NON-CONTACT IMAGE PROCESSING FOR GIN TRASH SENSORS IN STRIPPER HARVESTED COTTON WITH BURR AND FINE TRASH CORRECTION

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Abstract

This study was initiated to provide the basis for obtaining on-line information as to the levels of the various types of gin trash. The objective is to provide the ginner with knowledge of the quantity of the various trash components in the raw uncleaned seed cotton. This information is currently not available to the ginner for use in optimizing the gin machinery. An existing Kodak trilinear array color ccd line scan imager was connected to a PC in a laboratory environment. Due to the high levels of trash in stripper harvested cotton, an 8.0 in. by 10.0 in. viewing area was used thereby providing 100 pixels per inch of resolution. Images of seed cotton (taken from various stages in the pre-ginning cleaning process) were obtained without pressing the seed cotton against glass plates. This omission, of a standard cotton image acquisition technique, increases the opportunities for image acquisition in the gin to obtain the gin trash levels for use in optimal gin control by removing the necessity of capturing a sample of seed cotton to press against an imaging plate. Algorithms were developed to differentiate between: seed cotton, the various trash components and the background. Once the individual components were identified, an algorithm was developed to determine the levels of the various trash components; sticks, burrs, and leaves. Once this determination was obtained this information was then used to correct the total fractionated weight measurement.

Introduction

In the continuing quest to reduce cotton ginning production costs and to maximize returns to the grower new process control equipment has been recently developed for cotton gins. Anthony and Byler (1994) indicated that process control can range from $15,000 to $100,000 and return up to $7 per bale in lint savings. Most of the work to date has involved the online measurement of moisture and trash. Anthony (1990) reported on a system which used a dynamic programming model along with black and white video trash sensors to determine the optimum number of lint cleaners required for proper cleaning while minimizing the lint waste in order to optimize the returns to the grower.

It is inevitable that the cotton gins in the near future will become fully computerized and automated (Byler and Anthony, 1997). This is due to the fact that optimal control of the gin will increase quality and reduce production costs (Bennett et al, 1997). This will be advantageous to the growers, the ginners, and the processing mills as they will receive a consistent product that can be tailored to their desired specifications. In this regard, we expect the gins to become fully automated in the near future as this technology undergoes further development and becomes commercially available. It has already been shown that this automation will utilize some form of trash measurement system at several key locations scattered throughout the ginning process.

The majority of cotton produced in Texas is stripper-harvested. This inexpensive harvesting technique results in large amounts of trash contamination of the seed cotton. The current cleaning techniques present a tradeoff between trash removal and loss of the valuable lint. It has been recognized that the growers profit can be maximized by adjusting and reducing the seed cotton and lint cleaning equipment. The optimum number of seed cotton and lint cleanings can be determined if the trash content and turnout is known (Baker, 1994).

One of the major problems facing producers and ginners in the stripper harvested area is the presence of large variations in the trash content levels. Additionally the recent innovation of the field cleaner for stripper harvesters has intensified this variation. We feel that this variation leads to a wide range of optimal gin machinery settings for stripper harvested seed cotton cleaning.

This research was pursued to develop an automated method by which the trash content can be accurately determined and measured for use in gin automation. Gin automation is desirable as it will lead to an increase in the net economic yield for the grower, and will also help to reduce ginning costs (Anthony, 1990).

Trash Measurement

Current trash measurement systems in use today all require a physical sampling of the seed cotton in order to obtain both color and trash (lint only) measurements. Byler and Anthony (1997) reported on one of these computer-based systems that was used to control the drying and cleaning machinery selection. This system was installed at Servico Gin in Courtland, AL, in 1994. It was reported to be the most complete computerized gin process control system in the world. This process control system utilized two trash level sensors. The trash sensors were based upon a color/trash camera similar to the High-Volume-Instruments (HVI) that

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are used in the classing office. The first sensor was located opposite of a ram located in the back of the feed control. The ram was periodically extended to press cotton against a glass sample imaging plate. The second color/trash /moisture measurement station was located behind the gin stand and before the lint cleaners. A paddle sampler was used to obtain a sample from the duct and press the sample against a viewing window.

