UNMANNED AERIAL SYSTEM (UAS) FOR PRECISION AGRICULTURE: FIRST RESULTS FROM A GROWING CYCLE OF COTTON

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Abstract

Mounted with various cameras and sensors, a low-cost Unmanned Aircraft System (UAS) offers us a unique opportunity to develop smart applications for precision agriculture with high spatial, spectral and temporal resolutions. We are currently developing a UAS-based sensor platform that includes various sensors such as a high precise Global Positioning System/Inertial Navigation System (GPS/INS) system, an optical camera, a multispectral camera, and a thermal camera. The first version of the platform has been utilized to monitor a growing cycle of cotton in 2015. About 150 aerial images were captured at a weekly temporal resolution in a test field of 85 × 54 m meters. The UAS flied at a very low altitude of 15 meters in order to achieve a high spatial resolution of 7 mm/pixel. Images collected in a weekly fly mission were processed to generate 1) a geo-referenced mosaicked image that can be used to estimate the plant coverage during a growing cycle of cotton, and 2) a 3D canopy model that can be used to estimate the plant heights. The growing status of the cotton plants has been assessed on a weekly basis by evaluating two parameters: plant coverage and plant height. Our experience from monitoring one growing cycle of cotton shows that UAS has a great potential for precision agriculture applications.

Introduction

Airborne remote sensing is a popular technology for assessing crop growth and health over a large field scale for precision agriculture. However, it is usually not capable of offering images with sufficient spatial resolution for detecting certain micro-scale crop information such as disease observable on individual plant leaves. Moreover, due to the high operational cost and complexity, airborne remote sensing sometimes may not provide imagery with adequate temporal resolution. In recent years, increasing demands for making timely and accurate decision for crop management have raised in agriculture community (Aasen et al., 2015).

On the other hand, nowadays, camera-enabled unmanned aircraft systems (UASs) have been proven to be efficient and cost-effective imaging platforms for various applications. In precision agriculture, the versatility of the UAS platform allows to capture crop information, such as plant height, canopy coverage, canopy temperature, and plant reflectance with adequate spatial and temporal resolution in a low-cost manner. The advantages of the UAS over the airborne platform are that: 1) it allows ultra-low altitude imagery collection, 2) the temporal frequency can be enhanced due to its low operation cost and complexity, and 3) the platform is affordable to most end users such crop consultants and farmers.

We provide a case study monitoring a cotton field growth using a lightweight UAS platform with a regular RGB camera. The dataset was collected throughout the whole cotton growth cycle between early April and late July in 2015. The methods to extract plant height and canopy cover from consecutive RGB images are studied and assessed.

Materials and Methods

The cotton field (85 × 54 m) was selected at the Texas A&M AgriLife Research Center at Corpus Christi, TX. The cotton plants were planted on April 1, 2015 and the emergence was observed after 5 days. The cotton was harvested on August 17, 2015. As shown in Figure 1, there were totally 35 cultivars planted with four replications. At the first replication, the cotton seeds were planted in order of the cultivar number. In the latter three replications, the seeds were planted in a randomized order. The whole field was organized into 7 blocks and there were 56 rows in each block. Two adjacent rows in each block form a cultivar for any replications. 'F' in Figure 1 indicates filler rows that are excluded from the subsequent analysis and discussion. Four ground control points (GCPs) were set up for providing georeferencing source for the plant height estimation and suppressing cumulative error during image processing. There are totally 17 datasets collected during the cotton growing cycle, ranging from April 7 to July 30, 2015. During the first week, we flew the UAS on per day basis, and flew once per week or once the other week for routine monitoring.

