COTTON TRASH MEASUREMENT USING IMAGE ANALYSIS

Bugao Xu and Yu-liang Ting
Department of Human Ecology, University of Texas
Austin, TX
Michael Watson
Cotton Inc.
Raleigh, NC

Abstract

Trash in cotton refers to non-fiber particles such as leaf, seedcoat, bark, grass, dust and other foreign matters. Trash content in cotton is a strong consideration in the present cotton grading system, because the presence of trash degrades yarn evenness, yarn strength and fabric appearance and causes problems in textile processing. The methods that have been used for assessing trash content in cotton may be divided into two basic groups: geometric and gravimetric. The geometric methods estimate the trash portion in a sample according to sizes of particles, while gravimetric methods evaluate trash content by trash weight. The classer's grade (USDA) is the most commonly used geometric method by which a classer compares trash contaminants in a cotton sample with those in the standard samples. The HVI trashmeter is a replacement for this visual assessment method using the video image technology. The typical gravimetric devices are the Shirley Analyzer (mechanical separation of foreign matter from fiber) and the MicroDust and Trash Analyzer (aero-mechanical separation). The AFIS-T (Advanced Fiber Information System, Trash module) uses the aero-mechanical technique to separate a fiber sample into fractions, and an electro-optical sensor to measure particle size in each fraction.

The HVI trashmeter is a very efficient trash measuring instrument, and the result is correlated to the classer's grade [9]. However, current image analysis techniques used in the HVI trashmeter limit its data to the count and the percent area of trash particles. It lacks an ability to provide information about detailed particle size distribution and trash classification, which is extremely useful for process optimization and prediction of cleaning behavior during processing [9]. Since the trashmeter employs a black and while video camera and a simple image thresholding technique [6,7], trash mis-identification, such as surface shadow areas, cannot be effectively avoided, thus undermining the accuracy of trash measurements.

We have been conducting a research project to develop a new image analysis system for comprehensive, accurate and fast cotton color and trash analysis (CCTA). In this paper, we focus on the explanation of a new thresholding method, multi-dimension thresholding, for trash identification, and the methods for characterizing size, shape, color and density of trash particles. We conducted a trial test to compare the results obtained from this system with those obtained from Spinlab and Motion Control HVI machines, and to analyze the influence of trash particles on cotton color.

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Computer Vision System

The schematic set-up of the cotton computer vision system is presented in Figure 1. Cotton samples are pressed flat and imaged through a CCD camera equipped with a zoom lens or a color scanner. Both input devices are linked to the circuit boards plugged in a computer. An image captured by the system is stored as a 24-bits bitmap, which can possess up to 16.8 million colors. The color information plays an important role in trash identification and classification.

Trash Identification

In a cotton image, fibers appear white or slightly tinted white, while trash particles often appear in dark colors. Unevenly-spread fibers on the compressed surface may cause shadows when imaged. Although shadows can be reduced by increasing the compressing pressure and installing two lighting sources on the left and right sides of the sample [7,8], the image will always contain shadows. Some of shadows may be in the same darkness as trash particles (image A in Figure 2). In the HVI trashmeter, a threshold is selected based on the brightness of the image. If the threshold is selected too low, shadows may be falsely identified as trash particles (image B in Figure 2). On the other hand, some trash particles may be overlooked if a threshold is selected too high (image C in Figure 2). Therefore, selecting a threshold in brightness is critical to trash identification. Particle sizes also vary with the threshold.

A multi-dimension thresholding technique was developed to identify trash particles in this research. This technique is based on color attributes instead of only brightness. Three color primaries, red, green and blue (*RGB*), can be obtained for each pixel directly from a color image. *RGB* values are then converted to C.I.E. L^*C^*h, where $L^*C^*$and h represent lightness, chroma and hue, respectively (the conversion will be discussed in the section of trash color measurement). Since shadows always appear in gray, the chroma or saturation of pixels in shadows should be very low. Compared to trash particles, a shadow may have a similar lightness, but will differ in chroma and/or hue. Figure 3 shows the distributions of L^*C^*h of image A in Figure 3. A preliminary test has shown that trash particles have lower lightness (darker), higher chroma (more saturated) than cotton fibers, and have hues similar to cotton. Therefore, we can set thresholds in these three dimensions. Pixels will be considered as trash, if the following conditions are all met:

$$L^* < L_0; \quad C^* > C_0; \text{ and }, h_1 < h < h_2$$

where L_0, C_0, h_1 and $h_2$are the thresholds (Figure 3). Image B in Figure 4 displays trash particles identified from image A by this technique. All shadows were overlooked. A trial test has shown this technique is very effective in identifying trash particles.

