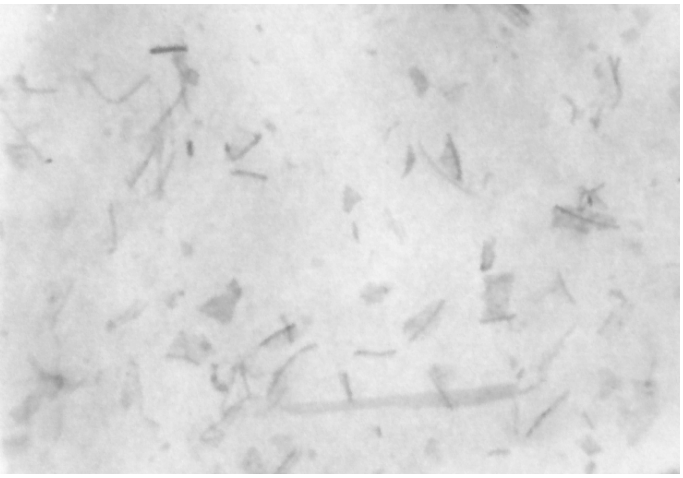

Figure 1. An x-ray transmission image of a grade 3 sample indicating moderate trash content and non-uniform background cotton.

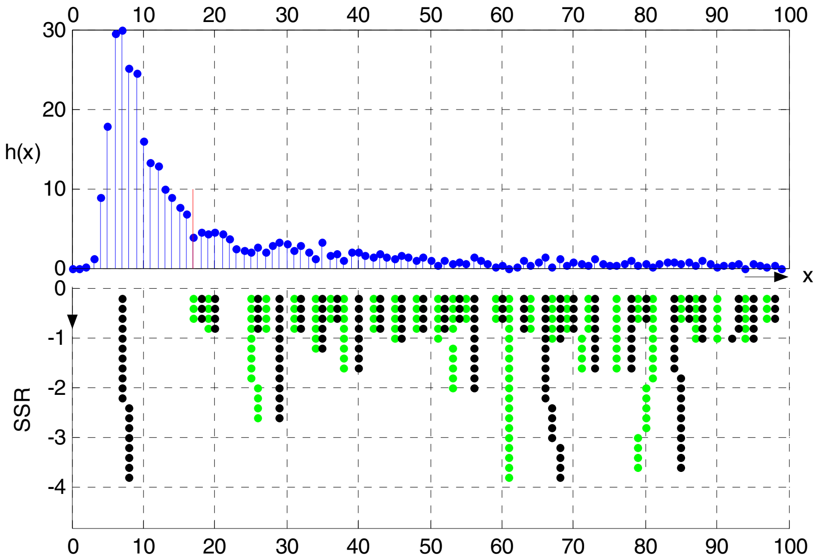

Figure 2. Multi-modality test results for the histogram of block variances of the image in Figure 1. Black points indicate the local maxima and the green ones indicate the local minima of the histogram at their corresponding scale (σ).

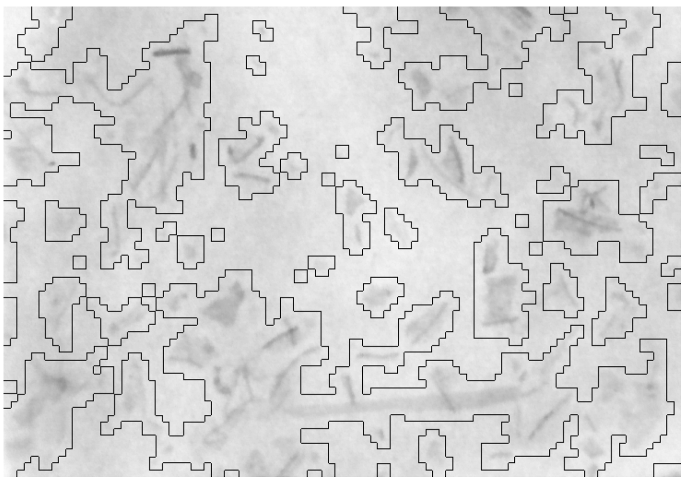

Figure 3. Selected background areas (i.e., areas exterior to any closed regions).

Figure 4. Background model generated.

