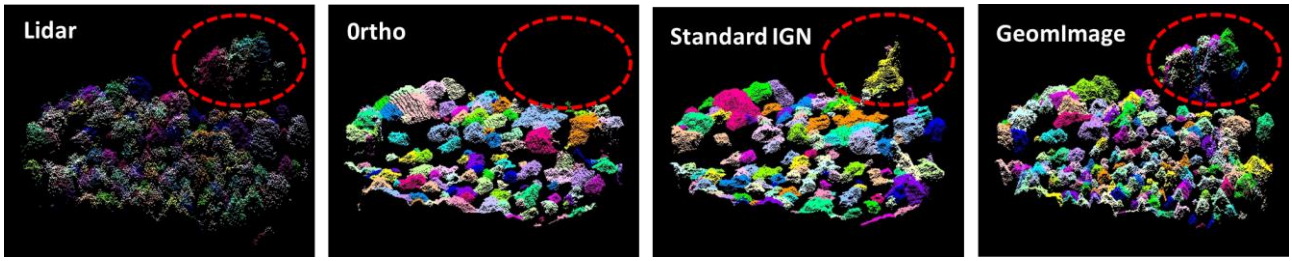
CHM-ERA



Photogrametric canopy height models to enhance forest resource assessment

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Context — The use of remote sensing for forest inventories and management plans is currently undergoing major progress, particularly with the airborne laser scanning (ALS) development. Meanwhile, the photogrammetric workflow is rapidly becoming more efficient, thanks to the development of digital cameras, processing capabilities, as well as algorithm improvements. Regular nationwide aerial image acquisitions may thus become an alternative data source, beside specific and more costly airborne laser scanning acquisition, for reconstructing and analyzing the 3D forest canopy structure and its evolution over time.

However, the quality of photogrammetric point clouds is influenced by the sun-sensor-object configuration, the image scale, and the image matching-strategies. Occlusions due to view angle and shadowing effects are challenging for image-matching algorithms and have a direct impact on the sampling quality and XYZ point distribution.

Objectives — The main objective is to assess the capabilities brought about by photogrammetric data for quantifying and mapping forest attributes over large areas, and to design an optimized and standardized workflow to extract forest parameters that will allow modelling the 3D structure of forest canopies.

Approach — The project was divided in three stages:

i) Optimization of the generation of photogrammetric point clouds over forest covers:

Several algorithms have been studied, among those that could be industrialised by the IGN, in order to facilite the transition to the operational stage: three "terrain geometry" algorithms (I25, currently the "IGN standard", Urban, Ortho), one "image geometry" algorithm (GeomImage). Two resolutions were considered: 25 cm (native resolution of the IGN photos) and 50 cm.

We studied the quality of the canopy model restitution trough visual inspection and numerical analysis (missing data, gaps), as well as the quality of tree detection (segmentation via SEGMA algorithm, B. St Onge).

ii) Development of forest variable models:

Two forest variables modelling methods relying on DSMs were implemented, using those implemented in the processing chain developed by ONF and those developed by LIF: an "individual-based" approach (ITC) and an "area based" approach.
The dendrometric models obtained with the DSMs selected at the end of Task 1 were compared with each other and with those based on the LiDAR cloud-point.

iii) Evaluation of the capacity to study forest dynamics using aerial image time series.

Because tools and processing chains was not mature enough at the project beginning, we had to devote much more time than expected to the first task. Thus, task3 could not be completed as intended. However, the actions foreseen in this task were partially covered by parallel projects, mainly the DIABOLO and IFM-GT projects.

Two study sites were specifically studied in the project. I) A first site in the Vosges department, nearby the Senones town. The landscape is composed of gentle mountains, hills and plains and has been covered by LiDAR data (9pts / m2, ca 300 km2) in April 20On this site, the LiDAR data were used as a reference to describe canopy surface and to model dendrometric variables. ii) A 7500 km2 plain site, dominated by deciduous trees, including the Sologne region and Orléans forest. The resuls on this second site have been supported by several parallel projects (DIABOLO (H2020), CHM-ERA, IFM-GT (ADEME)) which have contributed to the development of large-scale multisource estimation methods. Other sites are currently being processed, as an extension of the project, in order to test the robustness of the methods and models.

