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Potential of low altitude multispectral imaging for in-field apple tree nursery inventory mapping

Juan José Quirós*,. Lav R. Khot***

*Center for Precision and Automated Agricultural Systems, Department of Biological Systems Engineering, Washington State University, Prosser, WA 99350 USA (Tel: 509-786-9302; e-mail: juanquiros2@gmail.com; lav.khot@wsu.edu)
**Universidade de São Paulo, Escola Superior de Agricultura Luiz de Queiroz, Piracicaba, SP 13418-900 Brazil

Abstract: Aerial imaging based plant counting is a widely studied topic in remote sensing. Nevertheless, existing methodologies are not applicable for in-field nurseries tree counting due to the complexity in canopy shapes, irregular plant spacing and growth, and diverse textures captured on the images. In this study, a new algorithm has been developed in accordance to the specific requirements of apple nurseries images. Algorithm composed of two key steps, i.e. a raster processing followed by a vector analyses. First step attempt to isolate apple plant pixels using spatial, spectral, and radiometric enhancements. In vector processing, filters based on the size and location of the polygons were applied to isolate the areas resulting from earlier step to represent apple plants. Algorithm was evaluated to estimate number of apple trees in an young nursery imaged with low altitude multispectral imaging system at four altitudes of 10, 25, 40, and 50 m. Multispectral imaging sensor consisted of near-infrared (NIR), green and blue as three bands. For 10- and 25-m images, algorithm performance was evaluated in individual as well as in mosaic images. Low altitude images with ≤ 25 m above ground level were ideally suited for young apple nursery tree count with 5% or less estimation error. Tree count accuracy was 97% and 95% for 10-m altitude individual and mosaic images, respectively. Similarly, those values were 92% and 88% for 25-m altitude images. Based on the results, images at 40 m are recommended only when the methodology include four extra steps added to the base algorithm to have tree count accuracies of about 88%. Images at 50 m are not recommended in any case due to the low accuracy obtained (~ 75%). Overall, the low altitude multispectral imaging integrated with image processing algorithm developed in this study will aid nursery growers in low-cost and timely tree count needed for inventory mapping and management.

Keywords: Unmanned aerial system, remote sensing, nursery production, tree inventory.

1. INTRODUCTION

In Washington State, about 60 thousand hectares is under apple tree fruit production with most of the fruits sold in fresh market (USDA, 2014). For the ease of orchard mechanization to address pressing labour issues and with goal of being economically viable in competing international fresh fruit market, growers are transitioning from old cultivars to new apple cultivars that produce better quality fruits. Old tree architectures are also being replaced with modern vertical and y-trellised tree architectures.

Grower needs have translated into increased demand of cultivar specific seedlings (e.g. Honeycrsip) with most local nurseries pre-sold for next few years. Overall, nurseries are generally planted in plastic pots under semi-controlled conditions, where individuals present regular shapes and spacing (Hooijdonk et al., 2015). In the U.S. Pacific Northwest, the panorama changes, with plants growing directly on the ground with somewhat irregular shapes and spacing.

Nursery growers thus use labour-intensive techniques to count every seedling per season, i.e. four times a year, to have cultivar specific inventory. Manual plant counting is time consuming process and accounts for one of the major production expenses. Plant/seedling inventory is also critical for adequate insurance of the seedlings in late fall to avoid economic losses to nursery growers due to winter weather before harvesting the dormant seedlings.

Thus, nursery growers are in need of alternative and rapid inventory mapping techniques. Small unmanned aerial systems (sUAS) is emerging as a versatile technology for range of imaging based agriculture applications. sUAS have been employed for crop emergence (Sankaran et al., 2015a; Khot et al., 2016), biotic and abiotic stress scouting (Falkenberg et al., 2007; Sankaran et al., 2015b), irrigation management (Gago et al., 2015) and also for potted nursery tree inventory mapping (Leiva, 2014).

Between the aerial data collection and the generation of inventory maps, are placed the algorithms necessary to convert sensor raw data into information for practical applications (Sankaran et al., 2015b). Some algorithms exist for well-developed trees (Delenne et al., 2010; Recio et al., 2013) and potted nursery trees (Leiva, 2014) counting from aerial imaging. However, for nursery trees grown from the ground, new algorithms understanding imagery context, i.e. plant, weed, mulch, irrigation lines, trellis pols, are required. Therefore, key objective of this work was to develop a robust algorithm to process the sUAS acquired

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multi-spectral images for accurately counting number of plants in young 2-year apple nurseries where seedlings are planted directly into the ground at somewhat irregular spacing. Focus was also to evaluate optimal imaging resolution needed to effectively count the nursery plants.

