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COMPARISON OF SMALL TRASH MEASUREMENTS BETWEEN IMAGING TECHNIQUES AND AFIS

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Abstract

This paper discusses the identification of small trash objects in cotton using a machine vision based system; Cotton Trash Identification System (CTIS). Digital camera based (CTIS-Camera) and scanner based (CTIS-Scanner) systems were used to identify objects in target drawings, USDA-AMS Trash Under-Glass boxes, and cotton extracted at three locations in the gin. CTIS-Scanner evaluated scanner resolutions to accurately measure dust size objects. Measurements for trash count and trash area for Trash Under-Glass boxes were compared to High Volume Instrumentation (HVI) measurements. Machine vision results for trash, dust, and total count measurements were compared to Advanced Fiber Information System (AFIS) measurements. CTIS-Scanner first identified an optimum resolution (dpi) for measuring cotton dust. Comparisons were made among CTIS-Camera, CTIS-Scanner, and AFIS measurements. CTIS-Scanner measurements correlate well with HVI measurements on Trash Under-Glass boxes for trash count and percent trash (R^2 = 0.9858 and R^2 = 0.9932 respectively).

Introduction

Cotton is a natural fiber and in its raw form contains both lint and non-lint material. The cotton fiber is called lint and all extraneous matter is called non-lint material or trash. Currently 15-20 million bales of cotton are produced in the United Sates each year. All cotton grown in the United States is mechanically harvested. The term *ginning* refers to the process of separating the cotton fiber from cottonseeds. Seed cotton refers to the harvested cotton that enters the gin for processing. Before the fiber can be separated from the seed, most large extraneous material is extracted from the seed cotton. Following ginning, lint cleaning is performed to remove smaller trash. Modern gins produce more ginned cotton at a faster rate than their predecessors. Due to the presence of small trash in ginned cotton and increased textile mill sensitivity to small trash, techniques are required to better understand trash levels and sizes.

Certain quantities of trash remain in baled cotton despite advances made in harvesting, seed cotton cleaning, ginning, and lint cleaning equipment. Amount and types of trash in lint depend upon the quality of seed cotton entering the cotton gin. The amount and types of trash in cotton vary depending on the region, variety, and harvesting techniques (machine picked or machine stripped), which require various cleaning regimes. The main source of trash contamination in cotton is the plant foliage (stem, bark, leaf, grass, hulls, etc). These trash objects are usually collected along with the seed cotton during harvesting. Many trash objects are removed and some are reduced in size during seed cotton cleaning, ginning, and lint cleaning and become more problematic to extract without the loss of useful fiber. For example, large pieces of leaf particles are broken into smaller trash objects. The stem outer covering is stripped and ends up as bark objects, which are left behind in the ginned cotton.

The amount of trash present in cotton is represented by the leaf grade for classification purposes. The United States Department of Agriculture-Agricultural Marketing Service (USDA-AMS) grades cotton based on High Volume Instrumentation (HVI) measurement (Agricultural Marketing Service, 1993). The cotton trash measurement (percent surface trash area) computed by a scanning video camera is correlated to the classer's leaf grade (1 through 7 and a 'below grade'). The leaf grade represents the quality of cotton for marketing purposes.

Techniques that are currently available for the identification of trash in cotton include the Shirley Analyzer, Advanced Fiber Information System (AFIS), and High Volume Instrumentation (HVI). The Shirley Analyzer is a gravimetric measure that indicates the amount of total trash present in cotton samples. Trash measurements from AFIS include the percent content of foreign matter or visible foreign matter (dust and trash). The measurement is by an optical sensor and categorizes the trash objects in terms of the equivalent diameter of the objects. Trash objects of size 254-1016 microns (0.01-0.04 in.) are generally referred to as pepper trash (Baker et. al. 1992). Particles that fall between 0-15 microns (0-0.0006 in.) are called respirable dust, 15-50 microns (0.0006–0.002 in.), micro dust. All objects 50-500 microns (0.002-0.02 in.) are categorized as dust particles and all objects larger than 500 microns (0.02 in.) are categorized as trash (Foulk et. al. 2003). An AFIS histogram of the number of objects in 50 micron increments up to 2000 microns with trash objects ≥ 2000 microns (equivalent diameter) is provided along with the trash count and dust count per gram of cotton (Zellweger Uster®, Knoxville, TN). HVI trash measurements are reported in terms of percent trash and trash grade. The HVI trash measurement does not typically present types or size of trash objects found in cotton. Currently, no commercial techniques exist that can be accurately used in the cotton industry to categorize the trash objects in raw cotton (Siddaiah et. al. 2004).