Anthony (1989) reported that sample compression against an imaging window was used to increase the sample density in order to produce a more repeatable image by minimizing the shadows which produced a confounding effect on the image processing which resulted in unacceptable errors. Even with the additional complexity of the machinery to press the lint against a glass imaging plate, the coefficient of determination was still only reported to be $r^2 = 0.62$ and $r^2 = 0.72$ for the two trash measurement stations located at the feed control. The sample compression system was an integral and critical component of the system as evidenced by several device patents that were issued to the USDA (Patent, 1992). The main patent was obtained for a paddle sampler to accomplish the sample compression for the trash, moisture and color measurement. It is still in use to date in the Zellweger Uster Intelligin and was reported to be fully functional in two commercial gin's as conducted in a USDA study (Anthony et al, 1995).

The modern classing methods and use High-volume-Instruments (HVI) systems to measure trash content and lint color. The trash content and the lint color are currently measured by a composite instrument that is composed of a black and white video camera for the trash content determination and a two color-filtered silicon based optical sensor to measure the two color components used in the classing system: brightness (Rd) and yellowness (+b). Analysis of a two-dimensional black and white image is used to express the percent of the surface area covered by non-lint particles. The algorithm is based upon applying a reflectance threshold to the image. This turns the image into a binary image composed of either lint or of everything else (trash, shadows, spots, or any holes and voids etc) (Thomasson, et al. 1997).

By carefully placing a sample on an HVI instrument with care taken to avoid voids and shadows in the samples (that will be miss-classified as trash) the system works reasonably well. However, for an automated on-line system this may not always be the case and errors are bound to occur. As such this technique has the disadvantage in its inability to separate the trash from any holes that may appear in the sample when pressed up against the glass imaging plate. This results in an increased error in the measurement.

Another disadvantage to this technique is the need for pressing the cotton against a glass plate, as this restricts the possible locations where this technique can be applied in a cotton gin. However, this technique does have the advantage for very small trash identification and as such has been the preferred technique for the final classing of cotton for use in the classing office. By far the most work has been done with this goal in mind with notable work by the following.

Leiberman, 1997 reported the ability for shape discrimination for trash into the groups bark, sticks, or leaves/pepper trash after partitioning the pixels into trash or lint pixels in black and white images via the standard threshold technique by utilizing Learning Vector Quantization techniques.

Occlusion of multiple light beams has also been used to measure mass flow in both 2 and 3 dimensions. The disadvantage to this technique is the inability to differentiate trash from the lint particles and the associated mass versus volume differences, which are on the order of 100% or more difference by weight. This can be readily shown through the simple observation that dried leaf particles and cotton lint cover a large area with a minimal amount of weight, yet sticks and burrs cover much smaller areas yet weigh much more. While this may not be a large problem in picker harvested areas, it may be significant in striper harvested areas as the trash content can easily reach 35% or more.

Procedure

The non-pressed seed cotton trash measurement system consists of an algorithm for use in conjunction with a video camera intended for computer recognition of the various constituent trash in seed cotton or cotton lint. The technique is designed to be performed in real-time without the need for any mechanical sample preparation or presentation of the seed cotton.

The technique involves taking an image of seed cotton in a free-form, as would occur while the cotton lays naturally upon a conveying belt, in a cotton module, in a cotton harvester's storage basket, the feed control, or falling through the air into the gin stand.

The tri-color optical technique measures the image area that is covered by trash, lint (seed cotton) and void spacings. It then processes the colors pixels to distinguish and separate each individual pixel into either trash, lint, or voids. The system then groups like pixels togeather to form objects that are then classified by geometrical and color information assiociated with the the objects into either burrs, sticks, fine trash or lint (seed cotton) in addition to removing the influence of holes from the measurements. After classifying the image objects into these separate classes, it then determines the percent fine trash content, burr trash content and burr trash content.

This information is then used to determine the trash content (on a mass basis) of the sample. It is widely accepted in the literature that an image area measurement of trash is highly correlated to the trash content on a mass basis for small amounts of leaf trash, as this is the theory behind the HVI machines in the classer's office.

The minimal necessary components of the system include:

A. A Color Video Imaging Sensor to provide image data in a digital form (pixels).
B. Computer (digital) processing for the image analysis. This provides information extracted by the previously described algorithm regarding the amount of area covered in the image by trash, cotton lint, and the background. This information is then used to determine the percentage of the trash content of the entire cotton sample.

An alternative implementation would be comprised of a solely electronic hardware implementation that mirrors the functionality of the previously described system, with the output providing either an analog or digital process control signal.