Trash Characterization

After trash identification, individual trash particles can be located by scanning the image, and a number of characteristics can be calculated.

Size

The size of a trash particle in an image means the number of black pixels clustering together. The computer counts black pixels for each particle, and then calculate the following size descriptors. The area that one pixel represents can be determined through calibration.

Size Statistics: the mean, the standard deviation, the maximum and the minimum of trash size.

Area Fraction: ratio of the total size of trash particles to the image size. This is used as trash content.

Size Distribution: a curve that shows the primary range of trash sizes.

Shape

Small trash particles may always look circular in an image due to digitization, but large particles exhibit different shapes. Trash shape provides an important cue for trash classification.

Roundness (R): the ratio of fiber area to the area of a circle whose perimeter is equal to that of the particle. R measures the similarity of a given shape to a circle.

Ellipticity (E): the ratio of the semi-major and semi-minor axes of the **best-fit ellipse** [3] of a particle. E is a measure of elongation. Note that the area of the best-fit ellipse of a particle can be also regarded as an approximate size of the particle.

Color

Different categories of trash may be distinguishable by trash color. Unlike conventional colorimeters or spectrophotometers suggested in the testing methods of ANSI/ASTM D 2253 [2] and AATCC 153 [1], this computer vision system was designed to have capabilities of automatically locating individual particles and measuring the color attributes for each particle.

As explained before, colors are originally expressed in the (R, G, B) color system. While RGB values represent the way the detector works and the way the data are stored internally, they do not correspond to the way that people recognize or react to color. A color system based on hue, saturation and lightness is more consistent with visual perceptions. Therefore, we measure trash color using C.I.E. L^*C^*h, where L^*C^*, h stand for lightness, chroma and hue angle (Figure 6). It takes three steps to convert color values from the (R, G, B) system to the C.I.E. L^*C^*h system as follows:

(1) RGB -> C.I.E. XYZ:

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} 0.607 & 0.174 & 0.201 \\ 0.299 & 0.586 & 0.114 \\ 0.000 & 0.066 & 1.117 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

(2) C.I.E. XYZ -> C.I.E. $L^*a^*b^*$:

$$L^* = 116(Y/Y_0)^{1/3} - 16$$
$$a^* = 500[(X/X_0)^{1/3} - (Y/Y_0)^{1/3}]$$
$$b^{**} = 200[(Y/Y_0)^{1/3} - (Z/Z_0)^{1/3}]$$

where L^* is brightness, a^* is red-green content and b^* is yellow-blue content. The suffix 0 indicates that the value is for the reference white.

(3) C.I.E. $L^*a^*b^*$ -> C.I.E. L^*C^*h:

L^* is unchanged.

$$C^* = \sqrt{(a^*)^2 + (b^*)^2}$$
$$h = \tan^{-1}\left(\frac{b^*}{a^*}\right)$$

We first use the multi-dimension thresholding technique to generate a binary image from the color image being analyzed (e.g., Image B of Figure 2), extract boundaries of trash particles, and then superimpose the boundaries on the color image so that edges of trash particles are highlighted. This procedure is exemplified by the three images in Figure 7, in which two different types of trash (bark and leaf) were collected. We measured L^*C^*h values of these particles, and found out that the L^*C^*h values of these two groups are significantly different (see the average values in Table I). This difference provides a means to classify trash particles.

