DEVELOPMENT OF COTTON FIBER QUALITY SENSOR

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Abstract

A prototype multispectral sensor for in-situ cotton fiber quality measurement was developed at Texas A&M University. Results of testing the sensor with lint cotton to determine micronaire were promising. Objectives of the study reported in this paper were to automate the image acquisition of the sensor and evaluate performance of the sensor in measuring fiber quality of seed cotton. A ruggedized prototype of the multispectral fiber quality sensor was built for installing on a cotton harvester. An automatic filter wheel was added into the sensor system. The filter wheel could be controlled by software to change optical filters of the sensor so that images at selected wavebands could be acquired automatically. Thirty-six seed cotton samples were collected from a 90-acre field at Texas A&M University IMPACT Center. The samples were measured using the multispectral fiber quality sensor. The sensor takes images of the samples at three near infrared wavebands and one visible band, and saves them to be processed.

Introduction

Cotton fiber quality is an important piece of information in the cotton industry because it greatly affects the marketability and the producer's profit. When relating the price of cotton to the quality, micronaire is a very important factor. The price cotton will sell for has a very strong relationship with the micronaire value of that particular cotton. Field mapping is becoming an important tool in cotton farming today. Currently, there are ways to map cotton yield over the field and even ways to map cotton quality in a field on a per module basis (Ge et al., 2008; Sjolander et al., 2008). However, there is no such sensor, which can be used on a harvester, to measure the quality of cotton over a field so that a cotton quality map can be generated.

Sui et al. (2008) showed a strong correlation between the reflectivity of lint cotton at certain wavebands and the micronaire value. However, this measurement cannot be done until after the cotton has been harvested and ginned. In order to make this process useful during the harvest, it must be adapted to measure seed cotton and eliminate the affect of foreign particles in the cotton during the measurement. The system must also be compact, and able to repeat a program in which it collects a sample of cotton that is running through the duct of the harvester, takes the required images of the cotton, and releases the cotton back into the duct. This process is to be repeated as often as possible, and the location of each sample saved along with the images. This will ultimately result in a map of the micronaire distribution over the entire field. A map like this would allow farmers to customize field treatments to improve overall quality of their cotton and increase profit.

Materials and Methods

Sensor Description

The fiber quality sensor consists of an Alpha VisGaAs camera (FLIR Systems, Inc., Goleta, CA) with optical filters, a halogen light source, an image frame grabber, and an image analyzer (Figure 1). The camera and filters were mounted face down toward a cotton sample. Cotton fiber images acquired by the camera were captured with an image frame grabber board (IMAQ PCI-1422, National Instruments, Austin, TX) installed in a laptop-PC-based image analysis system which is used to collect, record, and analyze the images.

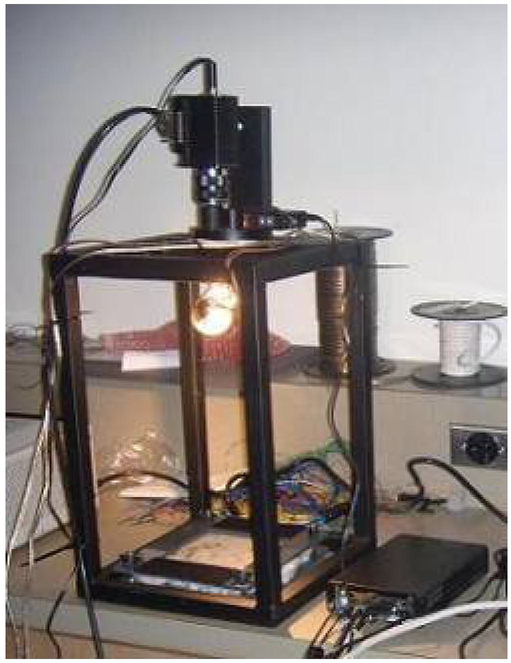

Figure 1: Frame with camera and filter wheel attached.

The camera used in the multispectral sensor was able to capture images in the visible and NIR regions (from 400 to1700 nm). With a frame grabber board and a digital interface cable the camera system could output real-time, 12-bit digital image data (i.e., pixel values from 0 to 4095) at a 30-Hz frame rate. Two 20-W halogen lamps (MR-16, USHIO, Cypress, CA) were used with a Frostline[TM] reflector to provide diffused light sufficient to illuminate cotton fiber during image acquisition. A sturdy frame, lightweight enough to be mounted on a harvester later was built out of 1 inch thin-walled steel box tubing. The outer dimensions of the frame are 12" x 12" x 16". The box tubing was welded together and painted flat black to reduce reflections. A 12"x12" square plate with a 1-3/4" hole in the center was welded to the inside of the top of the frame to allow the halogen lights to be mounted in two opposite corners, and shield the camera from any direct light coming from the lamps. The camera was attached to the FW102 Filter wheel (ThorLabs, Inc., Newton, NJ) using a custom machined adapter. The adapter is a ¼" aluminum ring with M40.5x0.5 threads on the outer surface and 1.035" – 40 (SM1) threads on the inner surface (Figure 2).