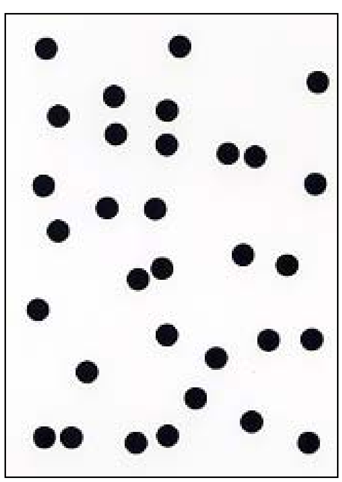
This research is to evaluate the feasibility of a machine vision based system for the identification of small trash and categorization of trash for use by the cotton industry for process control. This paper presents a comparison of trash measurements from the Cotton Trash Identification System (CTIS) using a digital camera (CTIS-Camera) and a scanner (CTIS-Scanner) based systems developed at the Southwestern Cotton Ginning Research Laboratory (SWCGRL). These measurements were compared with AFIS measurements.

Materials and Methods

Target Drawings

Target drawings with solid circles (dots) of varying sizes were drawn using the AutoCad Mechanical 2004, and printed using a Hewlett Packard 1220c DeskJet printer at 1200 x 1200 dpi resolution on Hewlett Packard Photo Paper. This was done to evaluate optimal parameter settings for the acquisition of images on an Epson Perfection 3170 Photo scanner. The main objective was to evaluate the best scanner resolution settings to identify the smallest possible particle size. Dots of sizes 0.16, 0.08, 0.04, 0.02, 0.01, 0.008, 0.006, 0.004 and 0.002 inches (4064, 2032, 1026, 507, 254, 203, 152, 102, 51 microns, respectively) in diameter were used. Images of the various dots at different scanner resolutions were acquired.

Scanner resolutions were set to 72, 200, 400, 600, 800, 1200, and 2400 dpi. Only drawings with dots of size 0.16 inch diameter (4064 microns) and 0.08 inch diameter (2032 microns) were able to be scanned at 2400 dpi due to computer display memory limitations. The scanned images were segmented using an entropy measure where the objects were separated from the white background. The acquired images were processed for area measurement and dust, trash, and total counts by *CottonEye* the image analysis software package developed at the SWCGRL. The *CottonEye* processing package used the Matrox Imaging Library (MIL Ver. 7.5) image processing software, along with custom algorithms to process cotton images to identify trash. Figures 1 and 2 represent the acquired raw image and the segmented binary image for the largest dot size (0.16 inch diameter, 4064 microns) and the smallest dot size (0.002 inch diameter, 51 microns) at 800 dpi scanner resolution, respectively. In both figures, images are surrounded by an artificial solid perimeter. In Figure 2 all the objects are within the artificial dashed region.



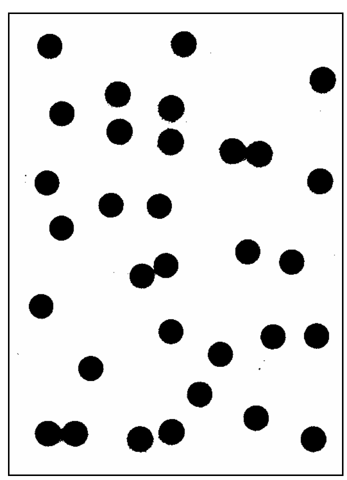


Figure 1. Raw and segmented images, dot size 0.16 inch diameter (4064 microns).

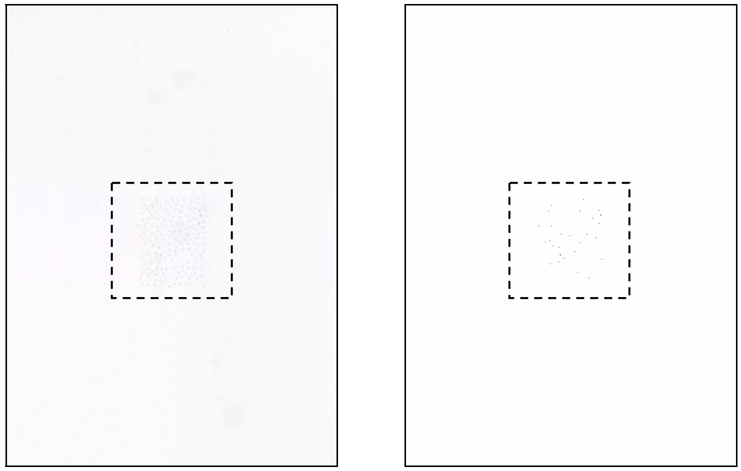


Figure 2. Raw and segmented images, dot size 0.002 inch diameter (51 microns).

Trash Under-Glass

Trash Under-Glass boxes prepared by the USDA-AMS, which serve as check samples for trash measurements of the HVI, were used to measure trash count and percent trash with CTIS systems. The six, Trash Under-Glass boxes with varying trash counts and percent trash were analyzed to determine the effectiveness of the scanner system. Measurements were made on these Trash Under-Glass boxes which had 13, 23, 37, 48, 54, and 60 trash objects with percent trash of 0.27, 0.42, 0.9, 1.42, 1.74, and 2.87 respectively. A total of five images of each trash box were scanned at 800 dpi scanner resolution. Figure 3 illustrates the scanned cotton image and the thresholded binary image with the minimum trash (0.27%). Figure 4 represents the images with the highest percent trash (2.87%). Percent trash results from the CTIS-camera system on the same set of trash boxes were reported under a previous study (Siddaiah et. al. 2000).

