CATEGORIZATION OF EXTRANEOUS MATTER IN COTTON USING MACHINE VISION SYSTEMS

M. Siddaiah
New Mexico State University, Las Cruces, NM
D. P. Whitelock
M. A. Lieberman
S. E. Hughs
USDA, ARS, Southwestern Cotton Ginning Research Laboratory
Mesilla Park, NM
S.L. Grantham
USDA, AMS, Cotton Program, Standardization & Engineering Branch
Memphis, TN

Abstract

The Cotton Trash Identification System (CTIS) developed at the Southwestern Cotton Ginning Research Laboratory was evaluated for identification and categorization of extraneous matter in cotton. The CTIS bark/grass categorization was evaluated with USDA-Agricultural Marketing Service (AMS) extraneous matter calls assigned by human classers for 210 cotton bale samples. AMS classers assigned extraneous matter calls on four cotton faces of a sample from a given bale of cotton. Scanner acquired images of the same four faces at 400 DPI and 800 DPI resolutions were analyzed to evaluate the CTIS performance. Soft computing techniques were used to identify trash objects in the acquired cotton images (4 in. x 7 in.) and categorize the objects into bark/grass, stick, leaf, and pepper trash categories. The primary goal of the study was to evaluate and calibrate CTIS categorization of extraneous matter using classer extraneous matter calls. CTIS agreed with the classer call 97% of the time when there was a classer extraneous matter call and 43% of the time when there was no classer call. CTIS may find a place as a tool to aid human classers in the classification of cotton by helping to identify extraneous matter.

Introduction

The USDA-Agricultural Marketing Service (AMS) has developed standardized procedures for measuring physical attributes of raw cotton related to the quality of cotton. Cotton classification, based on these physical attributes, is used to determine the price of cotton on the world market. All cotton produced under the commodity loan program in the United States is classed by the AMS cotton classing office under these procedures. AMS cotton classification currently consists of determinations of fiber length, length uniformity, strength, micronaire, color, preparation, leaf, and extraneous matter.

Extraneous matter (EM) is any substance in cotton other than fiber or leaf. Examples of EM are bark, grass, spindle twist, seedcoat fragments (scf), dust, and oil. The kind and an indication of the amount (light or heavy) of EM are noted by the classer on the classification document (Agricultural Marketing Service, 2001). There are a wide variety of factors that influence the type of EM and the quantities of the EM. EM found in cotton varies between the cotton growing regions of the United States, the growing season (typically it is expected to contain grass during rainy seasons), equipment maintenance (the presence of oil due to poor maintenance of gin machinery), and variety (upland or pima). The selection of the seed cotton cleaning equipment, the amount of lint cleaning performed, and the type of ginning (saw ginning or roller ginning) also determine the quality and quantity of some of the EM (bark/grass, scf) left behind in the ginned cotton.

Fiber length, length uniformity, strength, and micronaire are inherently fiber properties. These attributes along with color are measured using High Volume Instrument (HVI) machines. These HVI measurements have been accepted by the cotton industry for quality purposes. However, human classers determine the presence of EM by the visual inspection of the cotton sample during classification along with the leaf grade and preparation. This is a time consuming and labor intensive measurement.

The USDA-ARS Southwestern Cotton Ginning Research Laboratory (SWCGRL) has developed the Cotton Trash Identification System (CTIS); a machine vision-based system that has the capability to identify trash objects that are commonly found in ginned cotton. CTIS categorizes the trash objects into bark/grass, stick, leaf, and pepper categories. The goal of this research effort was to evaluate CTIS categorization of bark/grass in cotton samples and compare its efficacy in predicting extraneous EM calls. HVI systems that are currently used in the measurement of percent trash use an area of 9 in^2 in the imaging window. CTIS uses a larger area (28 in^2) and would be similar to what a typical human classer would observe when assigning classer grades.

Materials and Methods

Cotton Trash Identification System

The Cotton Trash Identification System (CTIS) developed at the Southwestern Cotton Ginning Research Laboratory (SWCGRL), is a Microsoft Windows based system for the acquisition and processing of cotton images. An EPSON® perfection 3170 photo scanner was used to scan cotton images. The scanner consists of a 6.5 in. x 9.45 in. imaging window that was fitted with a template (with color reference information) for calibration purposes. The cotton image window used of the analysis is 4 in. x 7 in. in size. Figure 1 shows a CTIS acquired image with the color information and the cotton image.

Figure 1. Cotton Trash Identification System acquired sample image (400 DPI).

A smoothing operation was performed on the acquired images to reduce noise and/or to prepare images for further processing. The entropy measure was used as a threshold to obtain the binary images where the trash pixels were separated from the lint pixels (figure 2). The binary images were then processed to obtain various features for use by a back propagation neural network to categorize the trash objects. Neural network weights previously generated from features collected from hand made training samples of bark/grass, stick, leaf, and pepper trash were used to categorize the trash objects (Siddaiah et al., 2000 and 2002). The neural network algorithms generated summary reports with counts of the four categories of trash along with the percent trash measurement for each cotton sample. In addition to the summary reports, images with the four categories of trash identified and labels with different colors were produced. Bark/grass objects were marked cyan, stick objects golden, leaf objects green, and pepper trash pink (figure 3). These images with trash identified and color coded allowed for easier evaluation of CITS with the classer calls.

