Factsheet # 14

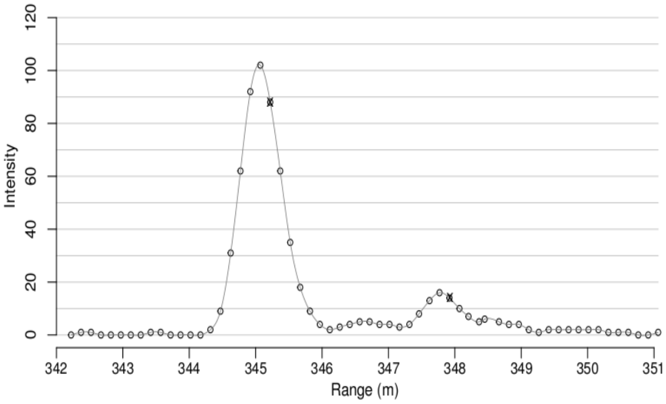
Identification of Individual Tree Species Using Full Waveform LiDAR

This research was funded by the UW Precision Forestry Co-op

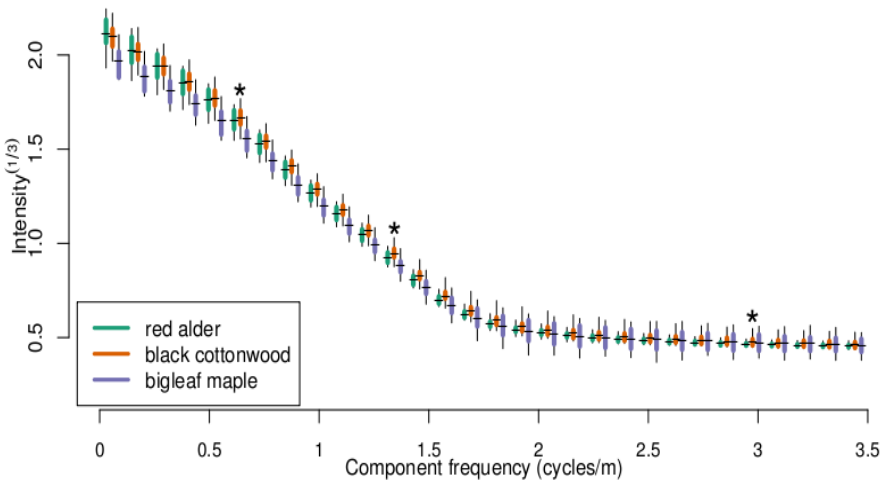
UW

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

Remote **S**ensing & **G**eospatial **A**nalysis **L**aboratory



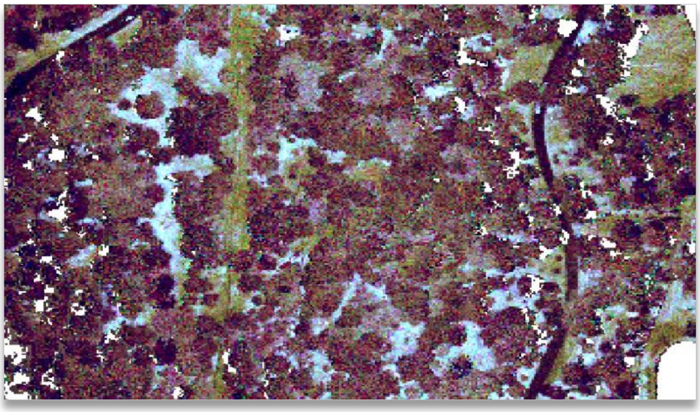
Full waveform LiDAR provides much greater detail about surface reflectivity than is available from discrete point LiDAR. This is because, rather than recording only the distance and intensity at the peaks, the entire return signal is captured. The figure to the left shows one such waveform and the points that might be returned by an onboard peak detector instrument. Previous attempts at species differentiation from waveform Lidar start with an immediate conversion to discrete points. With such data, one must focus on spatial arrangement of these points, or summaries of their intensity values. We were interested in determining if there was enough information at the waveform level to decipher tree species.



Each waveform collected with LiDAR is also a time series, and there are several tools available to evaluate such data. One such tool is the Fast Fourier Transform (FFT). The FFT results in a spectrum, which is simply the amount of influence of each of several frequencies within the time series. To illustrate how these spectrums might differ between species, the figure on the right shows the ranges of these spectrum values across all trees for 3 different species. Our first approach was to use the spectrum values for each species, averaged over each tree in the training data. Three frequencies, along with the mean intensity value of the untransformed waveform, were found to be important during the fit of a classification tree. These frequencies have wavelengths of 1.5, 0.75, and 0.35 meters (starred on the figure to the right). The classification tree results after leave-one-out cross-validation were as follows:

Actual	Predicted			
	BLM	BC	RA	Prod. Acc. (%)
Bigleaf maple (BLM)	7	2	1	70
Blk. Cottonwood (BC)	2	14	1	82
Red alder (RA)	1	4	12	71
User acc. (%)	70	70	86	Overall = 75%

The raster image below is not from a camera. It was made by averaging the spectrum values for all waveforms starting within the 1m x 1m pixel area. The red, green and blue channels are each set to one of the important frequencies mentioned above. Distinctions can be seen between tree types (species) even to the human eye.



It is encouraging to see that a relatively simple analysis of waveform LiDAR data still provides respectable results. It will not be long before we regularly use the wealth of information provided by waveform LiDAR for species identification. This analysis looked only at the individual waveform level, neglecting any relationships between adjacent light pulses on the same target. We tested the effect of reduced dataset size at four reduced levels (80, 60, 40, and 20 percent) The results were even more encouraging; reducing the dataset had a minimal effect on overall accuracy.

Dataset	Overall acc. (%)	Kappa
Original	75	0.62
80 %	82	0.72
60 %	61	0.40
40 %	54	0.29
20 %	66	0.48

Future analysis will include not only waveform-level information, but will incorporate spatial relationships among the waveforms. Also, because scan angle would likely have a large effect (not tested), incorporating this information should improve results. The information from individual waveforms should be mostly unrelated to spatial patterns of the tree in three dimensions. This means that the spectra information should combine well with more spatially-oriented analysis, taking the best information from both perspectives.

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Our other related work: Vaughn N., L. M. Moskal and E. Turnblom, 2011. Fourier transformation of waveform LiDAR for species recognition, Remote Sensing Letters, 2(4); 347-356.

THE ISSUE: Remote sensing tools are already capable of measuring the size of individual trees and their crowns with high precision and fair accuracy. Discrete point LiDAR is especially useful for such a task, but is not typically used to guess the species of a given tree. Waveform LiDAR offers more detail of surface reflectivity of a target, and this extra information aids in tree species identification.

THE KEY QUESTION:

Can waveform LiDAR data be used to identify individual tree species in a production application?

Citation: Vaughn, N. and L.M. Moskal, 2011. Identification of Individual Tree Species Using Full Waveform LiDAR. Factsheet 14. Remote Sensing and Geospatial Application Laboratory, University of Washington, Seattle, WA. Digital version of the fact sheet can be downloaded at: http://dept.washington.edu/rsgal/