Density

We can also estimate the population density of trash particles distributed in a cotton sample using the nearest-distance technique. First, we search for each trash particle, and calculate its mass center [3]; then, we create a map showing trash spatial distribution by placing a dot at the mass center of each particle (Figure 8, mass centers of trash particles in image B of Figure 3), and finally, we compute the Diggle's density estimator, which is derived from two nearest distances of each particle. Assume that n points are randomly generated in the map, and n particles are randomly selected. The Diggle's density estimator (D) is [5]:

$$D = n \Big/ \left(\pi\sqrt{\sum x_i^2 \sum r_i^2}\right)$$

where x_i is the distance from random point i to its nearest particle and r_i is the distance from a randomly selected particle to its nearest neighbor. It was shown that D has a low bias over a wide range of clumped to uniform spatial patterns [5]. D provides a measure about overall trash content in the cotton sample.

Results

Twelve cotton trash samples (S1-S12) with various trash contents were tested using the system being developed, and the results were presented in Table II. As an example, the images of the first cotton sample (S1) and its trash size distributions are presented in Figures 9 and 10. Three samples from each cotton were imaged and measured, and each image covered a 150mm x 100mm (6in x 4in) area on a sample. The results were also compared to those obtained with SPL and MCI HVI trashmeters. The trash contents of the samples measured by these systems are displayed in Figure 11. Although the differences exist between the three systems (SPL, MCI and CCTA), the consistent trends are still maintained. The differences may arise from different trash segmentation algorithms and calibration methods used in the three systems, and different portions of a sample used for capturing images in the systems.

Conclusion

It has been noticed that the simple thresholding method used for trash identification in HVI trashmeters is likely to cause mis-identification of trash particles and bias on particle sizes. A new trash segmentation algorithm was implemented in this new system, which seems to be more effective in identifying trash particles. Most shadow areas can be ignored and trash areas can be accurately located. The system can also provide comprehensive measurements for trash analysis, including size, shape, color and density. The system shows the potential for classifying trash particles and evaluating cotton color.

Reference

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Table I Color Attributes of Trash Particles

	leaf	*bark*
L^*	47.5	25.5
C^*	80.8	41.1
h	92.3	101.0

Table II Trash Measurements

	Count	Area (mm^2)	Diameter (mm)	% Area	Roundness	Color L	Color c	Color h	Density (1/inch^2)
S1	113	2.51	1.66	1.58	0.56	55.8	30.1	33.5	4.33
S2	20	0.47	1.01	0.05	0.82	15.0	45.1	40.6	0.78
S3	77	1.66	1.63	0.78	0.70	64.3	26.9	33.4	3.22
S4	35	1.25	1.38	0.25	0.91	58.9	28.2	29.9	1.48
S5	119	2.18	1.79	1.48	0.69	64.4	26.4	46.2	4.71
S6	73	3.71	2.29	1.46	0.46	52.5	26.1	29.3	2.64
S7	56	1.41	1.39	0.41	0.63	58.8	24.9	28.9	2.10
S8	39	2.32	1.39	0.52	0.46	63.1	26.1	33.3	1.31
S9	90	1.64	1.55	0.84	0.63	60.1	24.2	34.1	1.03
S10	122	1.49	1.50	1.02	0.77	61.5	27.2	30.2	4.36
S11	96	1.75	1.70	0.95	0.61	48.6	27.2	35.7	3.79
S12	137	1.64	1.52	1.28	0.68	60.1	27.8	33.3	5.85

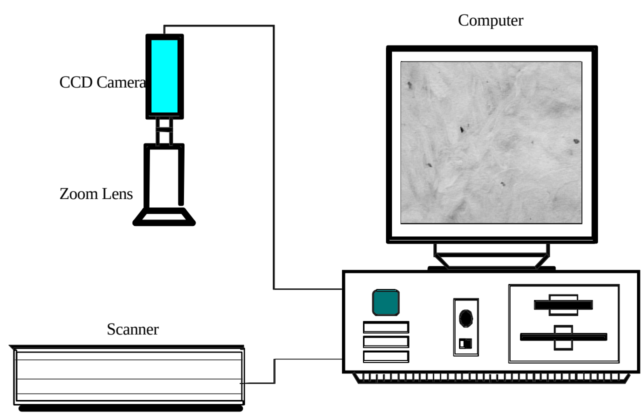
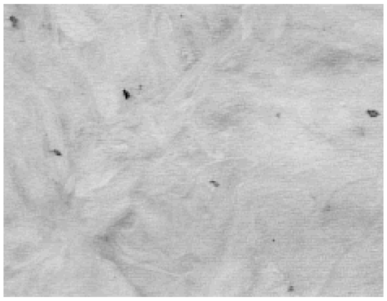
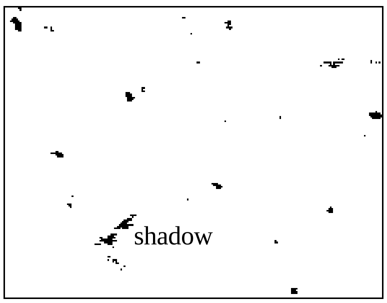