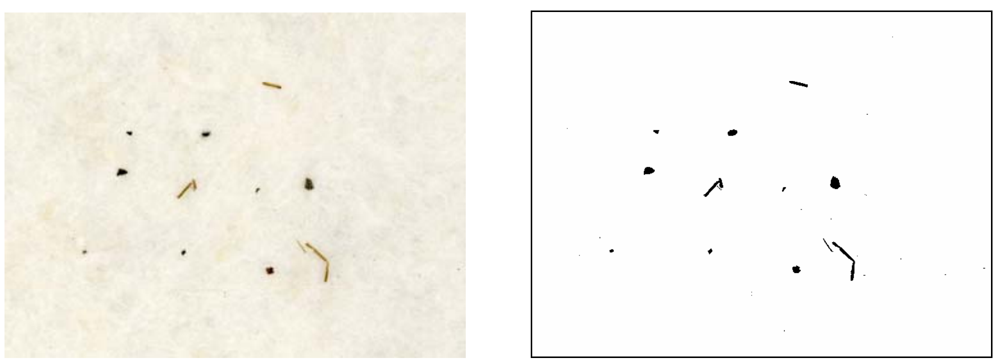


Figure 3. Raw and segmented images, Trash Under-Glass box 1 (0.27 percent trash).

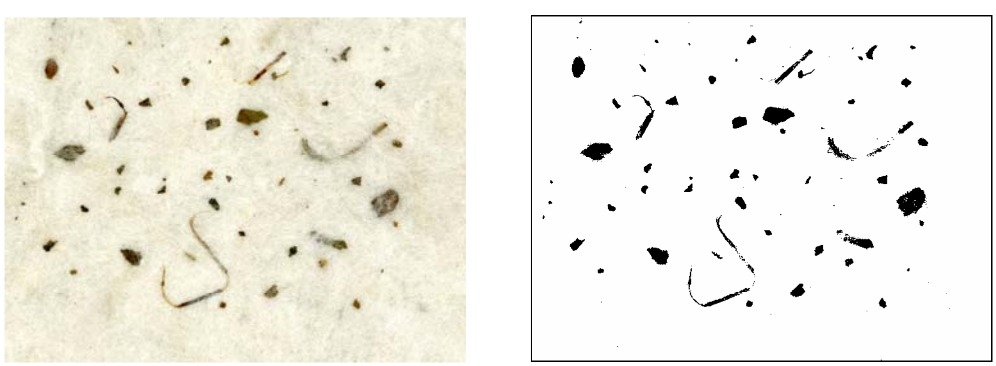


Figure 4. Raw and segmented images, Trash Under-Glass box 6 (2.87 percent trash).

Cotton Samples

Cotton samples from a defoliation test conducted at SWCGRL were analyzed for percent trash and particle counts. The sample set consisted of thermally defoliated, chemically defoliated, and untreated cottons. There were a total of 36 lots of cotton. Two lint sub-samples were collected for each lot at three different locations at the gin. The two lint sub-samples were collected after the gin stand, after the first lint cleaner, and after the second lint cleaner. There were a total of 216 cotton samples. Images were acquired using the CTIS-Camera and CTIS-Scanner systems and evaluated using *CottonEye*. Figures 5 though 7 represent the cotton images and the segmented images at the three different locations.

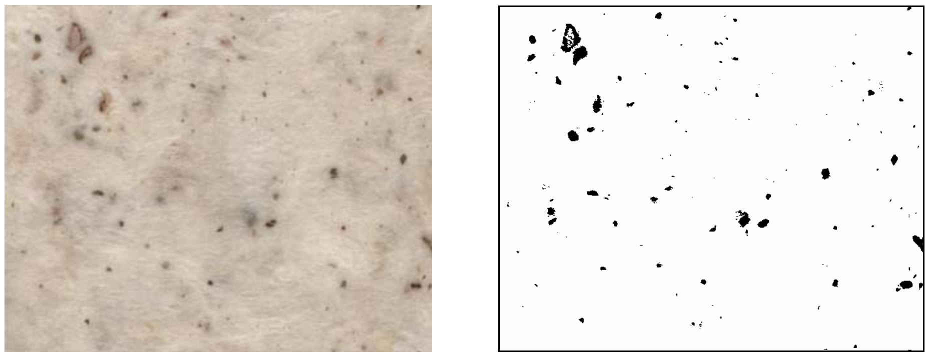


Figure 5. Cotton and segmented images, CTIS-Camera (after gin stand).

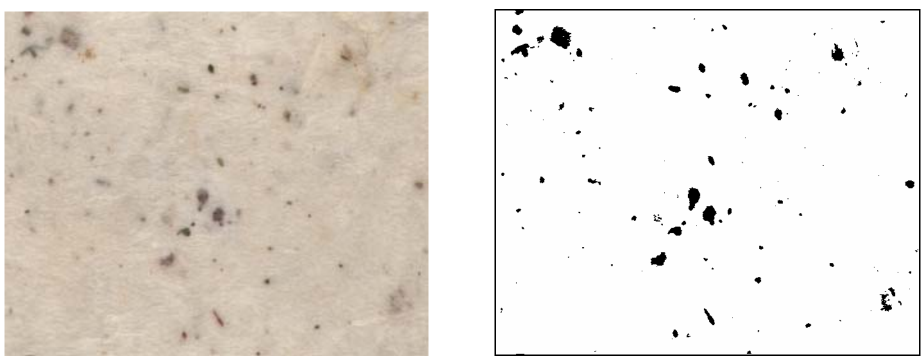


Figure 6. Cotton and segmented images, CTIS-Camera (after first lint cleaner).

