Progress on the use of terrestrial LiDAR data to estimate structural attributes of forest canopy

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Q19: What relevant and new structural attributes can be extracted from terrestrial LiDAR?

Background:

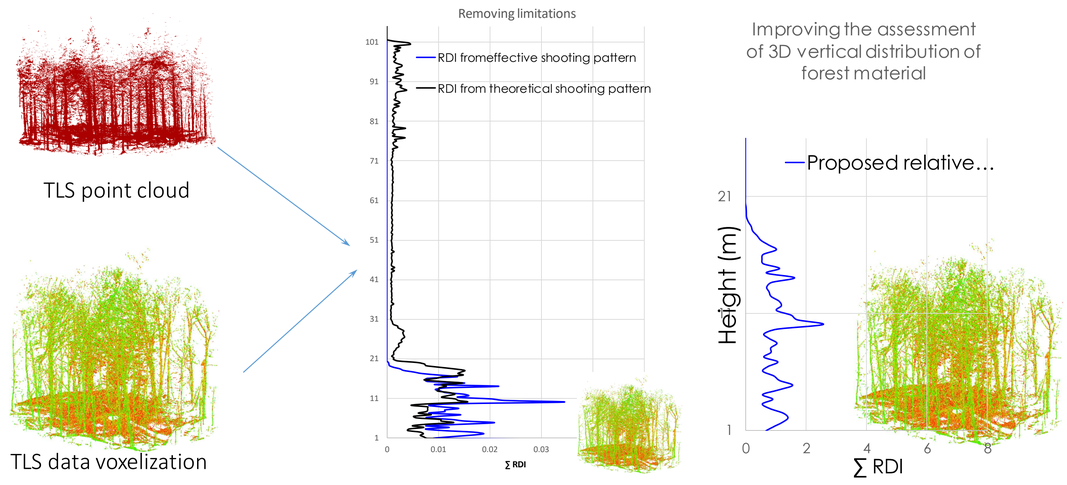
The point cloud acquired by terrestrial LiDAR systems (TLS), including fixed and mobile units, offers a unique way to estimate structural attributes at branch, individual trees and plot levels. Specific algorithms are needed to preprocess the point cloud to reduce the data limitations, namely occluded areas, noise and non-uniform sampling. Other specialized algorithms deal with estimation of structural attributes such as diameter at breast height (DBH), stem taper, canopy gaps, leaf and wood surfaces. Adoption of these algorithms depends on whether they can estimate the attributes at the same accuracy or better than *in situ* measurements and if they also provide a chance to expand new attributes not currently exploited because of the limitations of *in situ* measurements.

Specific objectives:

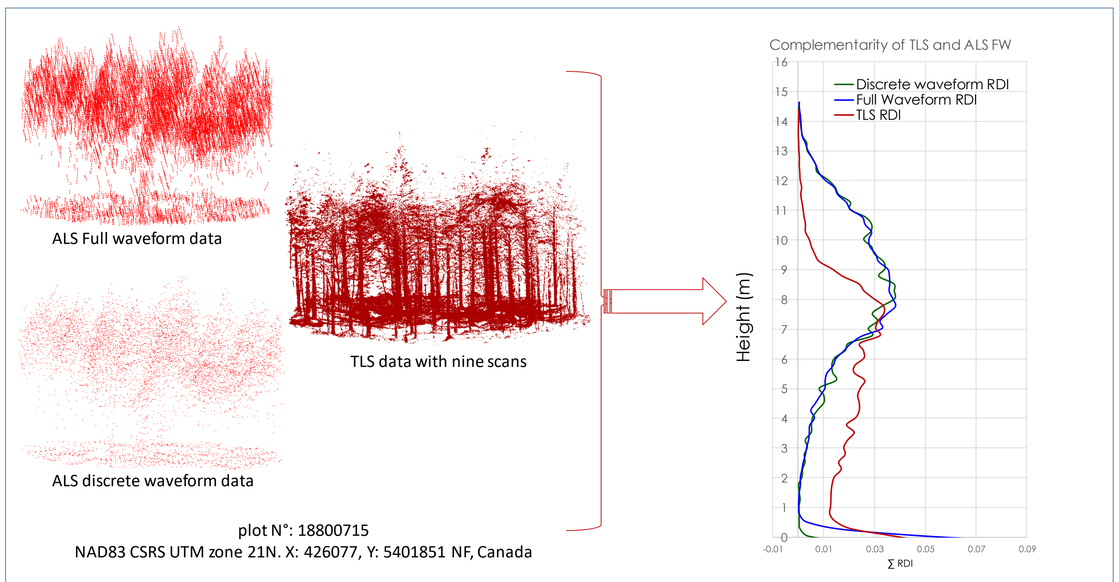
Investigate four topics to support the use of TLS for enhanced forest inventory:

