A DATA-FUSION BASED SEMI-AUTOMATIC TREE COUNTING ALGORITHM FOR USE IN EUCALYPTUS GRANDIS PLANTATIONS

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1. INTRODUCTION

Semi-automatic tree counting algorithms are typically designed to detect local image maxima and minima values for isolation of tree crowns [1]. The successful application of centroid and crown delineation algorithms requires that tree crowns be recognizable as discrete objects in remote sensing imagery. Maxima are typically identified as crown centroids indicating the geographic location of a tree, while minima are used to delineate the tree crowns [2]. In plantation forestry this is not always the case, because canopies are constantly intersecting and thus creating indeterminable crown boundaries due to the optimized growing conditions. It is therefore necessary to use image processing algorithms to isolate tree crowns prior to automated identification. Image pre-processing algorithms have been employed by [3] whereby band differencing (near-IR and red channels) was combined with Gaussian smoothing to simplify crown form and reduce image noise. Typically, the pre-processing is followed by segmentation of the data using template matching, boundary following or derivative based zero-crossing image partitioning [4].

2. METHODS

The following paper presents an algorithm that employs multiple data sets within a data fusion framework for the accurate delineation and subsequent counting of plantation *Eucalyptus grandis* trees. The study was conducted in even-aged (4-11 years) *Eucalyptus grandis* plantations located in the southern KwaZulu-Natal midlands of South Africa. Remote sensing data employed for this research included digital aerial photography captured in the visible portion of the electromagnetic spectrum only and a high density discrete return (two returns per pulse), small footprint lidar data set (±5 points/m^2). The algorithm workflow was as follows:

1. Both lidar intensity and canopy height were interpolated using a kriging-based interpolation [5] at a resolution of 0.5m.
2. Timber compartments were identified using geo-spatial vector data provided by an industry partner, while suitable compartments had their lidar and aerial photography masked out and saved for further processing.
3. The aerial photography and lidar-derived surfaces were subjected to a principal component (PC) analysis to enhance tree crowns where PC 1 was assumed to explain the largest variance component in the data. We determined that this component was associated with variation due to vegetation cover and thus highlighted the tree canopies; PC 1 was subsequently converted to a gradient image.

4. Watershed segmentation was used to segment the gradient image into discrete image objects. Spatial object operations, employing thresholding and mathematical morphology, served to remove non-tree crown segments and merge adjacent segments belonging to individual tree crowns.
5. Discrete tree crowns identified were vectorised and crown centroids were generated; these centroids were used to count the number of trees within each stand. Stems per hectare (spha - a standard forest enumeration parameter) were compared to field enumerated spha and returned accuracies comparable to previous studies [6].
6. Finally, individual tree heights were calculated using the crown centroids; espacement in *Eucalyptus grandis* plantations is 3 meters between rows and 2.4 meters within rows, thus allowing for a theoretical crown diameter of approximately 2m. Each centroid was buffered by 1 meter with the maximum lidar height value within each crown buffer taken as the height of the individual tree.

The algorithm was applied in several stands of varying age and site quality. Algorithm development was facilitated through the use of an open source image processing library called the ORFEO toolbox.

3. CONCLUSION

The combined use of both aerial photography and lidar based canopy models exhibited potential to enhance the individual tree crowns within the imagery. Preliminary analysis indicates that problems associated with off-nadir crown illumination could be negated through the use of lidar derived canopy surfaces (intensity and height). Full details of algorithm results will be presented at the conference, as well as recommendations for future enhancements and updates to the methodology.

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