Factsheet # 3

LiDAR-based Tree Crown Surface Reconstruction

UW R emote S ensing & G eospatial A nalysis L aboratory

Understanding multiscale dynamics of landscape change through the application of remote sensing & GIS

Application of the wrapped surface. The wrapped surface approach opens a new era of direct tree crown measurement from LiDAR data and yields finer scale tree crown information than previous approaches. The wrapped surface approach described here can be applied to a number of fields including tree physiology, wildland fire management, inventory analysis, and forest management. For example, pipe model theory (Oohata and Shinozaki, 1979; Shinozaki, et al., 1964) states that the cross-sectional area of stems and branches at some height is proportional to the total amount of foliage above the height. The crown volume, which is associated with photosynthetic activity, can be quantified by the wrapped surface. When done so, the cross-section of stems can be predicted at any height and stem volume can be estimated easily without destructive sampling. Furthermore, Shinozaki et al. (1964) found that DBH is the best predictor of foliage biomass, and our study found high correlation between DBH and crown volume (Figure 10), thus, the crown volume derived from the wrapped surface can be a good alternative predictor for foliage biomass (Bortolot and Wynne, 2005) and potentially carbon content (Patenaude et al., 2004). The wrapped surface can also produce more precise dimensions of crown width at any vertical height for the purposes of tree physiological analysis.. Point density and space enclosed by the wrapped surface can yield estimates of crown density which is a useful indicator in tree health monitoring (Schomaker et al., 2007; Zamoch et al., 2004). Tree health monitoring is, therefore, easily achieved by the wrapped surface.

Crown base height and volume measurements from LiDAR derived from the wrapped surface can improve simulation of fire behavior, including the probability of ground fires progressing to the crown under given conditions. Crown fire simulations depend on accurate estimates of crown volume and the three-dimensional connectivity between crowns. The wrapped surface method can provide those parameters to simulate fire spread at fine spatial scales.

Precise tree parameters given by the wrapped surface can be used for change detection of tree growth. Three dimensional differences between the wrapped surfaces created by multitemporal aerial or terrestrial LiDAR data be used to show the crown growth characteristics for a given tree species. Furthermore, the shape recognition of irregular tree crowns through the wrapped surface method can aid in distinguishing tree species on a morphological basis. Brandtberg (2007) reported that the intensity value of LiDAR data should be calibrated for use in species identification by using height thresholds to classify the intensity values between ground and canopy. With our method, the angle and direction of tree crown illumination can be distinguished between interior and crown surface LiDAR points, thus, allowing for the calibration of the intensity value. Furthermore, the structural component derived from the wrapped surface may improve micro scale shading technique in individual tree level and fusion technique with the other 2D images such as high resolution hyper spectral images for species classification.