The equipment used for this study consisted of a laboratory based 2000 element Kodak line scan imager set up to obtain 640 by 480 pixels for an 10.0 in. by 8.0 in. sample yielding pixel sizes of 0.015625 in. by 0.01667. The light source was a cold cathode tube. The color for each sub-pixel element was adjusted to an industry standard color target, the Kodak Q-60 color input target (KODAK Publication No. Q-60INSTR). The Q-60 color input target is designed to correct the lighting and the pixel's color filter to provide the image color to match the true color. The Q-60 color input target is designed for use in numerical image analysis. The target design provides a uniform mapping in the CIE L*a*b* color space as defined in ANSI standard IT8.7/2. The target uses twelve hue angles and three lightnesses at each hue angle. At each hue angle there are four saturation levels.

The implementation details of the systems algorithms have been filed with the US Patent and Trademark office and are currently available for licensing through the USDA, and as such will not be discussed here.

Raw harvested seed cotton was obtained at various levels of cleaning ranging from field cleaned to non-field cleaned. The experimental design was blocked on the types of stripper harvested seed cotton (field cleaned and non-field clean) The seed cotton was then sampled at three levels of cleaning. The first level consisted of untreated freshly harvested stripper seed cotton obtained before any ginning operations had taken place (directly from the module). The second level consisted of obtaining the seed cotton after one inclined and stick machine cleaning operation. The third level was taken at the gin stand feeder apron after two incline and stick machine cleaning operations. Each sample consisted of ½ lb. (225 gm) samples with multiple replicates.

Once the samples had been obtained; two images were obtained for each sample (one image for each side of the sample, as per USDA-AMS classing office standard configuration for trash analysis) for a total of 160 images.

After all images were obtained each sample was then fractionated by USDA standard methods to determine the mass content of the sticks, burrs, fine trash, pepper trash and seed cotton. This information was then used to relate back to the information obtained via the image analysis.

A subset of 10 images were randomly selected for use in the expert classification to obtain a random sampling of representative pixels from each of the following groups: trash (leaf, sticks, burrs, and other matter), background (voids), shadow, and lint. Spots were not included as a separate class in this analysis but are expected to be included into future work.

Once the representative pixels had been obtained from each of the respective groups they were then used to form the statistical basis for the Bayes Classifier which was then applied to every pixel for each of 1/2 of the 160 images to form a calibration set (figure 1). After the calibration had been established, the rest of the images were analyzed with the trash content predicted from the calibration equation (figure 2).

Multi-variate statistical techniques were then utilized to obtain a measurement of the total mass content due to the recognized objects (burrs and fine trash). After successful recognition and separation of the burrs and fine trash, this information was then used to apply a differental weighting to each of the objects by which to improve the initial trash measurement that was based solely on an area measurement. The final calibration and validation set revealed a moderate improvement in the total mass measurment (figure 7, 8).

Results

The equipment and algorithms appeared to function well after corrections and adjustments were made. The seed cotton tested ranged from 1% trash content up to a maximum trash content level of 27% (mass basis). The computer analyzed images were then correlated to the fractionated mass values via linear regression to build a calibration equation in which to test the technique against a prediction set which was used to quantify the accuracy of the new imaging technique.

The imaging technique was found, by expert classification, to be able to discriminate between the background and the seed cotton and the trash on a small selected subset of ten training images. The calibration phase of the processing of the imaging technique was shown to provide a suitable means for determining the trash content of seed cotton (figure 1). The validation phase of the technique was found to have a coefficient of determination of $r^2 = 0.91$ (figure 2).

The optical fractionation through the use of this technique was successful at differentiating the fine trash from the burrs. The fine trash was recognized in the validation set with a coefficient of determination of $r^2 = 0.83$ (figure 4). The burrs were recognized in the validation set with a coefficient of determination of $r^2 = 0.85$ (figure 6).

Next the original trash measurement was corrected to take into consideration the various constituent components (fine trash, and burrs) to improve the total trash measurement (mass basis). A new calibration and validation set was analyzed with the improved weighting of the various trash component objects to arrive at the final total trash measurement (figure 7, 8). The validation set improved the coefficient of determination to an $r^2 = 0.92$.

Once the validity of the solution for the determination of the various trash components was verified, the solution was used to perform an optical fractionation to determine the various trash constituent components of several test images (figure 9).