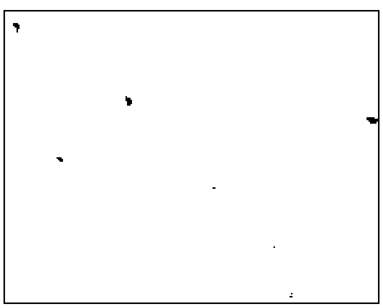
Figure 1 Schematic Set-up of the Computer Vision System



A



B



C

Figure 2 Brightness Thresholding

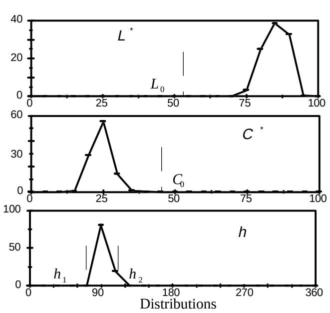
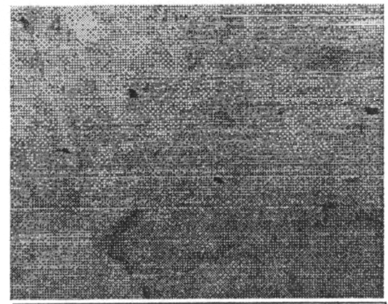


Figure 3 Multi-Dimension Thresholding

A



B

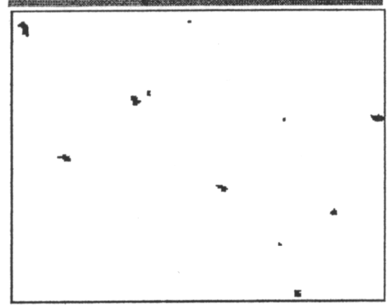


Figure 4 Effects of Multi-Dimension Thresholding

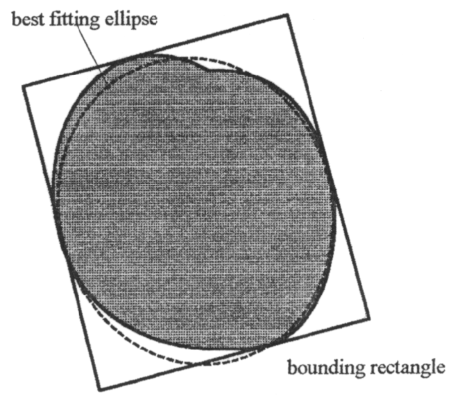


Figure 5 Trash Shape

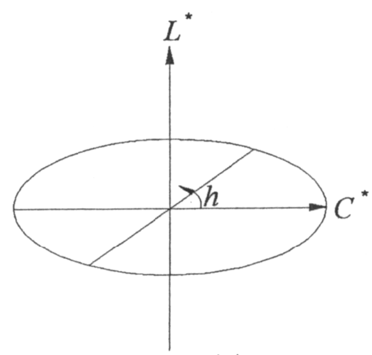


