FLUORESCENCE IMAGING OF COTTON TRASH

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Introduction

Cotton lint is contaminated with trash particles from botanical and non-botanical sources during harvesting with cotton strippers and cotton pickers (Wakelyn et al., 2007). The presence of trash admixed with lint causes problems during processing and ultimately reduces its monetary value (Brashears, Baker, Bragg, and Simpson, 1992). Seed cotton undergoes cleaning at cotton gins where most trash is removed; however, ever smaller particles remain present. Ginned lint is baled and samples from individual bales are graded at the classing office. Grading is performed by human classers and instruments, with instruments providing more objective assessments (Xu and Fang, 1998).

Grading instruments include the High Volume Instrument (HVI), Shirley Analyzer (SA), and the Advanced Fiber Information System (AFIS). The HVI obtains fiber measurements using the geometric method by imaging the sample area to calculate the surface area covered with trash, while the SA and the AFIS are based on the gravimetric method to mechanically separate fibers. All of the systems lack the ability to differentiate trash categories. In this study, the feasibility of using fluorescent imaging for cotton trash detection and classification was tested.

The following objectives were addressed in the current study: 1) characterize different categories of cotton trash with fluorescence spectroscopy, 2) build a fluorescent imaging apparatus and select excitation sources based on the results from fluorescence spectroscopy, 3) extract features from fluorescent image and classify cotton trash.

Materials and Methods

Fluorescence Spectroscopy Analysis

Botanical trash (bark, green leaf) samples extracted from four cotton cultivars- (DP 0912, DP 1050, PhytoGen 499, FiberMax 1944) and non-botanical trash (paper, plastic bag) samples were dissolved in dimethyl sulfoxide (DMSO) for two hours. Extracts were filtered and analyzed with a fluorospectrometer. Excitation wavelength ranged from 300 nm to 500 nm, and emission was recorded from 320 nm to 700 nm.

Fluorescence Imaging of Cotton Trash

A total of 30 samples per trash category were placed on top of a lint layer and imaged under two types of excitation light. Under blue LED, light bark and green leaf were imaged, while under the UV LED, light paper and plastic bag were imaged (Figure 1). A camera was equipped with a longpass filter (400nm when blue LEDs were used, and 500nm when the UV LED was used) to remove any reflectance acquired in raw images, which were converted to the TIFF images with an open source software UFRaw (http://ufraw.sourceforge.net/). The resulting TIFF images were binned 4x4 and further denoising was applied with the median filter. Regions of interest were delineated and color features from the RGB (Red, Green, Blue) and HSV (Hue, Saturation, Value) images extracted and tested for significance with the MANOVA test (SAS 9.2, SAS Institute, Cary, NC).

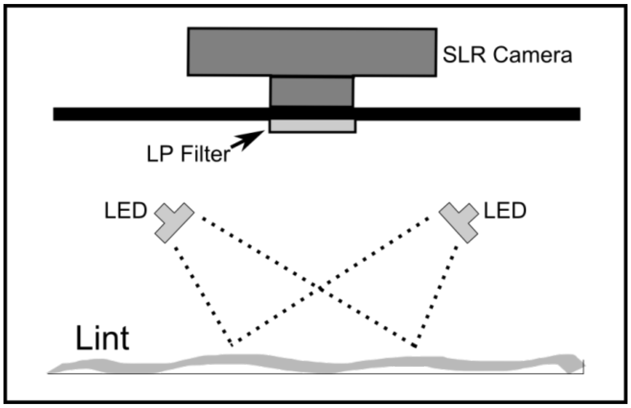

Figure 1. Fluorescence Imaging System Front View

Cotton Trash Classification

To classify cotton trash, the Linear Discriminant Analysis (LDA) algorithm (Matlab R2013a, Natick, MA) was used. Each trash category contained 30 observations, and 50 percent of the observations were used for training and 50 percent for testing. The order was then rotated, and those used for training were used for testing, and vice versa. Cross validation was performed with the leave-one-out and the 5-fold cross validation method.

Results and Discussion

Matrix 3D scan of bark (Figure 2) exhibits an emission peak in the red spectral range at 672 nm while excited at 430 nm. Green leaf was optimally excited at 410 nm and emitted at 675 nm. In contrast, paper and plastic bag exhibited optimal excitation in the UV spectral region (360 nm and 370 nm), with optimal emission at 412 nm and 417 nm, respectively. Both bark and green leaf fluoresce red because of a fluorophore-chlorophyll, while paper and plastic bag fluoresce blue because of presence of fluorescent whitening agents (in the case of paper), and coloring pigments (in the case of plastic bag).

