2-year Post-doctoral Offer
Multi-layer reconstruction of 3D point clouds : Application to forest 3D structure and biodiversity metrics extraction using airborne LiDAR and multispectral images

Workplace : IGN - Lab LaSTIG - Team ACTE
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Motivation and background

The project aims to produce a fine description of 3D vegetation structure in forested areas and to produce a fine mapping of species in order to derive forest biodiversity metrics. These metrics are related to the complexity of vegetation structure and spatial patterns of species. This fine characterization will allow us 1) to better model the forest micro-climate taking into account the spatial patterns of vegetation structure, 2) to study the relationship between observed vegetation biodiversity and derived biodiversity metrics that describes the 3D structure complexity.

The characterization of the 3D structure of vegetation and, in particular, the different layers of vertical stratification and the leaf area present in each of these strata, is essential for modeling relationships with microclimatic variables or biodiversity variables (Huang et al., 2014, Davies and Asner 2014). Currently, this characterization remains very rough and imprecise and does not measure the full complexity of forest ecosystems. The LiDAR tool has recently been exploited to provide variables related to both the vertical and the horizontal structure of vegetation. From a methodological point of view, the characterization of the vertical structure of the forest consists in detecting the presence of the different strata and characterizing their physical properties such as height, thickness and spatial extent (Ferraz et al. 2016). The vertical stratification of forest canopies was first conducted using the density profile analysis method (Holmgren and Persson 2004). Some studies model the vegetation profile by Weibull's unimodal distribution function (Dean et al., 2009). Jaskierniak et al., (2011) use a mixture of probability functions (Weibull, Gaussian, Gamma,...) to improve the modeling and understanding of plurimodal distributions. The disadvantage of these parametric methods is their lack of genericity.

Other methods are based on segmentation algorithms using 3D coordinates or intensity of LiDAR points to discriminate species and two strata of vegetation (Morsdorf et al. 2010). Although satisfactory results have been obtained, these methods are limited compared to the objectives of the project to characterize the different strata on more complex forests in order to model their three-dimensional structure.

Objectives

The postdoctoral position focuses on 3D vegetation structure extraction, specie 3D mapping and biodiversity metrics derivation. Airborne LiDAR data with a high density of points (50 pts/m2) will be used jointly to very high resolution UAV and airborne multispectral images. The LiDAR beam penetrates the vegetation until reaching the soil underneath, providing 3D points on the different strata. The multispectral image helps discriminating canopy species and allows us to have some priors on corresponding remaining strata species.

The candidate will be involved in research work related to :

— 3D volumetric segmentation of 3D point clouds to extract the number of vertical layers and characterize them.
— 3D semantic segmentation : Species detection from 3D geometric descriptors and multispectral images.
— Biodiversity metrics (3D structure complexity) derivation

Methods

While most surface mesh reconstruction methods aim at recovering only a single layer from the point cloud, the main novelty of the proposed work will be to extract multiple layers corresponding to the multiple echos returned by the LiDAR for a each beam. In order to achieve this, we propose to generalize the approach of [Caraffa et. al. 2016] that relies on a volumetric segmentation of a Delaunay triangulation of the input point cloud. In this approach, each tetrahedron is labeled as inside or outside based on a global discrete optimization based on a graph-cut balancing between data attachment and surface regularity. This ensures that the resulting surface is watertight as it separates an inside from an outside volume.

In order to handle the multi-layer case, several questions need to be addressed :

— How to model the space occupancy given by a LiDAR beam in the case of a multi-echo reflection inside the vegetation ?
— How to formulate the global optimization problem into a multi-label problem in order to extract each layer as the interface between tetrahedrons with two different labels
— How to optimize this multi-label objective, as graph-cuts only allow 2 labels. Multi-label generalizations of the graph-cut problem such as the one of [Landrieu and Obozinski 2017] will probably be of great interest to address this issue.

Once the Delaunay triangulation is segmented, each strata will be defined as the tetrahedra with a given label. This volumetric definition of the stratum will provide pertinent descriptors will be computed to characterize it.
For semantic segmentation, other descriptors will be extracted directly from the LiDAR point cloud and VHR multispectral images to better segment the canopy tree stratum with respect to vegetation species. This knowledge will lead to a priori information to identify the other strata vegetation types.
For biodiversity metrics, new 3D LiDAR metrics should be derived to be used as input for microclimate modeling and to better model the observed biodiversity (Bouvier et al. 2015, Véga et al.2016).

Study site and data

The study site is situated in Southern Western France. A joint airborne multispectral and LiDAR acquisition are scheduled for Summer 2019. The specifications are : a spatial resolution of 20 cm GSD and a LiDAR point density of 50 pts/m. Various scan angle acquisition should be added. In situ measurements have started (biodiveristy taxons, layers characteristics). Forest structure variables, crown diameter, stem diameter, height, density or tree spacing will be measured for some sampled trees.

1 Job requirements

— The candidate should have a PhD degree in photogrammetry/ lasergrammetry or 3D point cloud processing
— Excellent motivation in developing research activities both at theoretical and application levels.

— A prior knowledge and experience on forestry will be an asset.
— Good spoken and written English. Knowledge of French would be useful.
— Good knowledge of programming languages (C++) is mandatory.

Workplace description

The candidate will work at UMR LasTIG, IGN Paris (ACTE TEAM) in collaboration with EA GE and UMR BIOGECO in Bordeaux.
1. EA 4592 G&E, ENSEGID-IPB, University of Bordeaux, 1, allée F. Daguin, 33607 Pessac Cedex, France ;
2. UMR BIOGECO, Bâtiment B2 – RdCa Allée Geoffroy St-Hilaire CS 50023 33615 PESSAC

The IGN (Institut National de l'Information Géographique et Forestière), in Paris is the French National Mapping Agency. The LaSTIG Lab gathers full-time researchers on computer vision, machine learning and visualization of geographic information data. EA G&E has expertise on 3D point cloud processing and UMR BIOGECO represents the end-user of biodiversity metrics.

Funding

The Postdoc position offers full health, unemployment and retirement benefits and competitive salary. The candidate will be given the opportunity to develop his/her research skills by contributing to 3D volumetric segmentation and semantic segmentation applied to geographic information sciences. The funding includes a two-year post-doctoral contract and an operating fund (for travel, consumables, etc.). Salary per month : around 2300 euros (excluding taxes and with no accomodation).

The position will start from September to December 2019.

Application

Applications should be sent **before 15th June 2019** to :

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