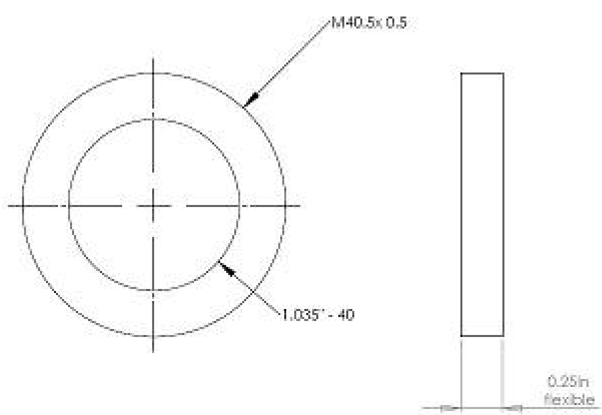

Figure 2: Custom Lens Adapter

Three optical bandpass filters FB1450-12, FB1550-12, FB1600-12, and one shortpass filter FES750 (ThorLabs, Inc., Newton, NJ) were placed in the filter wheel to collect images at central wavelengths of 1450, 1550, and 1600 nm each with 12 nm FWHM (full width at half maximum) and an image at a visible waveband (525 nm -750 nm). The camera and filter assembly were mounted on the frame facing downward through the hole in the top with the image that the camera sees centered in the 12" x 12" square.

Cotton Sampling

Thirty-six points in a 90-acre cotton field were randomly selected and marked using a handheld GPS unit. During harvest, at each of the points, seed cotton was collected by hand as it exited the duct and placed into a paper sack with an identifying number.

Sensor Testing

The camera was connected to a laptop computer through the Frame Grabber and accessed using IRVista. The filter wheel was connected to the laptop using a USB cable and run using the software that came with it. This allowed the sample of seed cotton and the sensor to remain untouched throughout the process of collecting images for each sample. By taking all four images of each sample in the exact same orientation, the different images can be compared. Since the image collecting can be done entirely from a computer, a program will be written to automate the process. The halogen lamps are powered by a model 1746B DC power supply (B+K Precision Inc., Chicago, IL) set at 12.0 volts. The lamps were turned on for 30 minutes in order to heat up to a constant temperature before acquiring images. The camera, filter wheel, frame grabber and laptop were all powered with 120V AC power using power adapters (Figure 3).

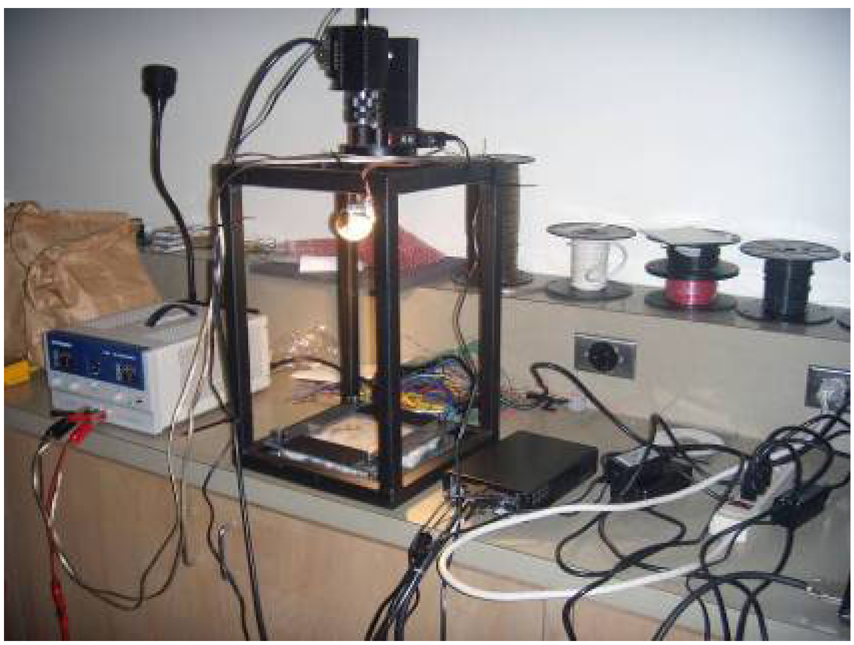

Figure 3: Composite Sensor Setup in Lab

To collect images, the system was placed in a dark room with no windows, and no lights other than the halogen lamps and the laptop screen. Any time the lights were turned on and warmed up, a pure white disk was used to get a new set of calibration images for the camera using the same image collecting procedure that the seed cotton samples go through. For the seed cotton, a 112.5g sample was taken from each field collection. The samples were weighed out by an electronic scale (Tenma Model 72-6787, MCM Electronics Inc.). The sample was pressed in the sample holder which is the same one used by Sui (Sui et al., 2008). It is a pair of PVC plates, one with a clear window at the center, with carriage bolts at each corner. One at a time, the cotton samples were placed in the holder and wing nuts were tightened at each corner until an estimated pressure, equal for each sample, was reached. Then, the sample holder was placed underneath the camera and 4 images were taken of each sample without touching the sample or the system. The first three images were each taken using the 1450 nm, 1550 nm and 1600 nm filters respectively at a the high gain setting on the camera, and a 16,000 integration setting. The fourth image was taken through the 750nm short pass filter at the low gain setting and a 11,000 integration setting. The images were taken by freezing the frame once the filter was changed (Figures 4, 5, 6 & 7), saving the frozen frame as a .bin file on the laptop's hard drive to be processed at a later time. In the images (Figures 4, 5, 6, & 7) two bright "hot" spots can be seen from the reflections of the halogen lamps along with random white and black pixels. These areas would change the micronaire value determined for each sample, so during processing a region of interest in the middle of the sample will be used, and the random pixels with no information will be filtered out.