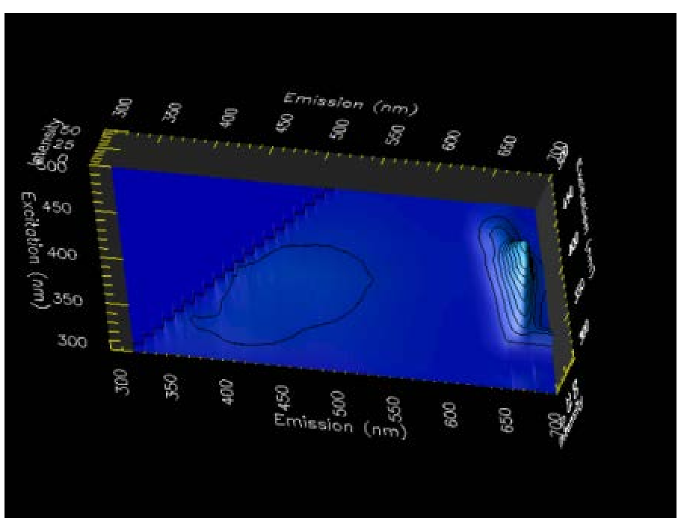

Figure 2. Fluorescence Spectroscopy Scan of Bark. Optimal Excitation/Emission Peaks Are at 430/672 nm

Based on the fluoroscopic analysis of botanical and non-botanical trash, it is possible to determine which excitation light sources can be used to induce optimal fluorescence emission in cotton trash. Fluorescent images of bark and green leaf were acquired under the blue LED excitation light and paper and plastic bag under UV LED excitation light (Figure 3).

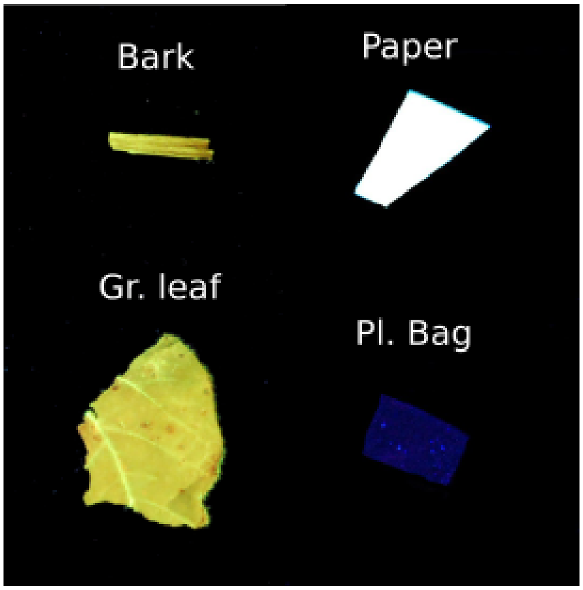

Figure 3. Fluorescent Images of Bark and Green Leaf (Excited With Blue LED Light) and Paper and Plastic Bag (Excited With UV LED Light)

To classify different categories of cotton trash, features from the RGB and HSV color model were extracted. Features from the RGB color model included red/green, red/blue, blue/green ratio, and features from the HSV images included H, S, and V. When images were acquired under the blue LED excitation light, features with the blue channel were not included because during imaging, the blue channel was effectively cut off to prevent any pseudo-fluorescence. To reduce the number of features, only the three features with the highest F-values based on the MANOVA test were used for classification. These features were red/green, H, and V (for images acquired under blue LED light), and B/G, S, and V (for images acquired under blue LED light). The LDA classification rates were highest for paper (100 percent), followed by green leaf (96.67 percent) and plastic bag (90 percent), and lowest for bark (76.67 percent).

Table 1. LDA Classification Results.

Trash Category	Classification Rate (%)
Bark	76.67
Gr. Leaf	96.67
Paper	100.00
Pl. Bag	90.00

Summary

The study demonstrated the capabilities of fluorescence imaging to detect and classify cotton trash. Fluoroscopic characterization findings of different types of cotton trash indicated their ability to be photoexcited and emit fluorescence in the UV and blue light spectral range. An imaging system was constructed with an SLR camera as the photo capturing device and blue and UV LEDs serving as excitation sources. Fluorescent images of cotton trash placed on top of lint were acquired and color features extracted from these images were used for classification. Classification rates of 90 percent and higher were achieved for plastic bag, green leaf, and paper. In comparison, the bark classification rate was noticeably lower at 76.67 percent. A potential explanation is that unlike other types of cotton trash, bark has a more heterogeneous appearance. Bark represents the outer layer of the stem and as such has a different appearance depending on which side is imaged, thus directly affecting its color appearance. This color variation affects the values of color features used in classification, and results in bark being misclassified as other trash types.

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