2. MATERIAL AND METHODS

2.1 Study site and data collection

The field data was collected from an apple tree nursery in second year of the production. Data was collected mid-September under dry/sunny conditions with a solar radiation of about 661 W/m^2 (Source: WSU, 2016) (Fig. 1).

Fig. 1. A study site (Lat: 47° 0'29.25"; Long: 119°49'30.29").

Small UAS (OktoXL 6S12, Oktokopter Inc. Germany) integrated with 3-band multispectral imaging sensor (XNiteCanonNDVI, LDP LLC, NJ) was used to acquire the aerial images of study plots (see Fig. 1 insert). sUAS can be operated both manually or using an autopilot guided by the GNSS embedded in the hardware with a defined flight plan. In this study, field maps were used for waypoints guided flights. Three band sensor constitute NIR, green (G), and blue (B). Typically, sensor has a resolution of 0.35 cm per pixel for images taken at 10-m altitude AGL.

Apple nursery plot of 50 (L) × 7.5 (W) m was imaged at four different flight altitudes of 10, 25, 40 and 50 m AGL. Inside the plot located were four tree lines (rows) spaced at 1.5 m. Tree spacing in a given row was about 0.30 to 0.75 m. In the middle row of study plot, different coloured panels along with reflectance panel (Fig. 2) were placed for ease of stitching images from low altitude flights. On the same day, ground-reference data was also collected to have actual count of the apple nursery trees per row and also between the reference boards on the ground.

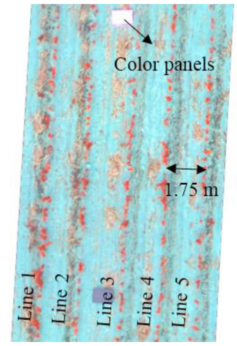

Fig. 2. Field dimensions and nursery tree lines.

2.2 Nursery tree counting algorithm

Image processing algorithm was implemented using ERDAS (2014, Hexagon Geospatial) (for raster analysis) and ArcGIS (10.2, ESRI, Redlands, Ca) (for vector analysis) software. Fig. 3 enlist 15 steps performed by the custom developed image processing algorithm, following the order through which they are applied. For 10 m and 25 m images, performance of the algorithm was analysed in individual as well as in mosaic images. Agisoft Photoscan (Agisoft LLC, Russia) was used to generate the mosaics.

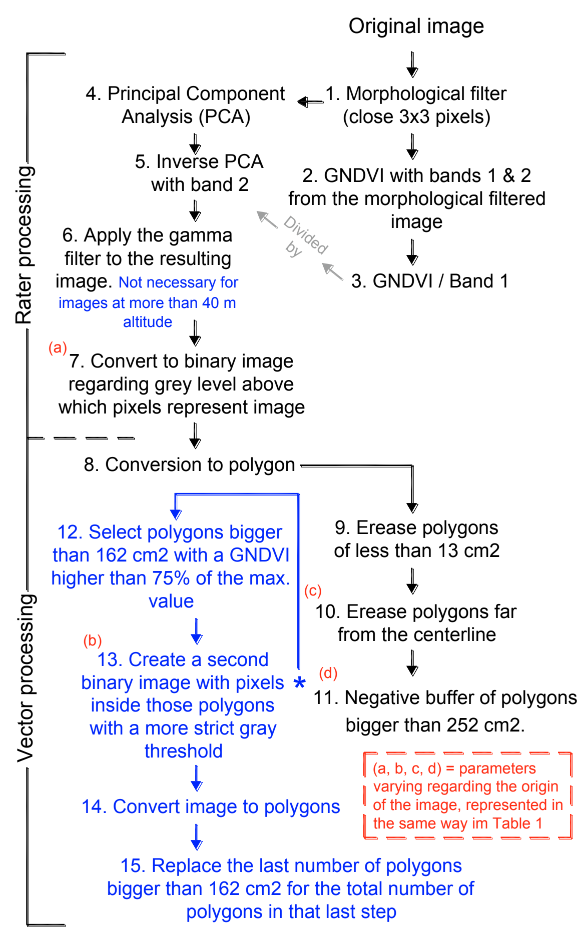

Fig. 3. Apple nursery tree counting algorithm to process sUAS based multispectral data.