1. Develop an algorithm that reduces point cloud limitations (occluded areas, noise and non-uniform sampling) and transform the point cloud into density mapping to allow **exact estimation of canopy element 3D distribution**
2. Use the 3D distribution of canopy element as reference to develop the ability to achieve similar **3D mapping with the aerial LiDAR system (ALS) using the full waveform** (FW) data. This will allow an exact mapping of vertical canopy layers and detect presence of understory.
3. Develop a specialized algorithm adapted to **estimate DBH and stem taper** from TLS point cloud data while being specifically resilient to TLS data anomalies
4. Develop an algorithm to **isolate individual tree crowns from the TLS data**

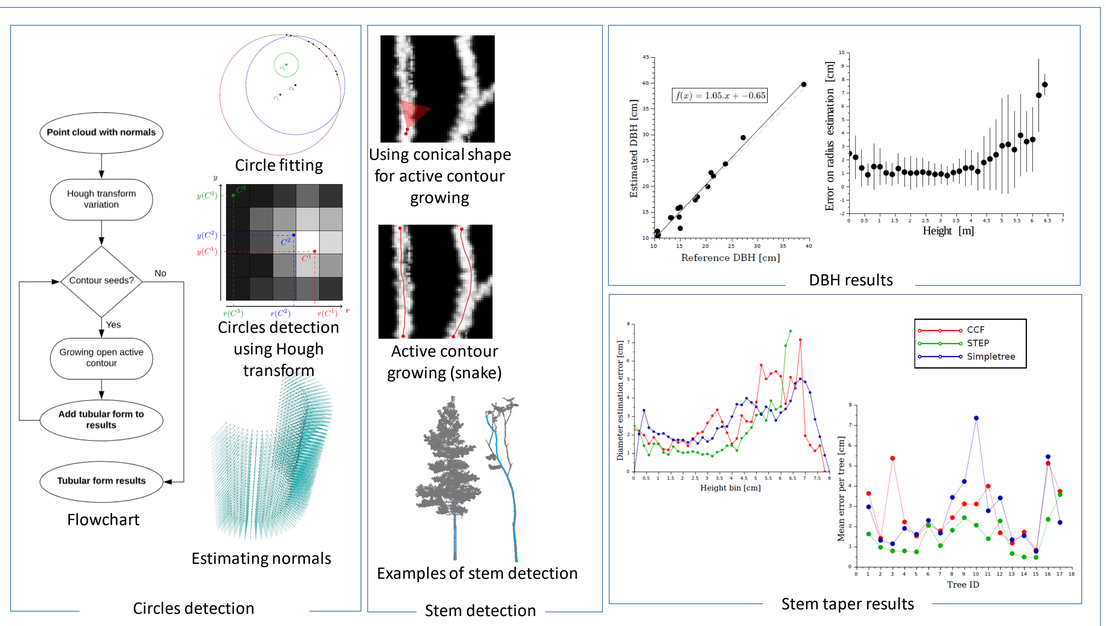
Methods and preliminary results



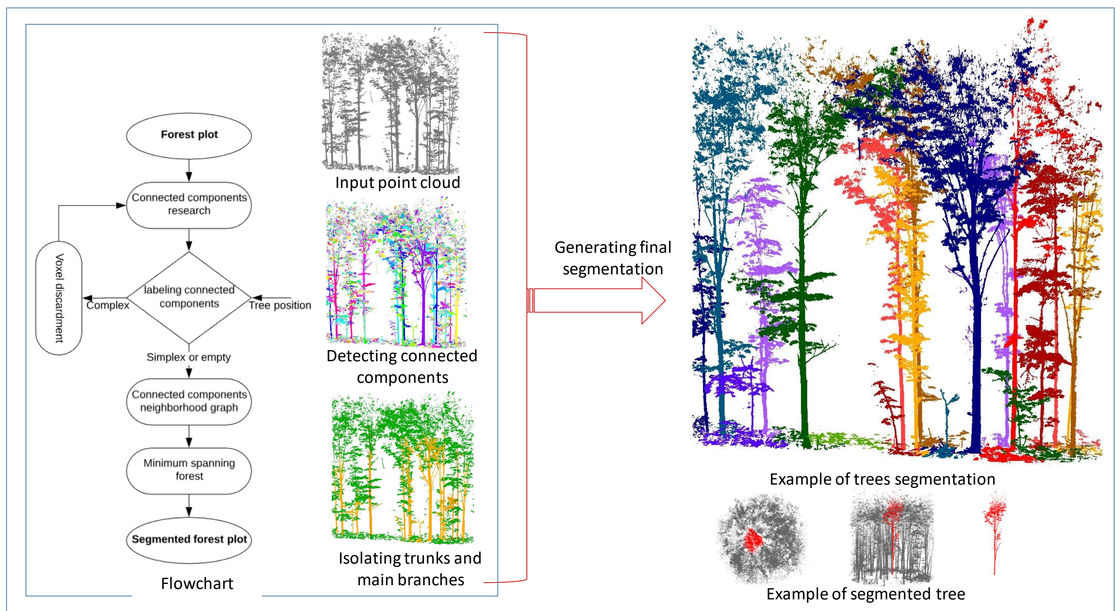
Exact 3D distribution of canopy elements: L-Vox algorithm to process TLS point cloud to remove data limitations: occlusion, noise, variable sampling



Canopy 3D mapping with ALS FW data with the use of TLS data as reference



Estimation of DBH and stem taper with the STEP algorithm



Tree crown segmentation from TLS point cloud

Discussion and recommendations

1. ***Exact 3D distribution of canopy elements***: L-Vox plugin was developed in the open source Computree platform to deal with TLS data limitations. It allows an exact 3D mapping of canopy element represented by voxels. It generally deals with the large majority of limitations but some occluded areas remain.
2. ***Canopy 3D mapping with ALS FW***: This work was made possible by the availability of L-Vox. TLS processed data will be used as reference values for 3D canopy element distribution. Initial difficulty to retrieve FW data in the original ALS data delivered was resolved. This study will use plots from two test sites (Canada & Spain) covering a gradient of stand configurations. Gain from the use of TLS, discrete ALS and FW ALS data will be explored.