2015 AgriLife Extension -- Nueces Monster Cotton Varieties
Station F7 - F8 Block 25
Planted 1-Apr
Emerged 6-Apr
Plot size 2 rows, 35 ft

N ↑

2F	24 124	23 123	22 122	21 121	20 120	19 119	18 118	17 117	16 116	15 115	14 114	13 113	12 112	11 111	10 110	9 109	8 108	7 107	6 106	5 105	4 104	3 103	2 102	1 101	6F
F	F	3 212	11 211	17 210	5 209	25 208	29 207	1 206	15 205	26 204	8 203	21 202	6 201	35 135	34 134	33 133	32 132	31 131	30 130	29 129	28 128	27 127	26 126	25 125	F
F	F	27 235	9 234	31 233	13 232	35 231	7 230	32 229	22 228	30 227	4 226	33 225	20 224	16 223	24 222	18 221	34 220	2 219	28 218	14 217	23 216	12 215	19 214	10 213	F
F	7 324	28 323	10 322	34 321	2 320	6 319	33 318	23 317	31 316	3 315	25 314	9 313	27 312	14 311	1 310	26 309	13 308	19 307	5 306	24 305	8 304	18 303	15 302	4 301	F
F	F	6 412	26 411	8 410	32 409	14 408	4 407	34 406	25 405	19 404	35 403	17 402	10 401	12 335	30 334	35 333	16 332	20 331	32 330	11 329	29 328	21 327	17 326	22 325	F
F	F	16 435	30 434	12 433	28 432	24 431	18 430	21 429	2 428	27 427	33 426	5 425	29 424	11 423	15 422	23 421	3 420	22 419	13 418	9 417	31 416	1 415	20 414	7 413	F
F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F

Figure 1. The cotton field selected for monitoring the growth over the whole life cycle.

As we have stated, the main goals are to generate 1) a geo-referenced mosaicked image that can be used to estimate the plant coverage during a growing cycle of cotton, and 2) a 3D canopy model that can be used to estimate the plant heights. With the development of the computer vision research, the structure-from-motion (SfM) algorithm has paved the way for utilizing low-cost RGB cameras to access high-resolution 3D point cloud and orthomosaics. It uses the matched features between adjacent images to establish the coplanar relationship between the ground object, the object on image and the camera location when the image was taken. The Pix4Dmapper Pro software was used to perform the orthomosaics and point cloud computation after loading the images and GCPs.

The point cloud determines the plant surface model (PSM) each time the fly was performed. The plant height information is accessible by subtracting the bare soil surface model before cotton emergence. On the other hand, orthomosaics enables canopy cover computation by performing an interactive supervised classification using the Esri ArcGIS software.

Results and Discussion

Figure 2 shows the relationship between days after cotton emergence and the average plant height. In this figure, the statistics starts from the April 25, 2015 and excludes the datasets collected previously because cotton sprouts were short and are not distinguishable from the measurement noises. The statistics also disregards the difference of the cultivars and the height is average according to all the rows under investigation. Green dots indicate UAS-based height measurements and the red error bars demonstrate the standard deviation. It is clear the cotton grows fast until the 74th day after emergence, and then the growth rate becomes slow before the cotton plants decline. Figure 3 displays the cotton plant height of different cultivars over time. This demonstrates that all the cultivars have the similar growth and development trend, yet different in detail, particularly around the peak height growing period. Figure 4 shows the relationship between days after cotton emergence and the canopy cover.

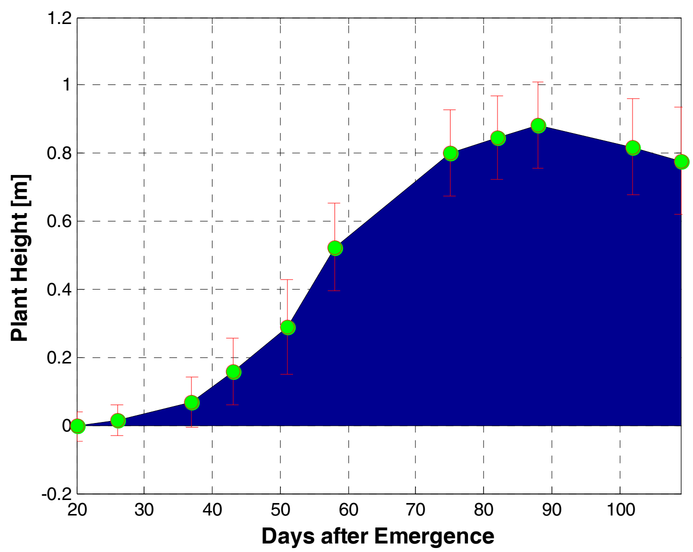

Figure 2. Relationship between days after cotton emergence and the average plant height.