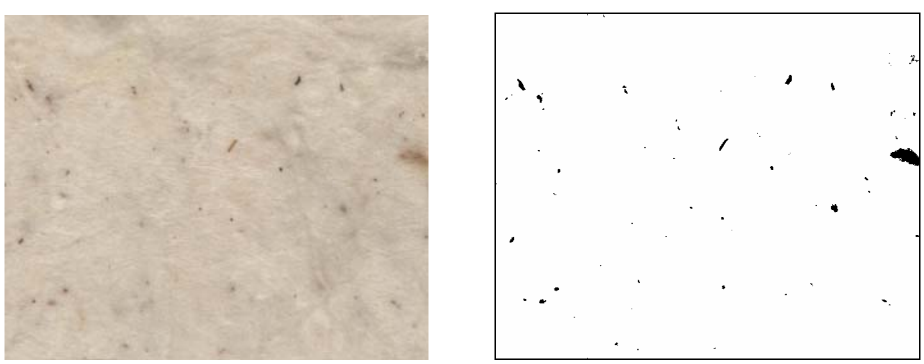


Figure 7. Cotton and segmented images, CTIS-Camera (after second lint cleaner).

The CTIS-Camera system acquires images using a RGB color camera and the Matrox® family series imaging boards. The acquired images were flat field corrected to remove spatial illumination non-uniformity (Lieberman and Patil, 1997). Trash pixels were separated from the cotton lint background (segmented) using an entropy threshold on the intensity (luma) plane in HLS (Hue, Luma, Saturation) color space to obtain a binary image where each trash object are identified (Siddaiah, et al., 1999a,b, 2000, 2002a,b).

The CTIS-Camera acquired images of size 1280 x 1024 pixels (3.2 in. x 2.4 in. viewing area, 7.68 in^2) for a pixel resolution of 0.0025 in. *CottonEye* uses a minimum object size of 2 pixels. The *CottonEye* identifies the trash objects in cotton images and computes the area (A) of the trash objects in terms of $microns^2$. The equivalent diameter of the trash objects are computed based on the area of the trash objects using,

$$\text{Equivalent diameter} = \sqrt{4 * A / \pi}. \tag{1}$$

A total of 10 images were acquired for each lint sub-sample and used to compute trash, dust, and total counts and percent trash. If the total trash area (sum of areas of all trash objects in the image) of any image was within mean ± 3-standard deviations of the image set, the image was included in the image set. This allows for the machine exclusion of images that may include voids, shadows, or cotton samples that are not fully covering the imaging window. This also rejects poorly segmented images.

The CTIS-Scanner system scanned images of size 2560 x 1920 pixels (3.2 in. x 2.4 in. viewing area, 7.68 in^2) at a scanner resolution of 800 dpi. A total of 5 images for each lint sub-sample were used to compute trash, dust, and total counts. Figures 8 though 10 represent the cotton images and the segmented images at the three different locations.

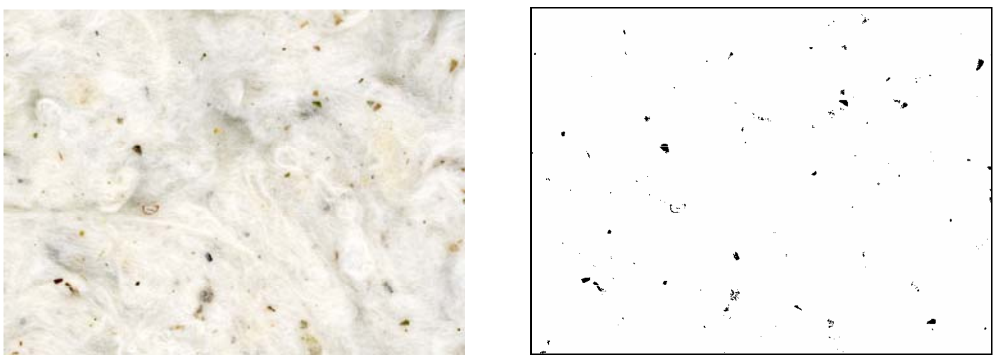


Figure 8. Cotton and segmented images, CTIS-Scanner (after gin stand).