3. ***Estimation of DBH and taper:*** The STEP(*) algorithm was developed to be adapted to TLS data limitations. It was tested to three sites with different stand configurations and availability of outstanding reference values. Comparison with existing procedures in CompuTree, and with an architectural model (SimpleTree) showed that STEP can be as efficient or better. The main limitation remains the ability to assess stem diameters in the high portions of the tree.
4. ***Tree crown segmentation from TLS data***: A new algorithm is in development. It already provides the ability to segment tree crowns with an accuracy from 82 to 96%. Omission and commission errors differ from conifer, deciduous and mixed stands. The algorithm needs to be adapted accordingly to improve the current accuracy levels.

(*) Snake for Tuboid Extraction from Point cloud

On-going work

1. Exact 3D distribution of canopy elements: Final options are being implemented before releasing the L-Vox algorithm to the scientific community. Tests have shown the strength/limitations of L-Vox. Relative density will be transformed in PAD (m2/m3) values. L-Vox will be extended to ALS data. A manuscript is being prepared for submission to a scientific journal.
2. Canopy 3D mapping with ALS FW data: This study is just starting. Plots are being selected from the two test areas. Data from TLS, ALS discrete and ALS FW are being aligned for comparison.
3. Estimation of DBH and stem taper: The STEP algorithm is being tested on data acquired with a mobile device. An operational sequence is being defined to include pre-processing of the point-cloud, improvements of the STEP algorithm to allow dealing with a wider range of stand & data conditions. A manuscript was sent with a formal comparison with two other methods.
4. Tree crown segmentation from TLS data: Fine tuning of the tree segmentation method will consider different parameters according to generic tree types (conifer vs deciduous). Tests will be done in a wide array of situations.