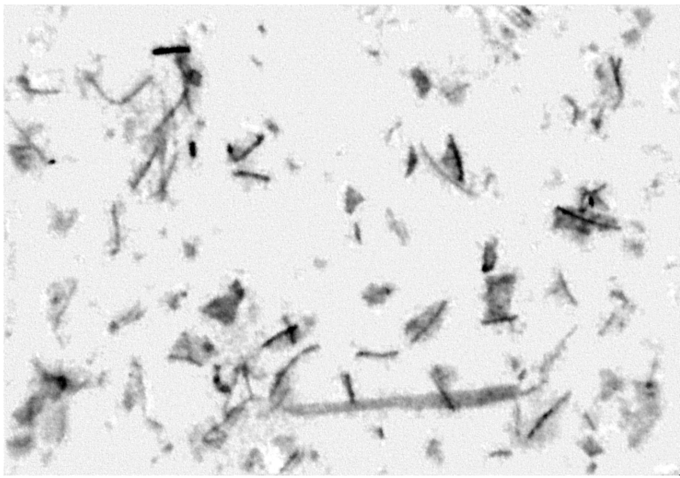

Figure 5. Output of the background normalization technique.

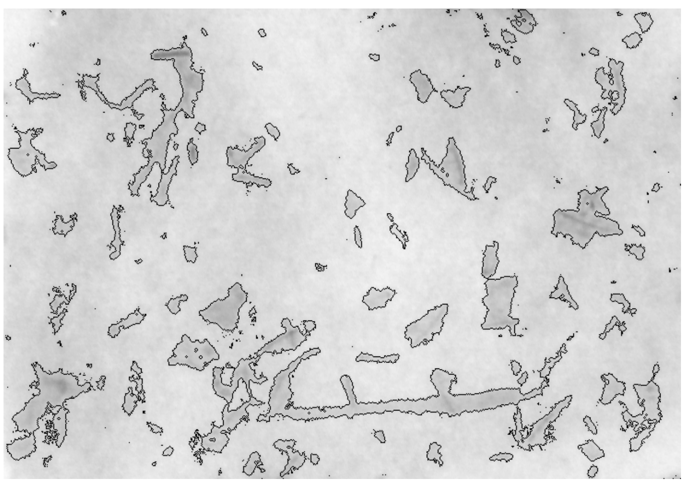

Figure 6. Final output obtained via thresholding.

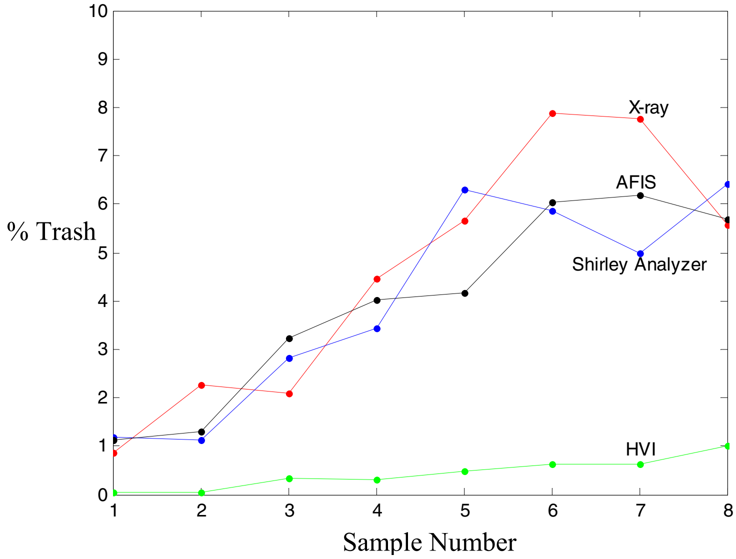

Figure 7. Experimental comparison of the proposed technique with AFIS, Shirley Analyzer and HVI.

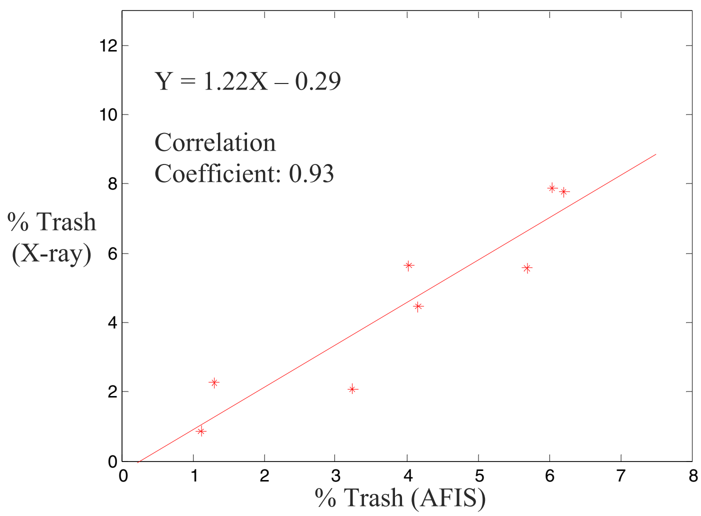

Figure 8. Percentage of the trash content estimated by the x-ray approach versus AFIS.