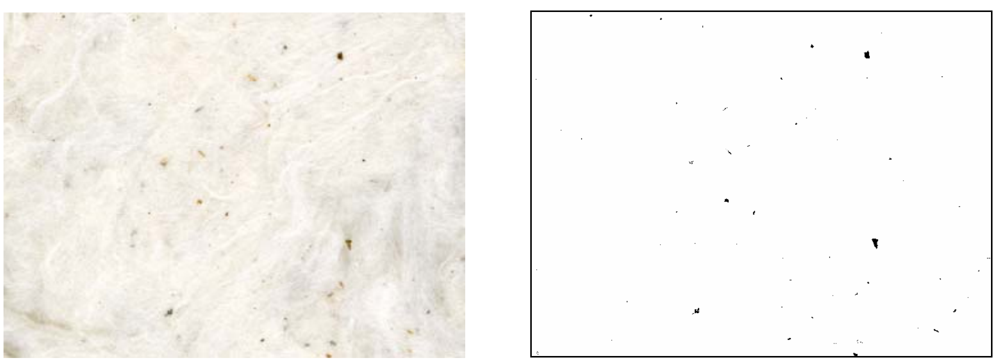


Figure 9. Cotton and segmented images, CTIS-Scanner (after first lint cleaner).

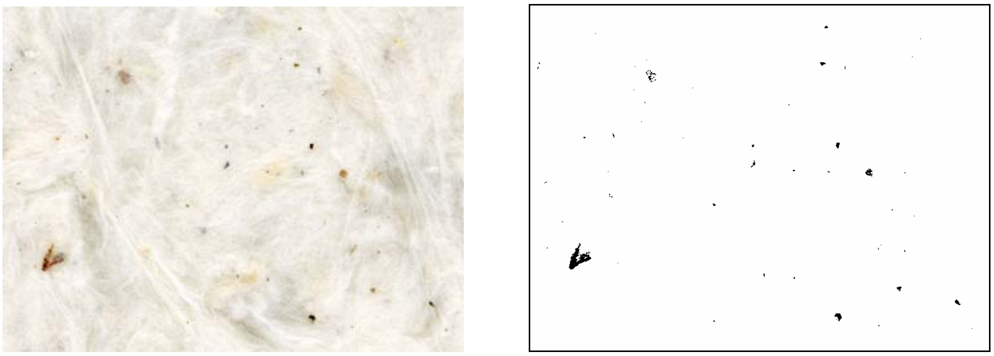


Figure 10. Cotton and segmented images, CTIS-Scanner (after second lint cleaner).

Results and Discussion

Table 1 illustrates the count measurements of the various dots at the different scanner resolutions. As mentioned earlier all objects less than 500 microns are considered as dust particles. With higher scanner resolution more objects are identified as dust particles. This is due to the inherent presence of defects on the photo paper and due to artifacts during segmentation and the presence of ragged edges of the drawn objects. However, when considering cotton samples the trash distribution is wide with objects of various sizes and would identify the objects based on the size of the actual trash object. In Table 1, there are no dust counts at 72 dpi as one "pixel" is greater than the size of dust. All objects of size less than 0.02 in. diameter (500 microns) are the size of dust; hence there are no trash counts. As the table indicates the best resolution for the identification of objects of size 0.002 in. diameter (51 microns) was between 600 and 800 dpi. A scanner resolution of 800 dpi was used to acquire the cotton sample images. The actual trash counts for the most part are usually smaller at the various resolutions. This is due to the proximity of the object in the tile. During segmentation they are identified as a single object. Further evaluation of image processing algorithms (binary erode, thinning) may result in more accurate trash and dust counts.

Table 1. Count measurements of dots at various resolutions.

Dot Diameter		Resolution (lines/in)	72	200	400	600	800	1200
(inches)	(microns)	Actual Count	CTIS-Scanner, *CottonEye* Trash Count / Dust Count					
0.16	4064	32	31/0	30/46	29/84	29/292	29/489	29/1177
0.08	2032	64	66/0	62/37	60/34	60/100	60/199	60/443
0.04	1016	96	85/0	86/6	85/17	85/45	85/122	85/213
0.02	508	128	126/0	126/5	125/62	125/103	125/263	125/549
0.01	254	160	29/0	0/161	0/175	0/190	0/221	0/243
0.008	203	160	15/0	0/157	0/169	0/195	0/217	0/274
0.006	152	160	10/0	0/148	0/160	0/176	0/185	0/202
0.004	102	160	1/0	0/45	0/158	0/167	0/174	0/187
0.002	51	160	1/0	0/35	0/150	0/162	0/164	0/167

Table 2 represents the trash count and percent trash for the scanner system and the AMS HVI measurements for Trash Under-Glass boxes. The difference between AMS and *CottonEye* counts is an artifact due to different system sensitivities to buried trash. This can be seen in Figure 4, where certain trash objects are covered with lint material and are not identified as a single object during segmentation. This might include identifying some trash objects as dust. However, good correlation exist between CTIS-Scanner, trash count and percent trash measurements with HVI measurements as illustrated in Figures 11 and 12.

Table 2. Count and area measurements vs. AMS measurements.