One important requirement for wrapped surface reconstruction is the need for **precise segmentation** of the tree crowns. We limited our study to open-grown trees for validation of the wrapped surface technique. For managed forest or stands with closed canopies, the segmentation method is critical for precise estimation of tree parameters. Once the points are well segmented, the wrapped surface fits exactly to the segmented points Current segmentation methods do not work well for stands with closed canopies or plantations, however, thinned areas can be used to estimate the tree parameters from the wrapped surface to apply them to predict parameters in the entire area, since LiDAR data acquired in thinned stands are easily segmented.
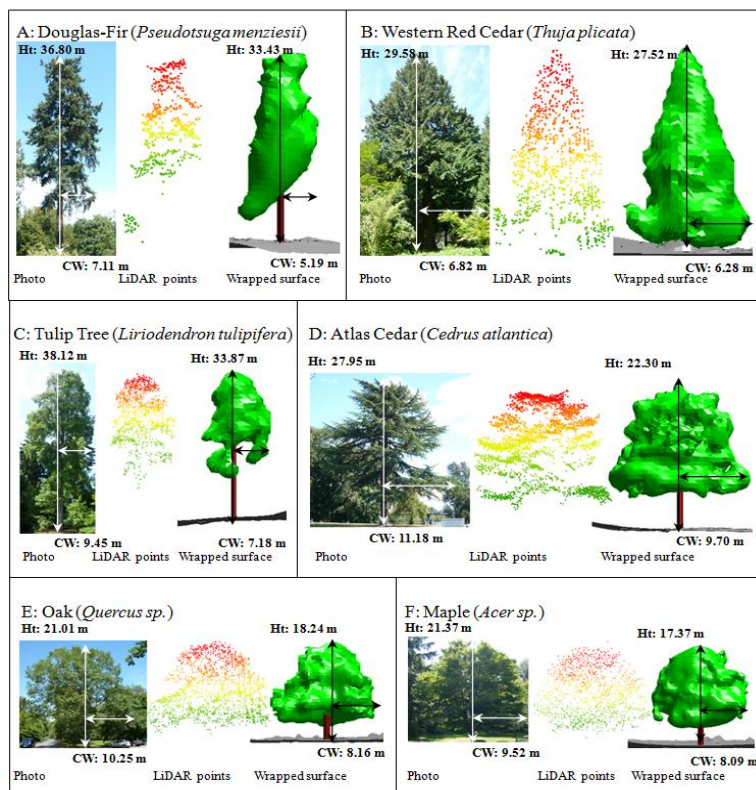
Visualization of the wrapped surface reconstruction. Shown are Douglas-fir (A), western red cedar (B), tulip-tree (C), atlas cedar (D), oak (E) , and maple (F). Ht: Tree Height, CW: Crown width.

Correlation of crown volume estimation between field and wrapped surface measurement (left) and crown volume derived from the wrapped surface and field measured DBH (right).
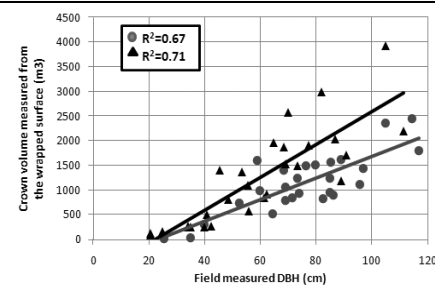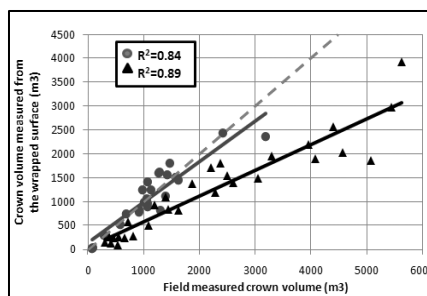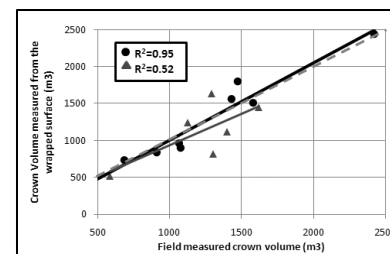
Correlation of crown volume estimation between field and wrapped surface measurement (left) and crown volume derived from the wrapped surface and field measured DBH (right). Grey circles and line represent coniferous trees and black triangles and line represent deciduous trees. Dashed line represents one-to-one correlation; p-values are 0.00 (< α = 0.05).

THE ISSUE: Forest structure data derived from LiDAR is being used in forest science and management for inventory analysis, biomass estimation, and wildlife habitat analysis. Regression analysis dominated previous approaches to the derivation of tree stem and crown parameters from LiDAR. The regression model for tree parameters are location-specific. We developed an innovative method called 'wrapped surface reconstruction' that employs radial basis functions and an isosurface. Utilizing computer graphics, we capture the exact shape of an irregular crown of various tree species based on the LiDAR point cloud.

THE KEY QUESTION:
Can we develop a universal approach to derive LiDAR based tree parameters?

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