UAV-BASED MULTISPECTRAL DETECTION OF PLASTIC DEBRIS IN COTTON FIELDS

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Abstract

The US cotton industry has major concerns for plastic contamination in the harvesting, ginning and spinning portions of industry. The goal of this project was to determine the potential and effectiveness of using multispectral cameras on a UAV platform paired with a commercially available image processing software. The project included introducing plastic bags into the field throughout the growing season to better understand the plant interaction, height and canopy widths, with the successful findings of plastic bags response value. The project relied heavily on visual detection within the imaging software, which leaves a human error for a false identification without multiple checks and rechecks. Different colors, such as tans and yellows, posed an issue for detection with the similarity of soil color and response indices. While the results of the experiments were promising for a few colors and the possibility of such use for the UAV and multispectral camera could be beneficial, more work is required to create a computer program, or learning code, designed to distinguish between crop, ground and plastic debris reflectance signatures.

Introduction

Agricultural fields close to roads, highways, or other high traffic areas are susceptible to motorist improperly disposing of their plastic trash. The United States is one of the top producers of cotton around the world. In recent years, plastic contamination has become more of a concern. While portions of the plastic contamination can be attributed to the introduction of the plastic wrapped module, any plastic collected by the harvester in the field will be bound in the inner portion of the module and be more difficult to deal with and remove in the ginning process. Detection of plastic within the field will help to eliminate part of the contamination problem with debris harvested within a module.

Unmanned Aerial Vehicles (UAV) have been used in the last couple of decades as a tool to assist producers with crop health and soil condition with prescription mapping. UAVs have also been used in recent years with image processing for open cotton boll using orthorectification thresholding (Yeom et al., 2017). Hardin et al. also conducted similar research using a Phantom 3 Advanced based platform with a camera to take images of cotton fields and detect plastic within the image (2018). Dodge designed a computer software to determine different aspects, e.g. leaf area index and cotton yield, using photogrammetry and machine learning with UAV imaging (2019).

The objective of this study was to determine the feasibility of using a commercially available image processing software paired with a UAV equipped with a multispectral camera for detection of plastic contamination in cotton fields.

Materials and Methods

Cotton research plots designed to study nitrogen application and irrigation methods were used as the testing area for the project. Plots 1-10 varied in nitrogen application Table 1. Cotton plants were measured for canopy widths and height. The widths were measured from the widest point of the leaves on one side to the farthest leaf on the opposite side of the plant. The plant heights were measured from the ground to the top of the plant. Ten plant measurements within each plot were taken to obtain an average of the overall plant heights in the portion of the plots were the plastic bags were places.

Table 1. Nitrogen rates per plot.

Plot #	N rate (kg/ha)
1	140
2	84
3	84
4	140
5	140
6	84
7	84
8	140
9	84
10	84

Figure 1 shows a DJI Matrice 600 Pro (DJI, Shenzhen, China) and a MicaSense RedEdge camera (MicaSense, Seattle, WA) used to fly over a cotton field during different growth stages after emergence. The spectral centers of the camera are blue (475 nm), green (560 nm), red (668 nm), red edge (717 nm) and near-IR (840 nm). Flights were conducted within 2 hours of solar noon to reduce shadow interference. Flights were automated using an application on a tablet. Flights were conducted at an altitude of 50 meters. Weather conditions, pesticide, and herbicide applications were limiting factors of flights and plant measurements being taken. Although most of a flight could be uninterrupted, small clouds could disrupt small sections of an image set.

Figure 1. Matrice 600 Pro (left) and MicaSense RedEdge camera (right).

Plastic t-shirt style bags (Figure 1) were purchased to place in the field. Random numbers were assigned to the plastic bags to associate them within 1 of the 10 test plots and either the left, right, or center between the crop rows. Bags were pinned down using plastic garden stakes and exchanged when dirt was washed over the bags after a heavy rain or the sunlight turned the plastic translucent. A Trimble R2 GPS system (Trimble Inc., Sunnyvale, CA) was used to locate the individual plastic bags to roughly locate them after the images were processed. The correction of each plastic bag was visually done and became difficult as the plants grew.