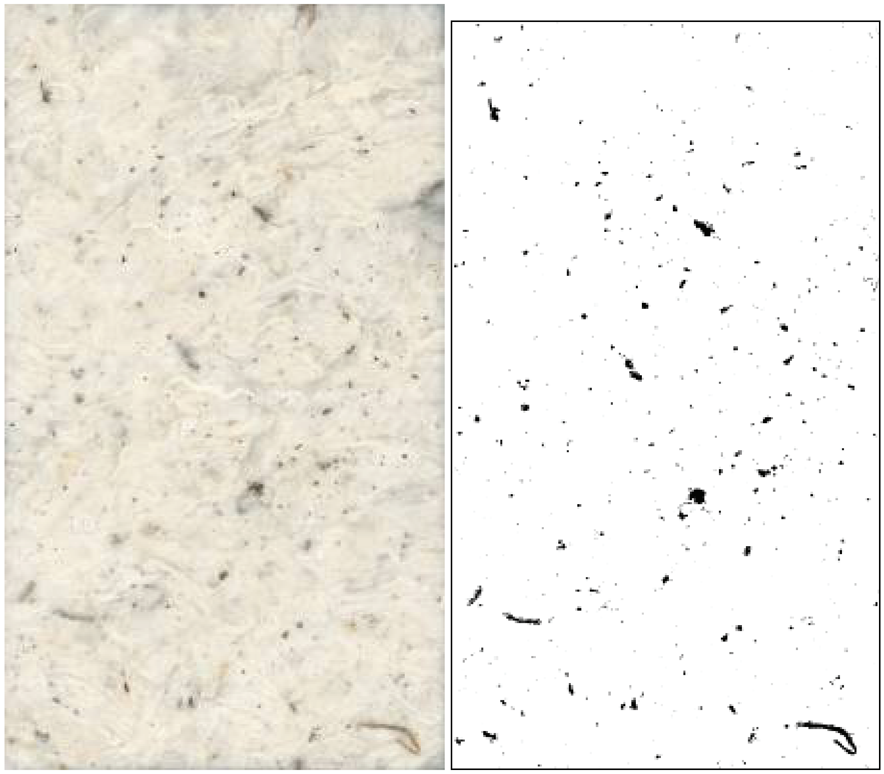

Figure 2. Cotton sample image with its thresholded binary image.

Figure 3. Trash identified and labeled image.

AMS Classing Data

Images were acquired by AMS classing officers at the USDA, AMS, Cotton Program, Standardization & Engineering Branch, Memphis, TN. Four images (called faces) were acquired from each classer sample. The classer noted the presence of EM in each of the faces. The EM call, if any, along with the leaf grade was assigned to each face. Images of each face were acquired at 400 DPI and 800 DPI scanner resolutions. The scanner acquired images along with classing information were stored on data disk for analysis. The acquired images were analyzed with CTIS at the SWCGRL to generate the trash identification summary reports. There were a total of 209 USDA-AMS (bale) classer samples that were used in the analysis. The classing officers acquired a total of 836 faces, both at 400 DPI and 800 DPI resolutions.

Results and Discussion

In order to evaluated CTIS, comparisons were made between AMS classer EM call for the 836 cotton faces and CTIS bark/grass categorization for the corresponding 836, 400 DPI images. The AMS classer EM call with leaf grade and the CTIS categorization for the labeled image in figure 3 are shown in table 1. The sample had a classer EM call of 11 (bark) and CTIS categorized 9 objects as bark or grass. Accuracy of the CTIS bark/grass categorizations for the 836 cotton faces analyzed is summarized in table 2. Of the 836 faces, 75 faces had a classer EM call of either 11 or a 21 (bark or grass). Of the 75 faces with AMS classer EM calls, CTIS identified the presence of bark/grass in 73 faces (96%). Out of the remaining 760 faces with no classer EM calls, CTIS categorized no EM in 121 faces (16%). The CTIS identified bark/grass objects in the remaining 639 faces with no classer EM calls.

Table 1. AMS classer calls and CTIS trash categorization for the sample shown in figure 3.

AMS Classer	
Leaf Grade	4
Extraneous Matter Call	11
CTIS	
Bark/grass count	9
Stick count	52
Leaf count	176
Pepper count	455
Total count	692
% Trash	1.11

Table 2. Accuracy CTIS bark/grass categorization of images with and without classer EM calls.

