Lidar Research at the Pacific Northwest Research Station

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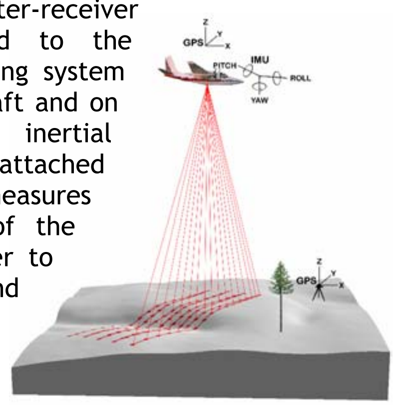
How Lidar (Light Detection and Ranging)Works

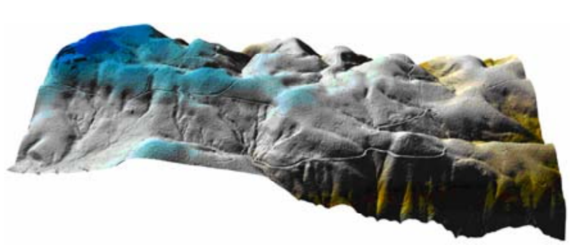
Airborne lidar technology uses four major pieces of equipment: a laser emitter-receiver scanning unit attached to the aircraft; global positioning system (GPS) units on the aircraft and on the ground; an inertial measurement unit (IMU) attached to the scanner, which measures roll, pitch, and yaw of the aircraft; and a computer to control the system and store data. Commercial systems commonly used in forestry are discrete-return, small-footprint systems. "Small footprint" means that the laser pulse diameter at ground level ranges from 15 to 90 cm.



The laser scanner on the aircraft sends up to 150,000 pulses of light per second to the ground and measures how long it takes each pulse to reflect back to the unit. These times are used to compute the distance each pulse traveled from scanner to ground. Using location and attitude data provided by the GPS and IMU units, and an exact coordinate is calculated for each point (or return). The laser scanner uses an oscillating mirror or rotating prism (depending on the sensor model), so that the laser pulses sweep across a swath of landscape below the aircraft. Large areas are surveyed with a series of parallel flight lines. Because the system emits its own light, flights can be done day or night, as long as the skies are clear.

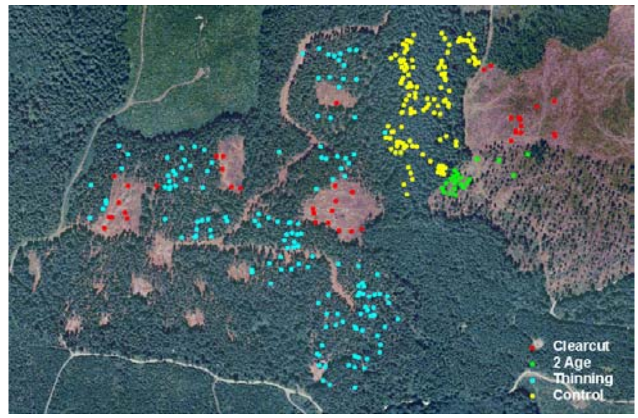
Lidar Accuracy—Ground

Lidar systems available today are capable of producing point measurements with absolute horizontal and vertical accuracy of less than 50 cm and 15 cm respectively. One of our first lidar studies evaluated the ability of lidar to accurately capture the ground surface under a variety of terrain and vegetation conditions. We acquired high-density (4-6 pulses/ meter^2) lidar data for the Capitol State Forest study area located near Olympia, WA prior to harvest in 1998 and immediately after harvest in 1999. Bare-earth lidar returns were identified by the data provider and used to create bare-earth surface models.



Bare-earth surface model created from lidar return data

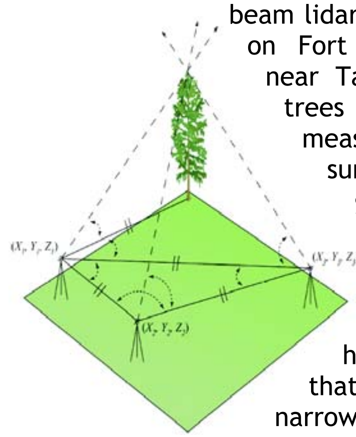
When we compared elevations from the 1999 surface model to surveyed control points, we found an average overall error of about 22 cm and maximum errors of +1.3 m and -0.63 m. Accuracy was statistically the same in the clearcut and the 70-year old control unit (Reutebuch et al. 2003).



