LiDAR and its use for the enhanced forest inventory

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**LiDAR - Principles**

**Pulsed** Laser: impulsion of 4 à 15 ns

Usually **near infrared** for land applications (1064 nm)

**Green** laser for marine applications (532 nm)

**Divergence:** diameter of the laser beam at a given distance. Usually small, about 0.15 à 1 mrad.

(divergence of 0.15 mrad gives a laser beam diameter of 15 cm at 1,000 m)

**Point density:** average nbr of laser beam per m²
LiDAR - Sensor

- Laser
- Detector
- Scanning mirror
- Telescope
- Laser beam (impulse)
- Surface
- Return (surface reflectance)
LiDAR – Laser beam returns
LiDAR: Light Detection And Ranging

Airborne LiDAR (ALS)

Terrestrial LiDAR (TLS)

Airborne LiDAR = Airborne Laser Scanning = ALS
Terrestrial LiDAR = Terrestrial Laser Scanning = TLS = T-LiDAR
LiDAR: Principles

Recorded returns

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- First return
- Intermediate returns
- Last return

Noise
LiDAR application

Aerial structures (pylones) and cables reflect the laser beams

From Juha Hyypa
LiDAR: Geoposition

- GPS base
- Mirror
- Range
- X₀Y₀Z₀
- XYZ
- INS

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LiDAR: flight line
LiDAR - Principles

Lidar beams are reflected by the **foliage** and canopy elements but can penetrate down to the **ground**.

From Juha Hyypa
LiDAR

Data points are spreaded according to the scanning speed and the aircraft displacement
LiDAR

Surface model

Digital elevation model (DEM)

Canopy height model (CHM)
Forestry Applications

Height of the forest cover
Biomass or volume maps
Species identification

(a) Multispectral image (b) CHM from LiDAR (c) Shadow modeled (d) Classified image – light green: Deciduous; dark green - Conifers; white: dead trees; brown: no forest.
Maps of canopy gaps
Identification & mesure of individual trees
Mesure & prediction of tree dimensions

- Top of the tree
- Base of the crown
- Lenght of the live crown
- Lenght of stem before crown
- Predicted DBH
- Ground

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Terrestrial LiDAR

Leica : ScanStation 2

Riegl : VZ-400

Zoller & Fröhlich : Imager 5010

Faro : Focus 3D
Terrestrial LiDAR

Data acquisition configuration

Most TLS acquire data for the whole hemisphere

Z+F, Leica, Faro: full hemisphere
Riegl has a dead zone above
Optech: on a moving base
T-LiDAR – Data acquisition (in a plot)

Data acquisition can be made in two main ways:

From the outside

From the inside
Hemispherical view
In the forest ...
Post-treatments

- Scan alignment is required to integrate multiple scans in a spatially coherent scene of point cloud in 3D.
- Targets are used.
- Filters can also be used to "clean" the point cloud.
Post-treatment

Scans alignment to create only one coherent point cloud scene in 3D. Field targets allow this complex operation. Filters can also be applied to clean the dataset.
Preview on T-LiDAR data
(10% dissimation of the original dataset)
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(10% dissimation of the original dataset)
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(10% dissimulation of the original dataset)
Limitations

Occlusion: obstruction of the laser beam or shadowing effect

Meteorological condition
Effect of wind

Scans alignment
ALS versus TLS

Comparison of ALS & TLS data in forest

Signal occlusion is the most important limitation to see canopy objects.

ALS is relatively blind to the forest understory.

Source: Hopkinsons et al. 2004
Point (sampling) density

Spacing between every laser beam forming the point cloud adjusted for the desired level of detail.

Example of a red maple at 15 m from the sensor:
T-LiDAR measurements

Tree structure

The T-LiDAR provides detailled 3D measurements of tree attributes of a stand. It improves from current measurement or add new attributes compared with the current forest inventory. Potential measurements include:

- Diameter at breast height
- Stem taper (up to the live crown)
- Tree height
- Tree crown (dimensions, density)
- Branchiness
Elevation/surface/canopy models

Canopy height model (CHM)

Canopy surface model

Ground elevation model (DEM)
Tree position map
Voxel representation of point cloud

Hypothesis: Volume interception is proportionnal to vegetation density

VDI (Vegetation Density Index) = \frac{\text{Nbr of returns from the voxel}}{\text{Nbr of beams crossing the voxel}} \times 100

Durrieu et al. 2008
Voxel representation

Data slices on a black pine

Viewing direction

Density classes

- Low
- Medium
- High
- Very High

Resolution voxel 1 m  Resolution voxel 50 cm  Resolution voxel 25 cm

Durrieu et al. 2008
Study on ice storm


Chaire CRSNG/Hydro-Québec sur le contrôle de la croissance des arbres
Centre d'étude de la forêt, UQAM
Study on tree compétition

O. Martin
R. Schneider
R. Fournier
Tree architecture

Real tree

LiDAR point cloud

Modeled tree
Tree architecture

Branch structure

Architect - Jean-François Côté, entre canadiende la fibre de bois
Tree architecture

2- Addition of foliage

Addition of shoots on branches

Addition of foliage shoots on dense area with high occlusion (based on a light model)

L-Architect - Jean-François Côté, Centre canadienne la fibre de bois
Tree architecture
Tree architecture

Pruche

Thuya Occidental

Sapin Douglas
Virtual plots

Stand simulation from a catalog of trees

Tree catalogue

Virtual stand

L-Architect - Jean-François Côté, Centre canadience la fibre de bois
What can we do operationnally now?

With airborne LiDAR:

- Ground – surface – canopy height models
- Plan best road configuration on complex terrain
- Produce very high quality maps of
  - Canopy/tree height
  - Stand volume & biomass
- Use area covered by ALS to map large area e.g. Newf. island
- Merge information gain from ALS & other satellite images
What can we do operationnally now?

With terrestrial LiDAR:

• Measure manually structural attributes
• Produce a tree map
• Availability of data processing platforms: Autostem (Treemetrics) and Computree (National Forest Inventory – France)
• Data acquisition protocol in a natural environment
What are we working on?

With airborne LiDAR:

- Identification of individual trees with their structural attributes
- Description of stand openings, layering (e.g. understory)
- Expand information from a low density data acquisition
- Improve automated processing for large datasets
- Assess methods for tree/stand type identification
- Reduce costs for data acquisition and processing
- Link LiDAR metrics to stand attributes like wood fibre attributes
What are we working on?

With terrestrial LiDAR:

- Improve automated data processing to reduce limitations: occlusion, wind, differential beam width, phantom signals, …
- Estimate structural attributes of individual trees of a stand operationnally:
  - Stem taper, branchiness,
  - Crown structural attributes
- Link LiDAR metrics to stand attributes like wood fibre attributes
- Establish a stronger link TLS-ALS (validation & method’s expansion)
- Produce virtual plots with TLS & ALS
- Inclusion into plot inventory within the operational constraints
Questions ?