Modeling and enhancement of LiDAR point clouds from natural scenarios

José A. Collado[1], Alfonso López[1], J. Roberto Jiménez-Pérez[1], Lidia M. Ortega[1], Francisco R. Feito[1], Juan M. Jurado [1]

[1]Department of Computer Science, University of Jaén

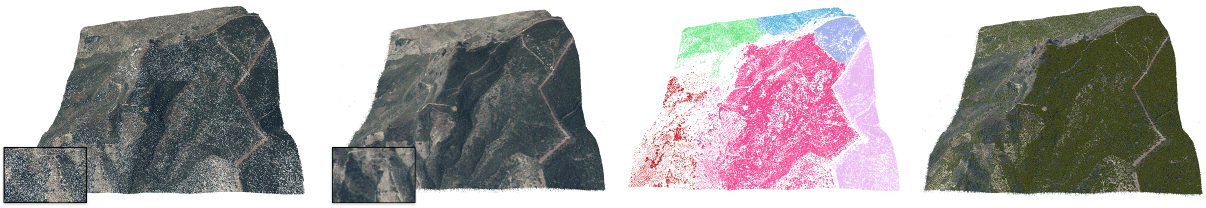

Figure 1: *Comparison of original LiDAR point cloud (a) and our reconstructed point cloud (b). (c) Result of clustering high vegetation and, (d) the reconstructed scenario including surface and high vegetation.*

Abstract

The generation of realistic natural scenarios is a longstanding and ongoing challenge in Computer Graphics. A common source of real-environmental scenarios is open point cloud datasets acquired by LiDAR (Laser Imaging Detection and Ranging) devices. However, these data have low density and are not able to provide sufficiently detailed environments. In this study, we propose a method to reconstruct real-world environments based on data acquired from LiDAR devices that overcome this limitation and generate rich environments, including ground and high vegetation. Additionally, our proposal segments the original data to distinguish among different kinds of trees. The results show that the method is capable of generating realistic environments with the chosen density and including specimens of each of the identified tree types.

CCS Concepts

• ***Computing methodologies*** → ***Point-based models; Modeling methodologies;***

1. Introduction

The generation of natural scenarios is a longstanding and ongoing challenge in Computer Graphics. Traditionally, procedural modeling is applied to create synthetic scenarios with a great level of realism. However, the proliferation of high-resolution cameras and Laser Imaging Detection and Ranging (LiDAR) devices allow us to obtain highly detailed 3D models of real-world environments. These are mainly 3D point clouds that are an alternative to represent realistic scenarios. Nevertheless, open point cloud datasets may present low density, and they do not provide a direct surface representation for applications such as games or autonomous agent navigation. Regarding procedural generation, modeling each semantic layer of a natural environment represents a complex task. Realistic ground surfaces are either approached using Digital Elevation Models (DEM) [AGP*19] or noise images transformed accordingly to real-world processes, e.g. erosion [GGP*19]. Also, vegetation modeling achieves a higher level of complexity through the simulation of ecosystems [MHS*19; KGG*20]. Thus, the spatial distribution and growth of vegetation are the main challenges for the 3D modeling of natural environments. In this context, the 3D reconstruction from real-world data arises as an alternative to classical procedural modelling methods [COB*18; KGG*20].

In this work, we present a fully automatic method for generating plausible large-scale natural environments using open LiDAR datasets. The realism of the resulting scenarios is achieved by following spatial and semantic constraints from the scanned data. Besides the 3D reconstruction, our method enables the procedural-based extension of the boundaries of LiDAR surveys. Moreover, it allows refining the density of sparse LiDAR point clouds.

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2. Method Overview

Our approach is based on guided procedural modeling of real-world point clouds using scanned data in order to generate synthetic scenarios in natural environments. To this end, open LiDAR data is used to determine spatial and semantic constraints. In this study, we focus on vegetation and ground layers that are identified from semantic labels following the LAS (LASer) standard. Figure 2 presents the main steps of the proposed methodology.