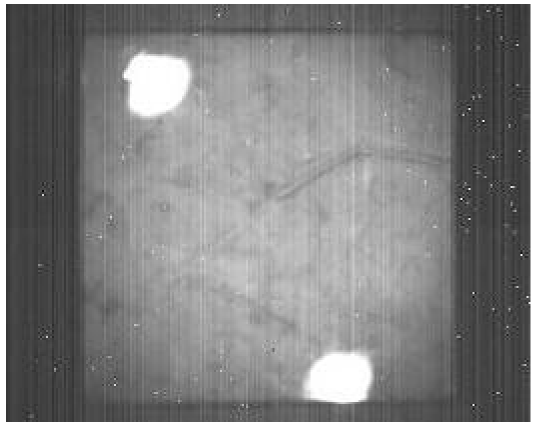

Figure 4: Image with 1450 nm filter

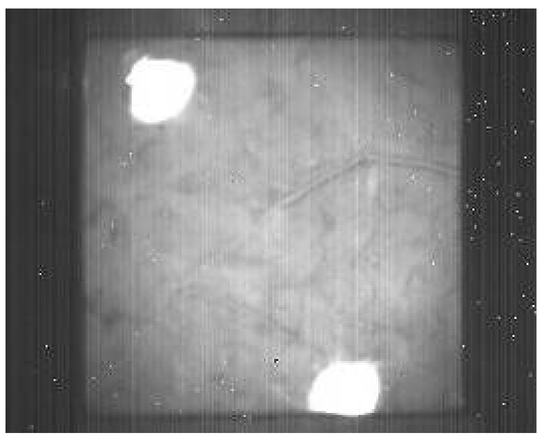

Figure 5: Image with 1550 nm filter

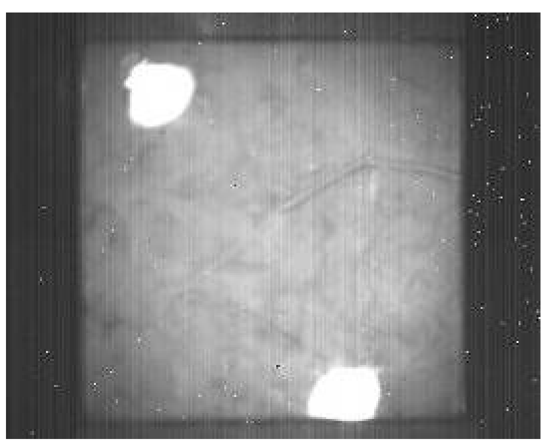

Figure 6: Image with 1600 nm filter

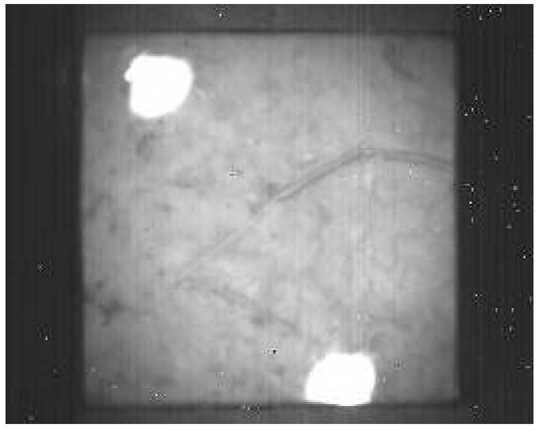

Figure 7: Image with 750 nm filter

Results and Discussion

The cotton fiber quality sensing system, while not fully automated yet, is capable of taking required images of a seed cotton sample presented. Once the sample was placed under the lens, all adjustments and procedures were done from the laptop computer connected to it. For testing, this procedure was done manually, but it could be programmed to be done automatically when triggered. The system, after running, returned 4 binary files for each sample of cotton presented to it. Each of these files was an image of the sample through a different filter. After processing these images to identify non-cotton pixels (trash, leaves, bark, etc.), the quality of the cotton can be determined using existing technology. This entire process can either be done on the harvester, or the binary pixel information can be collected from the harvest and processed later.

Summary

A prototype of multispectral sensor for cotton fiber quality measurement has been built, sturdy enough to endure the forces it must endure during field use, and still lightweight enough to be mounted directly on the harvester duct. The system was capable of generating the desired output of stored and labeled binary files. The next step in this research is to develop image processing methods for determining the fiber quality of seed cotton, to automate the process of collecting the images to run on an event trigger, and to automate the seed cotton sample collection.

References

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