Conclusions

A study was initiated to develop a technique by which to measure the trash content of stripper harvested seed cotton. One of the primary goals was to develop a technique that would allow the measurement of the trash without the necessity for pressing the sample up against a window for the measurement analysis.

The new USDA classifier was found to be able to accurately measure the trash content without the need to press the cotton sample against a glass imaging plate. By distinguishing between the trash constituents, the technique is able to provide a comprehensive measurement as to the trash content, size shape and spatial density. This information is felt to be vital for proper automated gin process control.

The main applications of this new technique are for improving trash recognition in gin process control by removing the constraint of paddle samplers. This will also allow trash measurements to be used in new, innovative locations as well as improving the current sampling techniques currently in use and will provide valuable additional information to aid the ginner (in a non-automated system) in providing a quality product to the mill.

Disclaimer

Mention of a trade name, proprietary product, or specific equipment does not constitute a guarantee or warranty by the US Department of Agriculture and does not imply approval of the product to the exclusion of others that may be available.

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Xu, B., C. Fang, Y. Huang, and M.D. Watson 1997. Chromatic Image Analysis for Cotton Trash and Color Measurements., *Tertile Res. J.*, 67(12), 881-890.

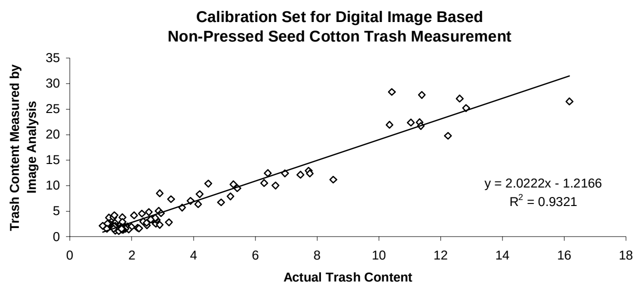

Figure 1. Image Analysis Trash Measurement Calibration.

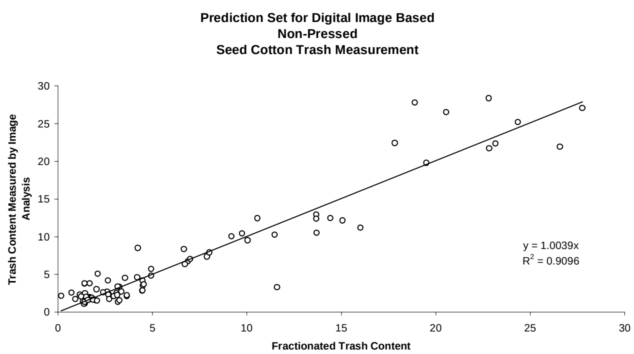

Figure 2. Validation Set for the prediction of Trash measurement by Image Analysis.

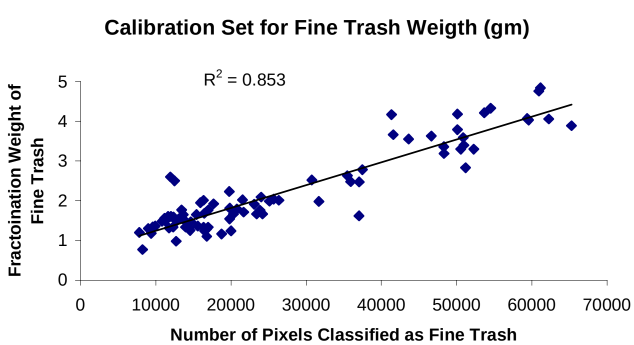

Figure 3. Calibration set for Image Analysis of Fractionated Fine Trash of Seed Cotton Trash Measurement.

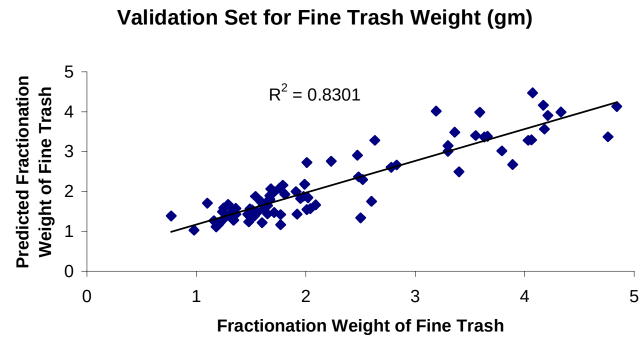

Figure 4. Validation set for Image Analysis of Fractionated Fine Trash of Seed Cotton Trash Measurement.