Figure 2. Plastic bags used for this research.

Pix4D mapper (Pix 4D SA, Lausanne, Switzerland) was used for image processing. Reflectance maps were generated, and the indices were arranged to remove most of the plant, earth, and noise reflectance in attempt to only leave small sections of vegetative rows and allows to detection of plastic to be more pronounced within the program. While this software can not specify exact wavelengths, variation in the response integers can be changed to remove large amounts of vegetation and ground responses.

Cotton plants were measured for canopy widths and height. The widths were measured from the widest point of the leaves on one side to the farthest leaf on the opposite side of the plant. The plant heights were measures from the ground to the top of the plant. Ten measurements of each were taken to obtain an average of the overall plant heights in the portion of the plots were the plastic bags were places. The variation between plot heights is due to different levels of nitrogen applied to the crops at planting.

Results and Discussion

Early detection of plastic materials was more successful due to the lack of size in the cotton plants. As the growing season progressed, detection of the plastic within each plot decreased as expected but gains some improvement as defoliant was applied. Outside of the hindrance of continuous growth of the cotton plant, herbicide and cultivation of weeds aided in clearing slight lines for detection within planted rows. Weeds and grass had a tendency of regrowth much faster and taller than the cotton plants. Such vegetation created an issue if herbicide or cultivation could not be completed on a consistent schedule. Late in the season, cultivation is not an option due to the damaging of the crop, yet herbicide could be sprayed to eliminate weeds and grasses, while also decreasing the amount of nutrients removed from the soil by nonvaluable vegetation.

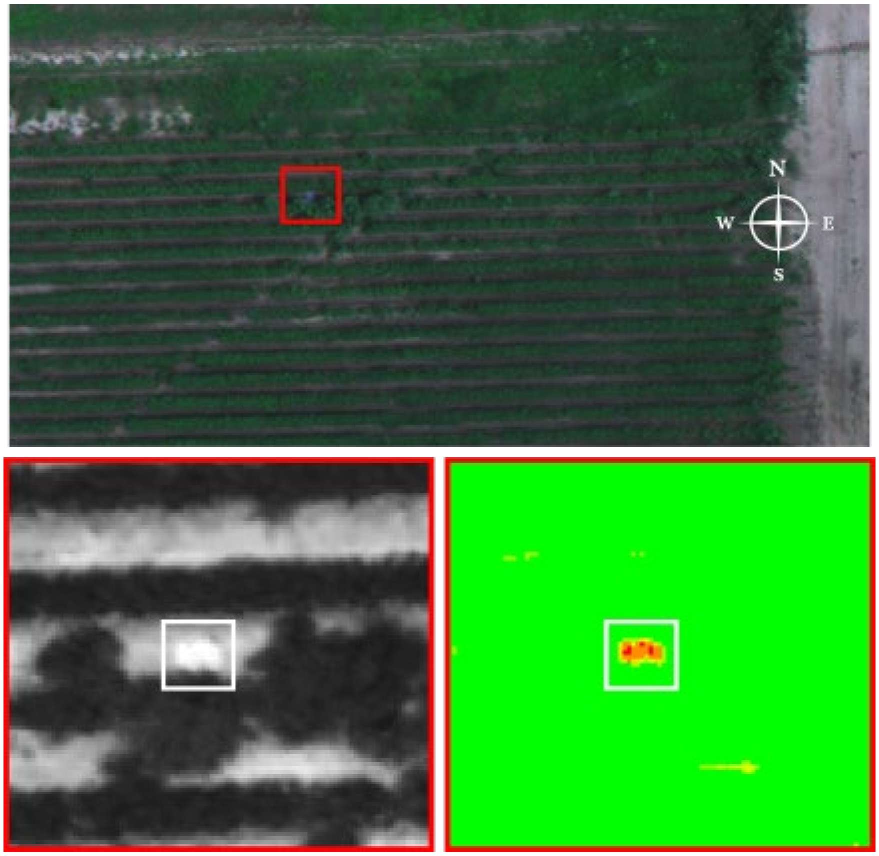

Figure 3. Blue plastic detection with RGB rendering (top), camera image blue band (bottom left), and index generated coloring (bottom right).