	CTIS-Scanner, *CottonEye* Measurements					AMS Measurements	
Trash Box	Particle Count	Dust Count	Trash Area (in^2)	Trash Count	% Trash	Trash Count	% Trash
1	165.8	153.8	0.0277	12	0.3601	13	0.27
2	338.8	314.6	0.0409	24.2	0.5328	23	0.42
3	377.2	346.4	0.0809	30.8	1.0535	37	0.9
4	685.8	641.2	0.1211	44.6	1.5762	48	1.42
5	828.4	778.2	0.1417	50.2	1.8451	54	1.74
6	1400.2	1344.4	0.2102	55.8	2.7367	60	2.87

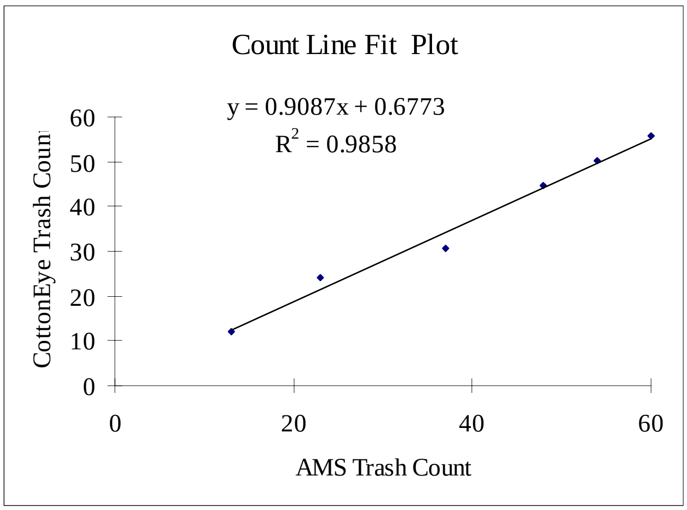


Figure 11. Coefficient of determination: CTIS-Scanner, *CottonEye* and AMS trash count of Trash Under-Glass.

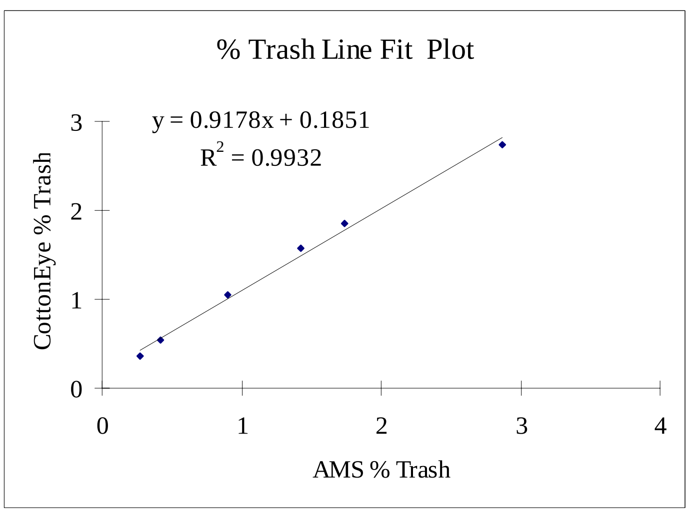


Figure 12. Coefficient of determination: CTIS-Scanner, *CottonEye* and AMS percent trash of Trash Under-Glass.

Figures 13 through 15 represent trash distribution histograms from AFIS, CTIS-Scanner, and CTIS-Camera system measurements. It can be observed that AFIS identifies more trash particles since it is a volumetric measure, in comparison to the CTIS categorization where only the surface of the cotton sample is analyzed. AFIS measurements are the average of 3 reps of 0.5 gram cotton samples as compared to an average of "n" images each with a viewing area of 7.68 in^2 (n = 10 for the CTIS-Camera system and n = 5 for the CTIS-Scanner system). The scanner system identifies more trash objects than the camera system due to the smaller pixel size. The histogram distribution exhibits an exponential decay as the size of the trash objects increases. Two observations from figure 13. For CTIS-Camera, the 50-100 micron interval count is lower compared to the 100-150 micron interval as two-camera pixels have an equivalent diameter ≅ 90 microns, missing many dust particles. CTIS-Scanner count is greater than AFIS count in the 50-100 micron interval but lower in other intervals. This might be related to the scanner interpreting larger objects as a larger one or more smaller object.

The images acquired by the camera system are more homogenous as cotton samples are pressed against a glass plate. The scanner system images were not compressed and as such the surface of the scanned images may include artifacts due to shadows and holes. These artifacts can result in an erroneous measurement of the trash and dust counts due to segmentation defects. The correlation between AFIS, CTIS-Camera and CTIS-Scanner systems are summarized in Table 3. Better correlation exists for the percent trash, trash count and total count between AFIS and the CTIS-Camera System. However the CTIS-Scanner system identifies more dust particles and correlates better with the AFIS measurements. Both findings are understood by comparing "pixel" sizes to trash/dust sizes. Further research needs to be conducted to evaluate the reliability and repeatability of both the CTIS systems and evaluate how close the trash count and dust count measurements track with AFIS measurements.

