IMAGE PROCESSING FOR STRIPPER HARVESTED COTTON TRASH CONTENT MEASUREMENT A PROGRESS REPORT

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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. 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.

Introduction

The need to produce a better quality product for sale to the cotton textile mills and to reduce labor costs during processing has led to considerable interest in process control for cotton gins. Anthony and Byler (1994) indicate that process control can range from $15,000 to $100,000. 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 video trash sensors to determine the optimum number of lint cleaners needed 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 produce optimal economic returns for a given ginned bale of cotton (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 becomes 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 profit can be maximized by adjusting the number of lint cleanings. The optimum number of 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).

Background

There are several needs for trash measurement in cotton harvesting and ginning processes. The trash content percentage can be used to optimize the seed cotton and lint cleaning processes in cotton ginning, and help control the seed cotton drying process.

Dryer Control

The seed cotton drying process is currently controlled via a human operator (or a resistance sensor in a feedback control system) that sets the dryer temperature such that the current seed cotton is adequately dried. Problems arise when only a portion of the module is extremely wet (>8% moisture content [wet basis]). This wet cotton needs a much higher temperature setting and subsequently brings the gin stands to a halt as they can't process the wet seed cotton. The human operator can not react fast enough to avoid this situation, and the resistance sensors can not determine that the seed cotton is wetter than 12% moisture content and hence cannot be used to control the dryer for these partially wet portions of the modules.

The main deterrent to automated dryer control is the current lack of a suitable moisture sensor. The current moisture

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content measurement techniques for seed cotton and lint are: infrared, resistance, radio-frequency (rf) and capacitive sensors. Each of these techniques have some strengths and some draw-backs.

Infrared Sensors:

- Currently are expensive, and have yet to be proved effective for high trash content stripper harvested seed cotton.

Resistance Sensors:

- Have to be presented to the sensor with a very controlled presentation force. This limits their use to locations where a sample of lint or seed cotton can be presented to the sensor with a uniform force.
- Have a limited range of moisture content measurement (5-8% moisture content [wet basis] (Byler and Anthony, 1995)). This precludes their use with extremely wet cotton, as the sensor cannot differentiate between 12% and 20% moisture content (in which the latter will need a significantly larger amount of BTU's to dry the cotton sufficiently before it can be safely ginned).

Capacitive and rf Sensors:

- Have the ability to perform contact-free measurement.
- Can detect a wide range of moisture contents, however they predominantly only measure the total mass of the water present. This makes their measurements subject to variations in density as well as the moisture content. In order to remove the influence of density from the measurement the sample must either be weighed, or the density presented to the sample must be controlled.
- Additional problems arise from large fluctuations in temperature. This can creates calibration problems, or a need for tight control over the temperature of the sample as its presented to the sensor.

As resistance sensors have a limited moisture content range, let's focus on the rf and capacitive techniques as they relate to dryer control.

Due to the small dwell time in the dryers, the predominant amount of drying occurs only on the lint. The seeds and trash hold the majority of the moisture, which is not adequately dried. This fact dictates that the moisture sensor must determine the quantity of water held within only the lint portion of the seed cotton. However, rf and capacitive moisture sensors will detect the entire mass of water within the bounds of the sensor's measurement zone (area), and the necessary mass flow sensor (to correct for density fluctuations) will measure all of the mass of the seed cotton. The knowledge of the mass of water and the total sample mass (water, cotton, lint, seed, and trash) is not enough information for use in automatic dryer control. The lint turnout must also be known in order to determine the quantity of water that will need to be evaporated (i.e. the number of BTUs to add to the system to dry the raw seed cotton). Due to this fact, it is felt that the measurement of trash is an important milestone in the development of automatic dryer control.

<u>Trash Measurement</u>

Byler and Anthony (1997) reported on a computer-based system 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 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. The coefficient of determination was 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 was felt to be important enough that several devices were developed to accomplish this and eventually a USDA Patent (1992) 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 use High-volume-Instruments (HVI) systems to measure trash content and lint color. The trash content and the lint color are 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 only two classes, the first class composed of the lint and the second class composed of everything else (trash, holes etc) (Thomasson, et al. 1997).

By carefully placing a sample on an HVI instrument with care taken to avoid voids 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. 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.

This research was undertaken to develop a new system that does not require samples to be presented to the imaging sensor by pressing the cotton sample upon an imaging plate. This is a major improvement as there is no need for paddle samplers or other mechanical presenters, such as are currently being used for image-based trash recognition in automated gin process control systems.

This new technique could be used 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.

Procedure

The system consists of an algorithm for use in conjunction with a video camera intended for computer recognition of trash in seed cotton or cotton lint in situ, to be performed in real-time without the need for any mechanical sample preparation or presentation.

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 in an alternative, preferred location.

The technique measures the image area coverage of trash, lint, or seed cotton, and distinguishes each from the background, removing the influence of holes from the measurements. After classifying the image into these three separate classes, it then determines the percent trash content. After a binary image has been extracted of only the trash components, the image is further classified to separate out the various trash components of sticks, leaves and burrs.

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, 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 CIELAB 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 are currently under review for patent application by the USDA patent attorneys, 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 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 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 with holes where the background was visible and one with the field of view completely filled with the seed cotton.

After all images were obtained each sample was then fractionated by standard methods to determine the mass content of the sticks and leaves, burrs, and seed cotton in which to relate back to the information obtained via the image analysis.

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 analyzed images were then correlated to the fractionated via linear regression 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. This allows for additional techniques to use area algorithms to post process the classified images for subsequent classification of the objects into the various trash constituents. This post processing provides information as to the various size, area, shape and color of the various constituent elements and their distributions within the images for use in automatic gin process control optimization.

The first pass processing of the imaging technique was shown to provide a suitable means for determining the trash content of seed cotton. The technique was found to have a coefficient of determination of $r^2 = 0.914$ with a standard error of 2.4% trash content (mass basis) (figure 1).

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. The technique is also able to use the same hardware for trash measurement as well as color classification of the lint (as separated from the trash and background (voids). The multi-dimensional classification technique enables the system to effectively identify trash particles, shadows and spots so they can be eliminated from the color measurement and additionally provides the ability to distinguish the types of trash in the seed cotton. 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.

We believe that the technique can be used in an automated process control environment and will provide valuable additional information to aid the ginner (in a non-automated system) in providing a quality product to the mill.

Disclaimer

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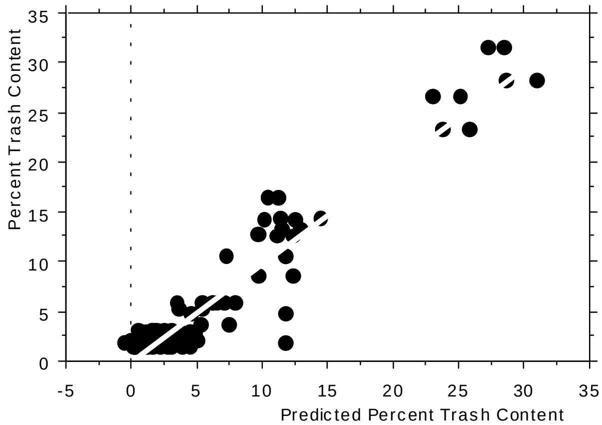

Figure 1: Image Analysis Trash Measurement Calibration.