Figure 6 C.I.E. L^*C^*h system

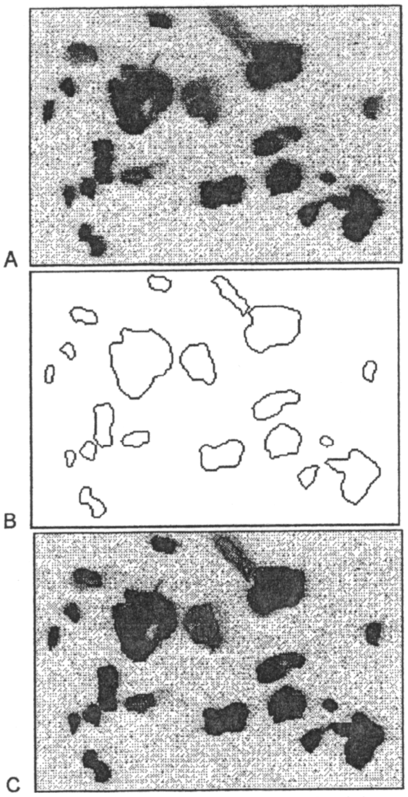


Figure 7 Leaf and Bark Trash Particles

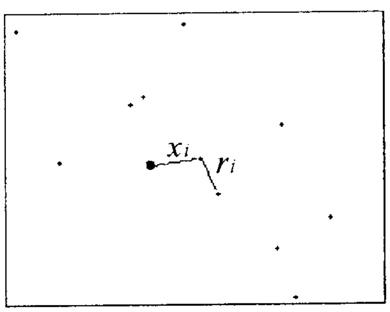


Figure 8 Mass Centers of Trash Particles in Image B of Figure 4

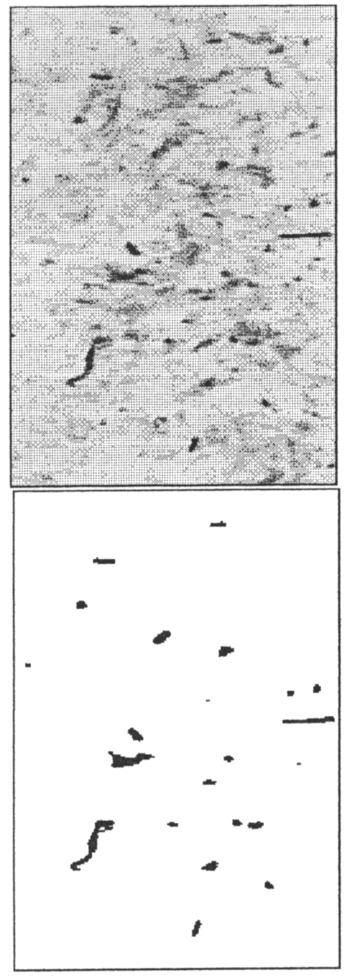


Figure 9 Cotton Sample

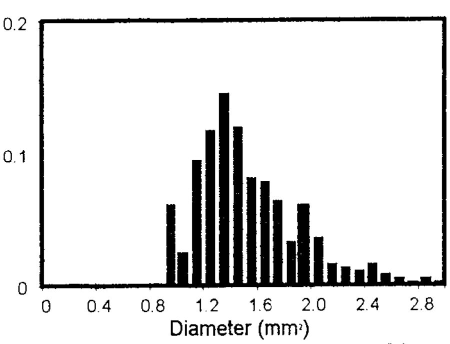


Figure 10 Diameter Distribution of S1

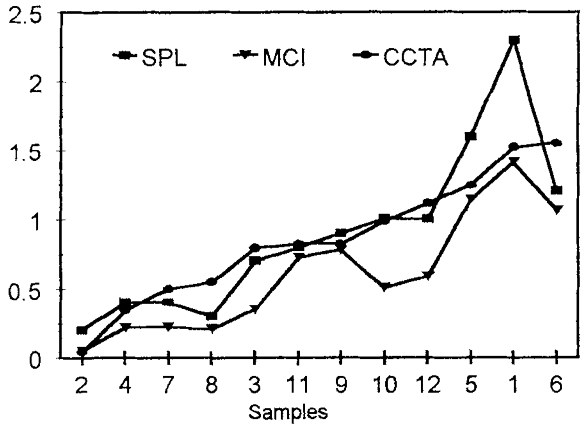


Figure 11 Trash Contents Measured by SPL, MCI and CCTA