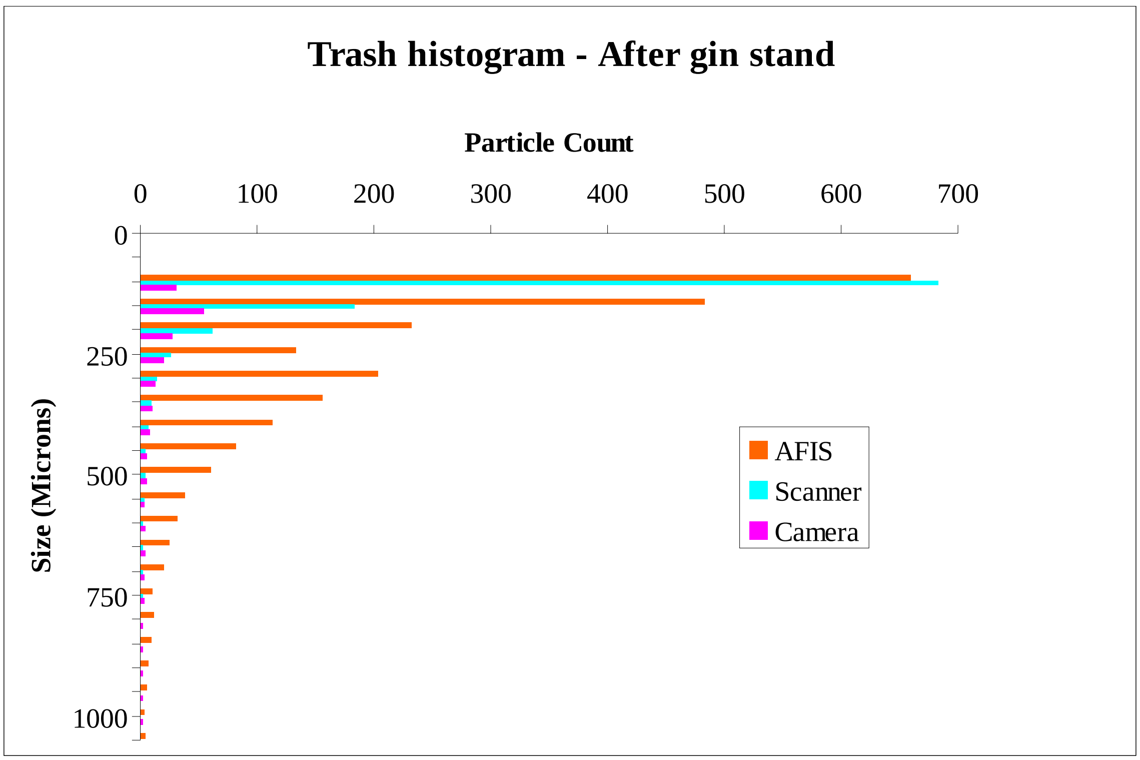


Figure 13. CTIS and AFIS trash distribution histogram of (after gin stand).

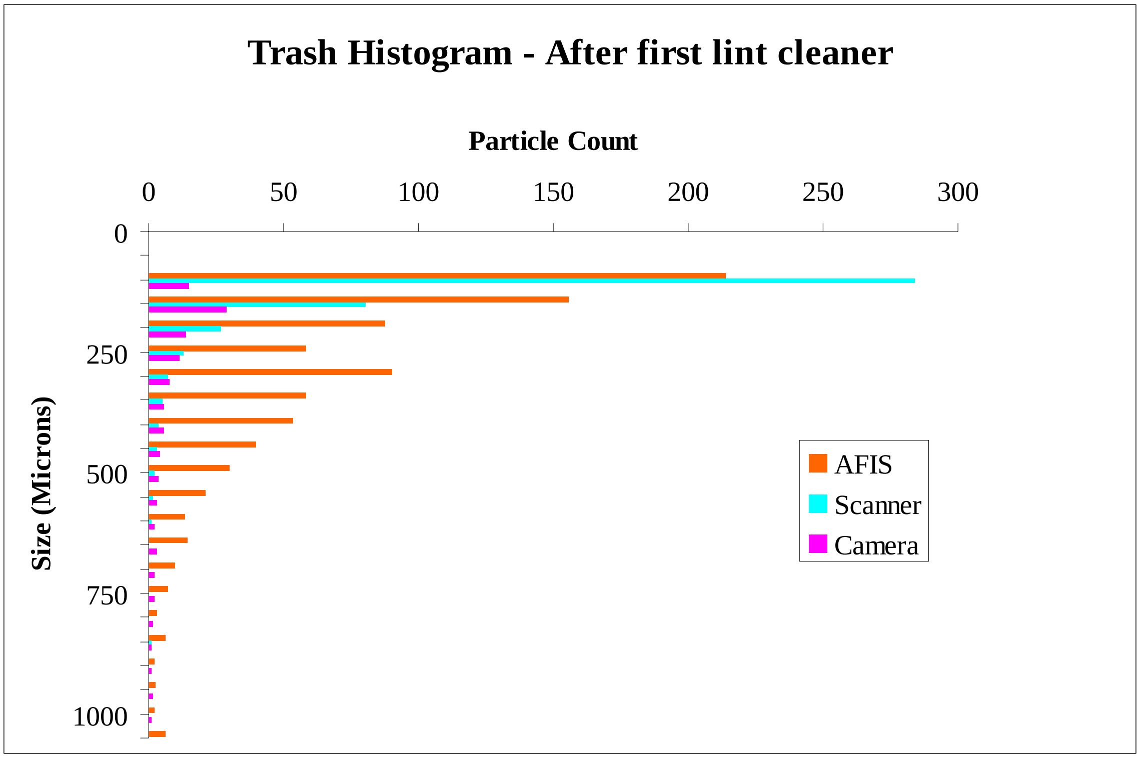


Figure 14. CTIS and AFIS trash distribution histogram of (after first lint cleaner).