The aerial photographs used as input for the photogrammetric point clouds are the 25cm resolution photographs acquired by the IGN for the BDOrtho® database, mainly in October 2018 for the CARTEFOR site, in 2013 and 201 for the Sologne site.

Until the end of 2018, in a first phase of testing, the project team encountered many technical difficulties due to the complexity of the algorithms and the instability of the tools to generate photogrammetric point cloud. These problems led to different technical choices for image matching and analysis between sites.
The CARTEFOR site was used for CHM optimization and image segmentation. The hardwood lowland forest site was used for surface models and temporal analyses at regional scale. The work on image matching optimization and forest canopies modelling has led to a close collaboration with IGN (Grégoire Maillet's team).

Key results —

Local description of the canopy shape

- The forest cover canopy model at the stand scale is worse with terrain geometry algorithms (Standard IGN, Ortho, UrbanMNE) than with image geometry algorithms, which are more compliant. With some algorithms, entire patches of stands may be missing or poorly modeled.
- Outside these problem areas, the differences between algorithms are mostly in areas with a high local stand heterogeneity.
- For tree detection (apex detection, segmentation), the algorithm relying on image geometry is more powerful, the standard IGN algorithm showing high omission rates.
- For well-detected trees, the height estimation shows a small bias compared to the field measurement, results obtained with the LiDAR data remaining slightly better.
- The 25 cm resolution has no specific gain compared to 50cm.

Modeling of dendrometric variables at site scale:

- LiDAR-based models slightly better than those using photogrammetry.
- However, the differences between the models from the different scatterplot models remain small

Main conclusions including key points of discussion —

The main output of the project is the identification of the (most) relevant photogrammetric DSM generation algorithms for stand scale forest mapping applications. Thus, among the 4 algorithms compared to LiDAR, the best option for the studied site is the "GeomImage" algorithm, at 50cm resolution. The current standard IGN algorithm is not adequate at stand scale, due to its poorly reliable description of the canopy model, but it can be used at the site (or lager) scale for statistical evaluations and inventory approaches.

Therefore, photogrammetric point clouds generated from IGN 25cm resolution photographs by the GeomImage algorithm at 50cm resolution seem a relevant alternative for the production of dendrometric maps, if a prior detailed description of the ground relief is available upstream (i.e a digital terrain model from a previous LiDAR coverage).

These results have to be confirmed in other study sites, particularly in areas of steeper relief where the impacts of shade-related occlusions are likely to be stronger, and on different types of forests (coniferous plantations, deciduous forests, irregular mountain stands).

Future perspective —
To be confirmed in other forest contexts, the project opens up ways towards the operational generation of photogrammetric point clouds suitable for forest mapping at the stand scale.
The results of this project and those obtained on the future test sites will be used in strategic discussions between the ONF and the IGN.

Several directions for further scientific studies are also to be considered:

- Species or species-groups identification with “tree-based approaches” and by enriching the point clouds with "colorimetric" information extracted from the aerial photographs;
- Temporal dynamics analyses, using of point clouds acquired at different dates (canopy gaps, sylvicultural cuts, storm damage, fertility, ...) following the results of previous projects (DIABOLO, FORWIND, IFM-GT).

Valorisation —

Articles

Irulappa-Pillai-Vijayakumar DB, Renaud J-P, Morneau F, et al (2019) Increasing Precision for French Forest Inventory Estimates using the k-NN Technique with Optical and Photogrammetric Data and Model-Assisted Estimators. Remote Sensing 11:991. https://doi.org/10.3390/rs11080991.

Reports

Dumay, Florine, 2018 : *Segmentation de houppiers à partir de données LIDAR et photogrammétriques*, rapport de stage, projet tutoré, Master 1 FAGE, Spécialité Fonctionnement et Gestion des Ecosystèmes, Université de Lorraine, 16p + annexes.

Kilieger Pierre, 2017 : *Segmentation de houppiers à partir de données LIDAR aéroporté*, rapport de stage, Master 2 FAGE, Spécialité Bois et Développement Durable, 25p + annexes

Presentations

Jolly, A., Renaud J.P., Souter T., Piboule A., Vega C., St-Onge B., 2017 : *Vers l’utilisation de modèles photogrammétriques de canopée pour la cartographie de la ressource forestière*. Colloque Labex ARBRE, 13 décembre 2017.