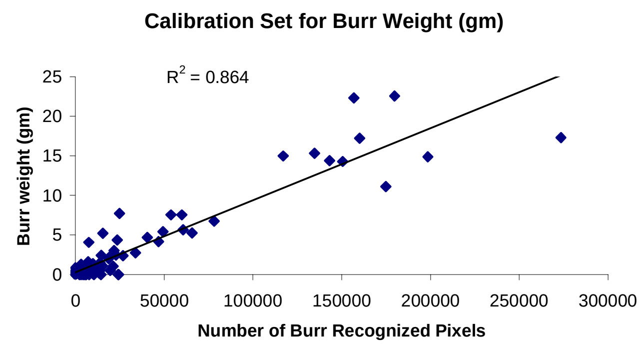

Figure 5. Calibration set for Image Analysis of Fractionated Burr Trash of Seed Cotton Trash Measurement.

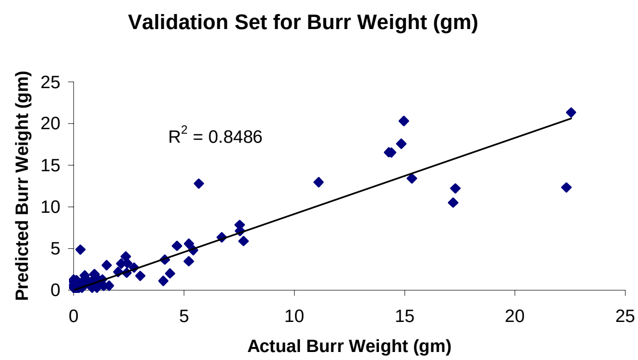

Figure 6. Validation set for Image Analysis of Fractionated Burr Trash of Seed Cotton Trash Measurement.

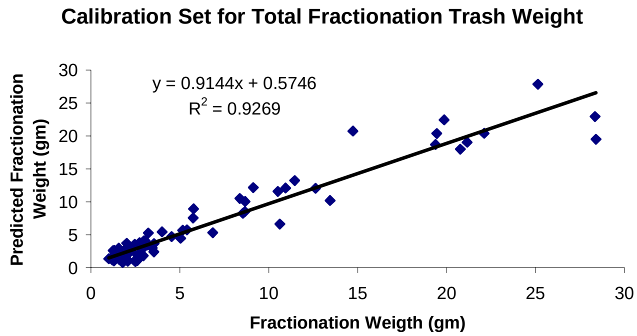

Figure 7. Calibration set for Image Analysis with Burr and Fine Trash Correction of total Fractionated Seed Cotton Trash Measurement.

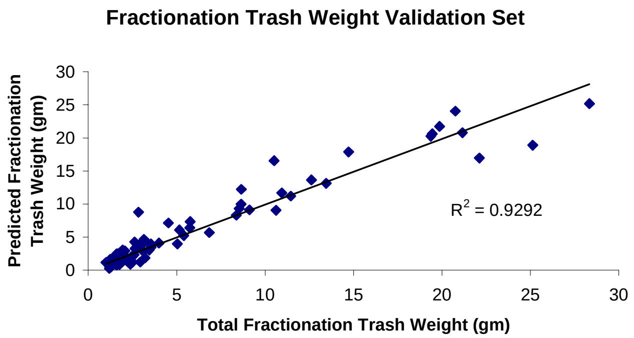

Figure 8. Validation set for Image Analysis with Burr and Fine Trash Correction of total Fractionated Seed Cotton Trash Measurement.

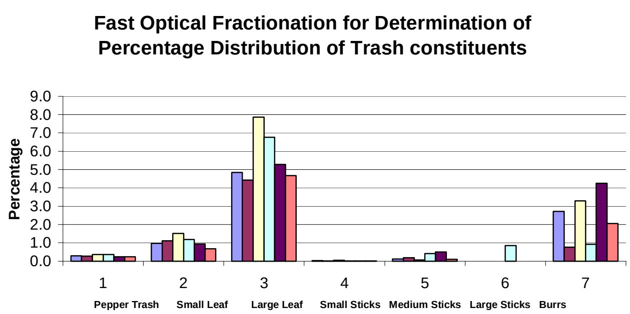

Figure 9. USDA Fast Optical Trash fractionation performed on stripper harvested seed cotton by image processing algorithms.