Using aerial lidar and mobile terrestrial GNSS to estimate signal attenuation in foliage

Predicting the performance of satellite navigation tools in forestry environments requires that the signal propagation characteristics of foliage be known. A study has been undertaken to fuse aerial drone based lidar measurements of forest canopy shape with data from mobile terrestrial GNSS receivers, with the end result being a standardized method for estimating the attenuation coefficient of GNSS signals passing through foliage. Initial results are presented based on a survey of planted radiata pine of two different sizes, which yield estimates of the attenuation coefficient consistent with theoretical predictions.

Estimation of signal attenuation through a volume of foliage mapped with lidar presents a significant choice in how to approach the use of lidar points to model the presence of foliage. The most straightforward approach is to simply voxelize the point cloud by checking each 3-D bin for the presence of lidar return. This, however, assumes that all foliage is accessible to the lidar sensor. In practice, penetration of laser radiation and resultant measurable return decreases with foliage depth. This means that, for dense canopy structures, only the outer portion of forest canopy can be reliably mapped.

Theoretical predictions of signal propagation in forest environments often overcome this limitation by approximating forested areas as homogenous slabs with some vertical variation in the attenuation coefficient. While this is sufficient to model the average attenuation of signals propagation at shallow elevation angles, such as telecommunications, GNSS signals are necessarily spread across a wide range of elevation angles, with individual detection vectors possibly passing through or between canopy foliage, depending on exact location.

A compromise between direct measurement of the entire canopy and an oversimplified slab is therefore introduced. The volume of attenuating foliage is modeled by using lidar data to extract the external envelope of forest canopy, based on the maximum height of lidar return in each horizontal bin. Signals are considered to be travelling through foliage when their propagation vector is within the canopy envelope. Currently this uses only the upper boundary of the canopy, but in future this method can also be used from beneath with terrestrial lidar and combined with aerial data to produce a realistic 3-D volume based on the upper and lower edges of the canopy.

Results are presented from a survey of two regions of planted radiata pine with ages of 10 and 19 years. Canopy volumes inferred from lidar derived external envelopes have been compared with data recorded by a GNSS receiver carried on a traversal that ranged from outside the forested area, along the edge, and inside the interior. Attenuation coefficients were estimated from the observed SNR of each detected satellite at each point along the traversal. Values of the attenuation coefficients produced using this method are consistent with theoretical predictions and other similar studies. It is intended that these results will be the first step in producing more accurate predictive model of GNSS performance for high-precision forestry applications.