Using the five different bands, the blue band had more promising result with a larger number of the overall plastic colors being found. Figure 2 shows the contrast of the RGB image with the reflectance image shown in the bottom left. Blue and white were distinctively brighter than other portions of the images. Yellow plastic was found using the blue band, yet the accuracy for a definitive answer was not possible so may not have been counted in the results. Tan was the more difficult color to detect, due to its likeness to the soil or dirt coloring, but with the red band, tan was typically able to be found. Plastic also tended to appear as voided pixels when an index map was unclamped, or pixel responses were unaveraged and left vacant in the index coloring.

GPS locations of the plastic were entered in the software, but the accuracy of the locations varied greatly and needed corrections once entered. The adjust locations of the plastic varied from within a meter to over five meters away. This misalignment was due to the accuracy restriction of the UAV and camera system and the very precise centimeter grade accuracy of the R2 system.

Table 2. Number of plastic bags found through growing season.

Color	Total	7-9-19	8-21-19	9-16-19
White	6	5	3	3
Black	6	4	2	0
Blue	6	6	5	3
Tan	6	0	2	0
Yellow	6	2	1	1

Table 2 shows how at different time of the plant grow the different colors of the plastic bags can be found. A major drawback this portion of the study was the visual basis of which the plastics had to be found. The Pix4D software was not designed for specific detection of such small portions of imaging, leading to a difficult positive identification of plastics. In many cases of the tan and yellow colors, a positive result was not made if any dirt in the image was giving a similar response in coloration. The 2 tan colors found were during a growth stage with heavy leaf vegetation to cover the center of the row dirt responses.

Tables 3 and 4 give a good indication of how the plants grew through the season. 7/9/19 was early in the growth stage with the main stem growth and few leaves. 8/21/19 was during the heavy flowering growth stage and the plant appears fuller. 9/16/19 was the end of the growing season and the start of defoliation. A major drawback is the number of open bolls leading to misleading positive results when looking for the white and blue plastics which share similar response indices. Fallen leaves create another challenge for late season success, having covered plastic underneath the cotton plant.

Table 3. Cotton plant heights.

Date	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6	Plot 7	Plot 8	Plot 9	Plot 10
7/9/19	18.7	22.0	21.4	19.9	22.8	21.1	22.6	22.0	19.8	20.4
8/21/19	30.9	26.9	30.0	32.2	32.7	27.4	30.5	33.9	30.1	29.5
9/16/19	29.4	28.1	28.5	29.3	31.3	27.2	27.3	31.9	27.8	27.5

Table 4. Cotton plant canopy widths.

Date	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6	Plot 7	Plot 8	Plot 9	Plot 10
7/9/19	19.1	20.7	21.6	21.4	21.1	20.7	22.0	22.1	20.6	21.4
8/21/19	27.3	30.5	28.0	31.4	30.7	25.8	26.1	28.0	28.3	29.2
9/16/19	20.4	21.8	20.9	22.7	22.8	19.5	20.2	23.0	20.7	20.8

Summary

The results of this study show a favorable possibility of using commercially available image processing software. Difficulties with using a UAV automated flight plan is the camera will not be positioned perfectly to detect potential objects in each row without precise planning, which would significantly impact battery performance. The Pix4D software is useful and can allow the user to pin point locations of more importance, such as road sides or high contamination spots. Maneuvering through multiple wavelength responses, index generated coloring, and other feature can create confusing if a firm methodology is not followed between image sets. While this software was not 100% effective, more research in developing a program designed to read images and determine whether plastic can be detected.

Condition outside of the control of a UAV, camera, and software added a degree of difficulty when trying to improve methodology. Rain, wind, and leaf dropping must be accounted for to find recent plastic debris in a real-world implementation. This project was able to remove soiled plastic from rainfall runoff and eliminate wind drift with garden stakes, which would not be the case in practice.

Disclaimer

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