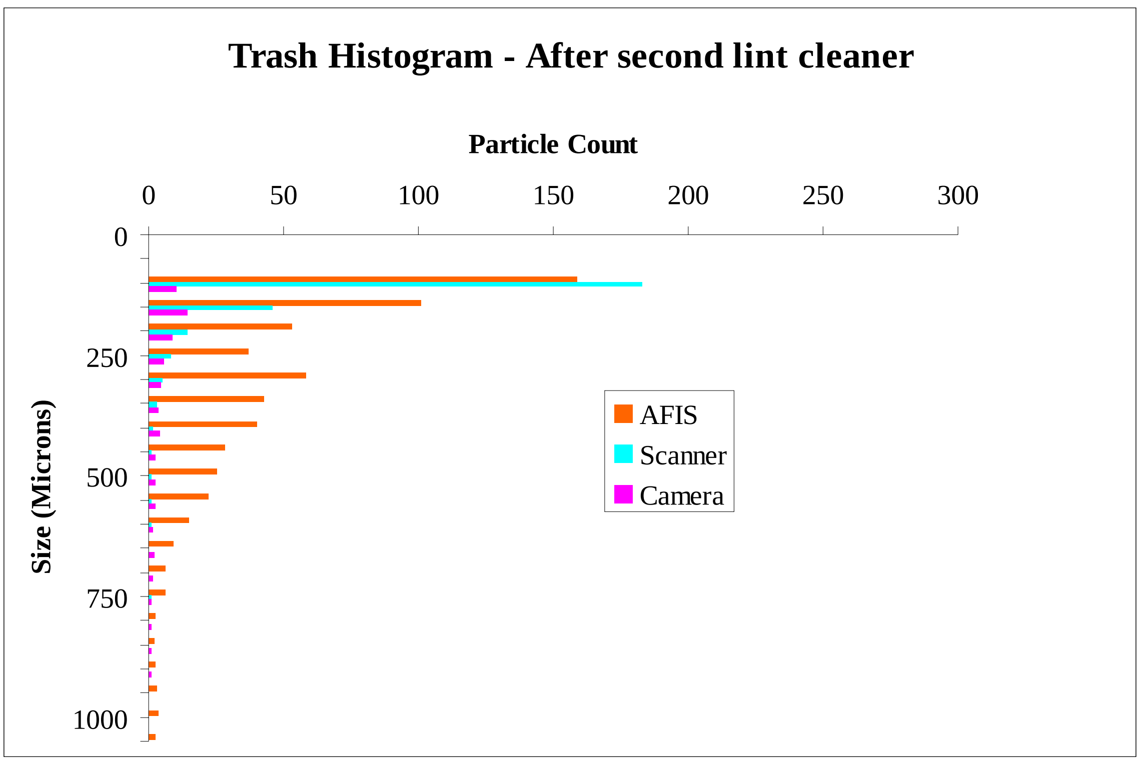


Figure 15. CTIS and AFIS trash distribution histogram of (after second lint cleaner).

Table 3. Coefficient of determination (R^2): CTIS and AFIS measurements.

Station	Systems	% Trash (R^2)	Total Count (R^2)	Dust Count (R^2)	Trash Count (R^2)
After Gin Stand	AFIS vs. Camera	0.7340	0.8756	0.3811	0.9241
	AFIS vs. Scanner	0.5544	0.6147	0.6049	0.6590
	Camera vs. Scanner	0.4507	0.5917	0.2486	0.6403
After First Lint Cleaner	AFIS vs. Camera	0.4632	0.7896	0.3426	0.8139
	AFIS vs. Scanner	0.2242	0.5359	0.5287	0.7294
	Camera vs. Scanner	0.1858	0.4719	0.2221	0.6517
After Second Lint Cleaner	AFIS vs. Camera	0.7238	0.8509	0.5500	0.8142
	AFIS vs. Scanner	0.5512	0.7538	0.7497	0.6347
	Camera vs. Scanner	0.6812	0.7063	0.3524	0.7635

Conclusion

Categorization of trash objects in cotton was performed using camera based and scanner based imaging systems. The trash objects were categorized into various size categories based on the equivalent diameter of the trash objects. The CTIS trash, dust and total counts were compared to AFIS measurements. Work is required to optimize the process of locating hidden trash, proper sample pressure, and relationship with HVI results. Future research for on-line identification of trash objects to individual categories could be useful for the spinning industry for process control. The impact of such a system is wide ranging and could have significant benefits to the entire cotton industry.

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.

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