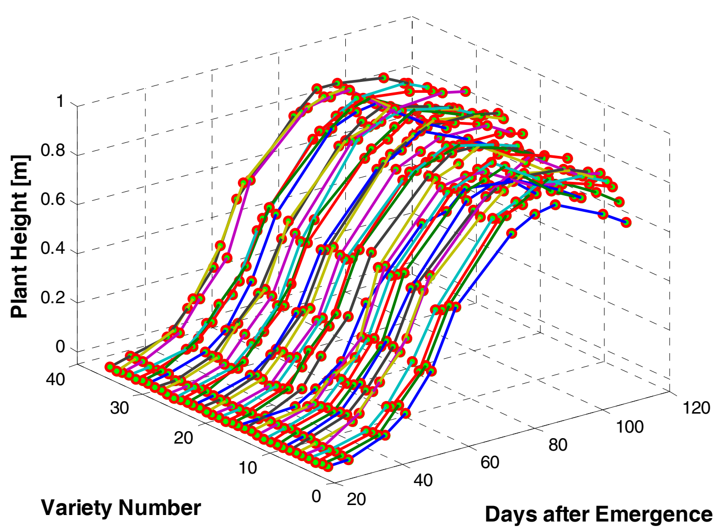

Figure 3. The cotton plant height of different cultivars over time.

According to the National Cotton Council, the growth and development of the cotton plant follows a typical sigmoid curve. Both the cotton plant height and canopy cover calculated using UAS-based imagery match the empirical understanding.

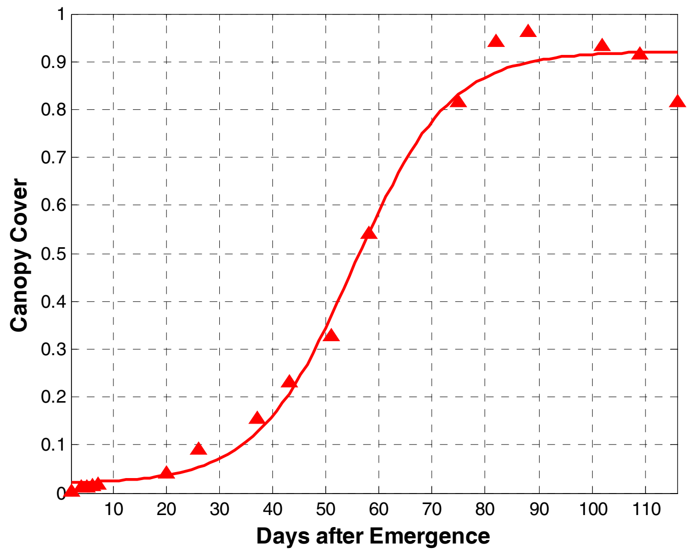

Figure 4. Relationship between days after cotton emergence and the canopy cover.

Summary

Mounted with low-cost camera sensors, low-cost UAS platforms offer us a unique opportunity to develop smart applications for precision agriculture at very low cost with high spatial, spectral and temporal resolutions. This research used a lightweight UAS platform to monitor the cotton field over the whole growth and development cycle. The UAS-based RGB imagery is capable of generating high resolution mosaicked images as well as dense 3D point cloud. Classification of the mosaicked images can obtain 2D plant coverage information. 3D canopy digital surface models can be obtained at a very high resolution based on the point cloud. Plant height can be estimated with the 3D canopy digital surface model. Our results are in general agreement with the statistics acquired from the ground measurements. In the next phase, more onboard measurements from the thermal camera and multi-spectral camera should be incorporated for better monitoring the cotton growth and health status.

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References

Aasen, H., Burkart, A., Bolten, A., and Bareth, G. 2015. Generating 3D hyperspectral information with lightweight UAV snapshot cameras for vegetation monitoring: From camera calibration to quality assurance. ISPRS J Photogramm Remote Sens. 108:245–259.

Growth and Development of a Cotton Plant. Available online: http://www.cotton.org/tech/ace/growth-and-development.cfm (accessed on 20 January 2016).