	Classer Call	
	Extraneous Matter	*No* Extraneous Matter
	--------------------No. of cotton faces --------------------	
CTIS bark/grass categorization	73 (correct)	639 (Type II error)
No CTIS bark/grass categorization	2 (Type I error)	121 (correct)

As seen in Table 2, CTIS identifies bark/grass objects in a significantly high number of images that had no classer EM call. Figure 3 and table 1 shed light on this issue. The number of objects that are categorized as bark/grass objects is high in the image and it is clear that certain objects maybe mis-categorized as bark/grass objects or the categorization as bark/grass is meaningless due to their very small size.

Some of the reasons for such a high number of images with bark/grass identification are:

1. Poor segmentation due to inadequate compression over large area.
2. Artifacts of buried trash segmentation resulted in misidentification.
3. Higher resolution images permit segmentation to capture more buried trash.
4. CTIS identifies very small objects as EM that the classer would ignore as insignificant due to size or call as leaf.

In order to improve the categorization accuracy of CTIS, various techniques were explored to obtain conformity with the classer calls. Images acquired at 400 and 800 DPI images appear to have buried trash objects erroneously identified as numerous objects in the segmented binary images. The quality of the segmented images deteriorated for the 800 DPI acquired images. Thus, images acquired at 800 DPI resolutions were not included in the analysis of the data for this manuscript.

The CTIS categorization was performed on lower resolution images. The 400 DPI images were converted to 200 DPI images using the ACDSee© Photo Software. Table 3 summarizes the comparison of the CTIS bark/grass categorization at 400 and 200 DPI resolutions for the 760 images that had no corresponding classer EM call. Decreasing the resolution increased the accuracy of CTIS. The number of images with no CTIS bark/grass counts increased from 121 to 322. Also, the images with 1 or 2 CTIS bark/grass counts increased, whereas the images with higher counts decreased by 24%, 51%, and 88% for 3, 4, and > 4 CTIS bark/grass counts, respectively. These results indicate that there may exist a threshold level of continuous CTIS bark/grass count that will coincide with the yes/no EM call of the classer.

Table 3. Comparison of CTIS bark/grass categorization between 400 DPI and 200 DPI resolutions for images with No classer EM calls.

	Image Resolution	
No. objects categorized as bark/grass	400 DPI	200 DPI
	---------------No. of faces ---------------	
none	121	322
1	91	179
2	72	125
3	80	61
4	68	33
> 4	328	40

When human classers assign EM calls to cotton samples, there is little information with regards to decision making process. There is need for additional input about other attributes (such as numbers, size, distribution, etc.) that the human classer considers when assigning classer calls to cotton samples. Towards this end, a new set of images was acquired by AMS, where the human classer identified the EM objects in each face when an EM call was assigned. Figure 4 shows an example image with classer's marks (circled objects on printed image) identifying the EM that warranted an EM call of 11 (bark). Future research will use this information to better understand the assignment of EM calls (i.e. the size limits and number of EM objects prompting an EM call, etc.). Algorithms within CTIS will be modified accordingly to gain better agreement between CTIS system performance and the human classer.

Summary

AMS cotton samples with EM were analyzed with the Cotton Trash Identification System to evaluate its performance in identifying bark/grass trash found in cotton. The preliminary results show that CTIS agreed fairly well with the classer in the identification of bark/grass in cotton samples. CTIS categorized bark/grass in 97% of the samples with a classer EM call and did not categorize bark/grass in 42% of the samples with no classer EM call. Additional input is required from AMS classers with regards to the decision making process in terms of numbers, size, and distribution of EM when assigning EM calls. This information will be used to modify CTIS algorithms to increase the systems accuracy in predicting classer EM calls. Hardware modifications to obtain a more uniformly compressed sampler during image acquisition need to be evaluated. Better thresholding techniques, and better, and larger training data sets for the neural network algorithms could reduce the effects of artifacts during segmentation. The current CTIS may aid the cotton industry in identifying the presence of EM.

Figure 4. Classer identified objects when assigning extraneous matter call.

Disclaimer

Mention of a trade name, proprietary product, or specific equipment does not constitute a guarantee or warranty by the U.S. Department of Agriculture and does not imply its approval to the exclusion of other products that may be suitable.

Acknowledgements

The authors would like to thank AMS, Cotton Program for their support and/or active participation in the project.

References

Agricultural Marketing Service. 2001. The classification of cotton. Agricultural Handbook 566. Agricultural Marketing Service, USDA ARS, Washington, DC. 24 pp.

Siddaiah, M., M.A. Lieberman, S.E. Hughs, and N.R. Prasad. 2000. Identification of trash types and correlation between AMS and SWCGRL trash content in ginned cotton. Proceedings of the Beltwide Cotton Conference. San Antonio, TX. 4-8 Jan. p. 1549-1555.

Siddaiah, M., M.A. Lieberman, S.E. Hughs, and N.R. Prasad. 2002. Automation in cotton ginning. Proceedings of the Beltwide Cotton Conference. Atlanta, GA. 8-12 Jan.