Survey checkpoints used to evaluate bare-earth surface model accuracy

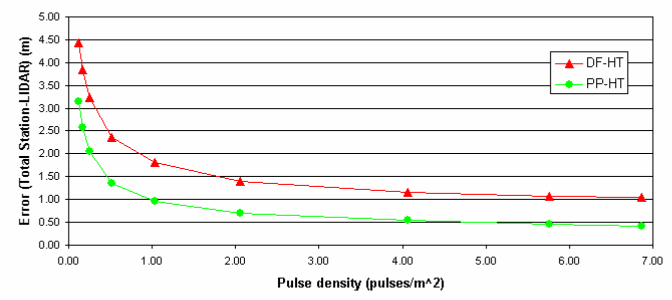
Lidar Accuracy—Tree Heights

To assess the accuracy of individual tree height measurements obtained using both narrow- and wide-beam lidar data, we conducted a study on Fort Lewis Military Reservation near Tacoma, WA. For this study, trees were accurately located and measured using a total station survey instrument, survey-grade GPS, and a rigorous field procedure. Heights were estimated from the lidar data and compared to the field-measured heights. Overall, we found that heights measured with narrow-beam lidar were 73 cm less that the field-measured heights (mean error ± SD = -0.73 ± 0.43 m). Lidar-derived measurements were more accurate for Ponderosa pine (-0.43 ± 0.13 m) than for Douglas-fir (-1.05 ± 0.41 m). Overall error for wide-beam data was -1.12 ± 0.56 m. Error was -0.77 ± 0.24 m for ponderosa pine and -1.49 ± 0.56 m for Douglas-fir (Andersen et al. 2006). In a follow-up study, we found that overall height error increased as the pulse density decreased. We also found that acquisitions with pulse densities below 1 pulse/m^2 did not provide sufficient data to accurately measure individual tree heights.



Forest Inventory Parameters from Lidar

The basic principles of allometry, or laws of proportional growth, can be used to develop regression models relating



Error in Lidar-derived tree height measurements increases as the pulse density decreases.

the spatial distribution of lidar returns within a plot area to plot-level stand inventory variables (e.g., height, volume, stocking, and basal area). lidar measurements essentially represent a detailed measurement of all reflecting surfaces within the canopy (foliage, branches, and stems). The metrics used to describe the spatial distribution of lidar returns include height percentiles, mean height, maximum height, coefficient of variation of height, and a lidar-derived measure of canopy cover (e.g., percentage of lidar first returns above 2m). This plot-level approach has been used by researchers in North America and Europe to estimate stand inventory parameters in several different forest types, where predictive regression models were shown to explain from 80 to 99% of the variation (i.e., R^2) in field-measurements. In a study performed using 99 field plots in second-growth Douglas-fir measured at the Capitol State Forest study site, strong relationships between lidar-derived predictors and field-measured values were found for several critical inventory parameters including basal area (R^2=0.91), stem volume (R^2=0.92), dominant height (R^2= 0.96), and biomass (R^2=0.91) (Andersen et al. 2005). Because this approach relies on a single mathematical model to relate the lidar metrics to a given inventory parameter over a range of different stand types, it is important to obtain representative plot-level field data that capture the full range of variability present in the area of lidar coverage and to accurately locate field plots.

Lidar Visualization and Processing Software

The FUSION/LDV software system developed by the Robert J. McGaughey at the Pacific Northwest research Station (http://forsys.cfr.washington.edu/fusion.html) provides visualization and analysis capabilities for lidar projects. The software is currently distributed free-of-charge by the Remote Sensing Applications Center of the USDA Forest Service (http://www.fs.fed.us/eng/rsac/).

The FUSION/LDV system consists of two main subsystems: a highly interactive data exploration system (FUSION and LDV programs) and a command-line processing system (PDQ viewer and analysis programs).

FUSION displays project data using a 2D display typical of geographic information systems (GIS). It supports a variety of data types and formats. Users interact with FUSION to select subsets of LIDAR data for display in LDV, an interactive 3D visualization environment allowing the examination of spatially-explicit data subsets including lidar returns, images, surface models, and 3D objects (e.g. tree models).

The command line processing system provides a set of analysis and processing programs that help users assess the overall quality and completeness of lidar data, develop a basic set of derived products, and automate a variety of processing and analysis tasks.

References

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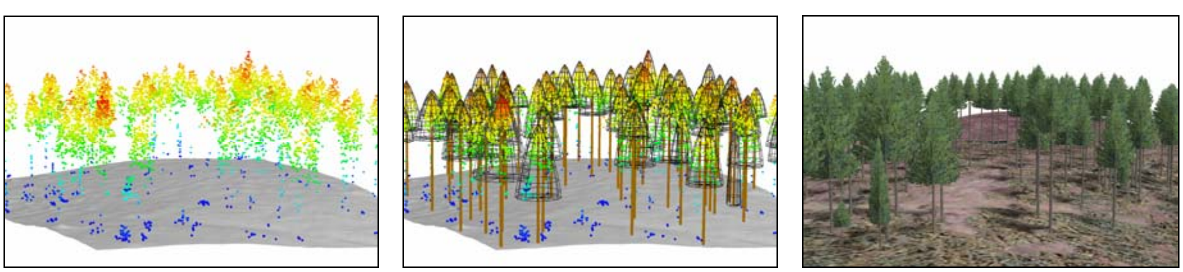

The lidar point cloud includes direct measurements of various canopy elements including stems, branches, and foliage. This series of images shows the lidar data for above-ground vegetation, tree objects inferred from these data, and a visual simulation of tree objects and terrain derived from lidar and rendered with PNW Research Station's EnVision software.