Ground modeling. As a first step, the ground is uniformly split using a regular grid. The voxel dimensions are either defined as the Ground Sampling Distance (GSD) of the point cloud or selected by the user. For each voxel, relevant point data is aggregated, such as their color and elevation. Next, a NURBS (non-uniform rational B-spline) surface is automatically built using the prior voxel discretization. Control points are defined as representative points for each voxel, considering the aggregated elevation. To resample the reconstructed ground, we use a spatial probability distribution function for each voxel so that better-filled spaces present less probability to generate new points. Hence, voxels are populated with new points as long as a given density goal is not achieved. This approach guarantees to fill both holes and sparse areas. Besides *XZ* coordinates, which are uniformly distributed, the elevation is given by the NURBS. As a result, we represent the ground as a 3D spline that allows both to build the scene as a triangle mesh or as a dense point cloud.

Vegetation modeling. Points labeled as high vegetation are then processed to reconstruct forestry areas. To this end, these points are clustered to differentiate tree specimens. We resolved this using a clustering method based on a threshold distance and color similarity. Once clusters are built, we generate a regular grid for each one. Each voxel of this regular grid will be compared with its equivalent one in the ground regular grid. Hence, tree roots are considered to be located in voxels whose density is significantly higher than the ground density. The vertical position (Y) of each tree will be determined by the NURBS created in the ground process, whereas their size is computed considering non-empty voxels of the area around the *XZ* position.

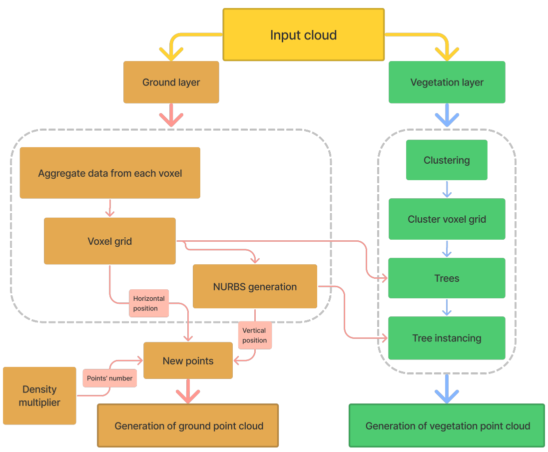

Figure 2: *Overview of the proposed method to process ground and vegetation layers. Both processes lead to a dense point cloud.*

3. Results

With the proposed method, we generate point clouds with a user-defined increase of point density. Figure 3 compares the input and the resulting point cloud with 10x more density. Furthermore, we reconstruct vegetation that is poorly acquired with a LiDAR sensor by instancing and sampling tree triangle meshes. As depicted in Figure 3, the first image barely shows tree canopy returns. However, our result fills the ground areas not reached by LiDAR with dense vegetation. Also, we managed to replicate 254417 different trees within the obtained clusters.

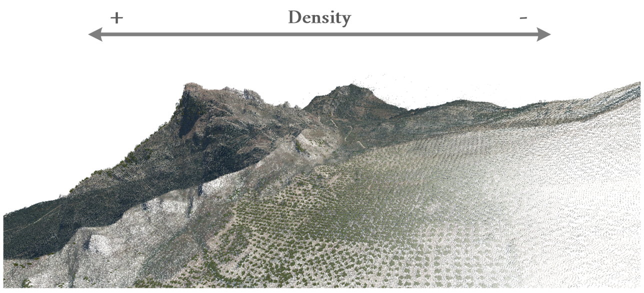

Figure 3: *Dense point cloud generated using the proposed method. In the left, the reconstruction result, whereas the right side depicts the original point cloud.*

4. Conclusions

We have presented a preliminary study regarding the reconstruction of real-world environments, to output either realistic scenarios or more dense point clouds. Our results suggested that it is possible to reconstruct ground and vegetation to generate a virtual scene similar to the original source. However, we aim to extend this solution with other scene layers, such as low-vegetation, and to acquire lighting details to homogenize the rendering of all the layers. Also, this method can be implemented as part of an out-of-core solution to extend the dataset boundaries with procedural forest, following patterns similar to those observed in the original dataset.

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