2014 OAN/ODA FINAL Progress Report

Project title: Use of aerial imagery and object based software to obtain plant inventory in an open-field container nursery

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Collaborating nursery: Greenleaf Nurseries, Park Hill, OK

To date, the research team has accomplished the following:

1. Renewed (May 31, 2014) site license for ArcGIS: $1,500
2. Renewed (August 31, 2014) site license for Feature Analyst: $1,000
3. Gave presentation at Cultivate14 Seminars on project (7/13/14)
4. Completed processing and analysis of digital images for several experiments (outlined below)
5. Submitted a $48,253 Specialty Crop Research Initiative(SCRI) Planning grant in June 2014 (not accepted)
6. Wrote an article for AmericanHort summarizing our research with credit to the OAN grant: http://americanhort.theknowledgecenter.com/AmericanHortNews/index.cfm?view=detail&colid=147&cid=4447&mid=8252&CFID=3258555&CFTOKEN=19e6a28555450482-A0C22241-E233-B12E-5983D12BECCF062F
7. Wrote an article for Great Lakes Christmas Tree Journal [9(4): 10-12] summarizing our research with credit to the OAN grant.

Research:

Several factors contribute to the complexity of imagery used for plant inventory analysis including plant characteristics (plant color, species, plant size & shape, canopy cover, plant health), ground/surface characteristics (bare soil, gravel, ground cloth), and environmental factors (sunlight, shadows). Because these factors could influence the data obtained from remote sensing images, these conditions must be accounted for when using these images. Since nurseries grow a wide range of plants this may require several counting algorithms.

Previous OAN reports summarized results from several experiments designed to evaluate the effect of plant spacing, production ground cover, canopy shape and presence of flowers on counting accuracy of container-grown plants using two different counting algorithms.

This study was designed to evaluate the effect of the presence of dead plants in production beds on count accuracy

Plant status (living or dead)

Experimental design

Container-grown plants were spaced in staggered rows with a canopy separation of 5 cm between canopy edges. Buxus × 'Green Velvet' growing in #2 black polyethylene containers. The dead plants still retained a majority of brown leaves (Fig. 3.5). For each treatment, a set of 49 containers (7 × 7) were established outdoors on black polypropylene fabric ground cover on 16 May, 2014 at Greenleaf Nursery, Park Hill, OK (35.779098, -94.904323). Treatments consisted of sets with only living plants, and sets with 14% dead plants randomly positioned within the set (Fig. 3.6). Treatment sets were replicated four times in a randomized complete block design (RCBD) for a total of 8 sets. Two additional sets representing both treatments, were positioned adjacent to the treatment sets and were used to train the algorithm using FA, and henceforth referred to as training sets. After taking images from all sets at 1010, a second round of images were taken at 1245. Two images of each set were taken at 12 m above the ground (one per each round) and then used for algorithm evaluation. Four plants per set were used for plant measurements. These were the corner plants on each set. Image were taken using a Sony NEX7 camera.

Fig. 3.5. Photograph of a dead Buxus × 'Green Velvet' with its leaves still retained in a treatment set.

Fig. 3.6. Left: set with 0% dead plants. Right: set with 14% dead plants.

Algorithm training

Algorithm training procedures using FA were similar to those described in previous reports, with the exception that when using a training image with 14% dead plants, all dead plants (7) were used when digitizing training samples. A total of two algorithms were trained, one for living plants and the other for dead plants. Each algorithm was applied to all images. Dead plants identified as alive, and vice versa, were calculated using output images from the algorithm. Images were not analyzed using the algorithm trained in MATLAB due to time restrictions of the graduate student at the University of Florida.

Variables

In order to determine if the algorithm could distinguish between dead and living plants, the number of living plants counted as dead was recorded when the algorithm was trained using dead plants and, the number of plants counted as living was recorded when the algorithm was trained using an image containing only living plants. Since the number of living plants is different in both treatment sets, count accuracy data are not comparable. Image selection parameters are the same as those described in the previous chapter.

Results and discussion

Algorithm trained using living plants

Since the number of living plants is different in both treatment sets, total count error, false positives and unidentified plants data are not comparable. An algorithm was trained with living plants using FA and then applied to images displaying plant sets with and without dead plants. Table 3.9 shows the number of dead plants counted as living. No dead plants were counted as living, regardless if sets contained only living plants or 14% dead plants.

Table 3.9. Number of dead Buxus x 'Green Velvet' plants counted as living when training an algorithm with living plants using Feature Analyst®

Treatment sets (% dead plants)	Number of dead plants counted as living
0%	0
14%	0

Algorithm trained using dead plants

An algorithm was trained with dead plants using FA and then applied to images displaying sets with and without dead plants. Table 3.10 shows the number of living plants counted as dead. No living plants were counted as dead regardless of the treatment set.

Table 3.10. Number of living Buxus x 'Green Velvet' plants counted as dead when training an algorithm with dead plants using Feature Analyst®

Treatment sets (%dead plants)	Number of living plants counted as dead
0%	0
14%	0

When training 'samples' are digitized containing dead or living plants, the segmentation in FA distinguished between pixel information from both classes. The 'Green Velvet' images used in this experiment had a consistent spatial resolution and results indicated that the training 'sample' used was representative enough that no misclassification was observed.

Conclusions for All Experiments:

The research as performed focused on investigating some parameters (e.g. canopy spacing; presence of flowers) that might influence the ability of two object-based methods to count plants in an open-field container nursery. Although some of the experiments used a UAV to obtain images, in the long term other methods (e.g. mobile boom) may be more appropriate for this application, although the economics of this approach will need to be evaluated. A UAV is simply one method to collect requisite images. The major benefit of this research was to begin evaluating software as a means to automate the counting process of plants in open-field nurseries. These studies also evaluate the utility of using off-the-self color camera for inventory management purposes.

Feature Analyst (FA) is easy to use but several parameters had to be changed when training the algorithm requiring a great amount of time. While FA generated good counting results, the MATLAB algorithm yielded better overall count accuracy for plants placed on gravel as a result of a ratio obtained from images for plants placed on black fabric. The addition of this correction ratio, suggests that data from previous images could be used to increase count accuracy. It would be difficult to establish an exact cost for each method as the actual value will be determined by factors such as discounts, number of users, and the actual cost of the output program writing using MATLAB.

With the exception of the algorithm trained using non-flowering roses, results from data analyzed using FA were not influenced by plant canopy shape, plant status and presence of flowers when using images taken at 12 m above ground. The algorithm trained in MATLAB did not find any differences when plant canopy shape and presence of flower were evaluated for the species studied. Factors such as canopy shape, presence of flowers and plant status were evaluated independently, however in a commercial nursery setting, these and many other factors (e.g. slope of production area, variation in canopy size and plant height) might be involved and need to be evaluated.

Continued research with FA and the customizable algorithm trained in MATLAB are likely to improve future plant counting efforts by reducing the requirement for manual labor in the counting process. Based on the preliminary results from this study, further research is required to improve counting results using different algorithms, sensors (resolution, image distortion, angle of view, multi spectral and/or narrow bands), methods to obtain images, and environmental conditions (light variations –sun angle, shadows-, moisture on the ground cover).

Although results from these experiments have advanced our knowledge on certain parameters (e.g. two object-based methods; UAV versus boom lift; plant shape), our conclusions are limited to the conditions and parameters studied. Many more experiments need to be conducted before we can determine if this technique can be used to count plants in open-field nurseries in a commercial setting.