Development of an algorithm to generate a Lidar pit-free canopy height model

Introduction

Lidar-derived Canopy Height Models (CHMs) are commonly used for extracting relevant forest information. Often irregular height variations – also called data pits or simply pits – are present in the CHM.
These pits typically appear when the first Lidar return is far below the canopy which tends to happen for two reasons. The first reason is that a laser beam deeply penetrates into the branches and the foliage before producing the first return (Persson et al., 2002). The second reason is multiple laser beams – possibly from different flight lines – produce their first return in close horizontal proximity but with a great height difference because they "see" the canopy or the ground from different angles (Leckie et al., 2003). These pits hamper the correct extraction of forestry metrics from the CHM.
Previous studies recommend applying smoothing methods such as a median filter or a Gaussian filter to reduce the data pits. However, smoothing modifies the CHM leading to subsequent misinterpretation of the biophysical tree parameters (Solberg et al., 2006).

Study area

The Bois Noir (black wood) forest is a part of the Barcelonnette basin which is located in the southern French Alps (44° 23′ N, 6° 45′ E).
The size of the study area is about 1.3 km^2 which is mainly covered by coniferous plantation forests.

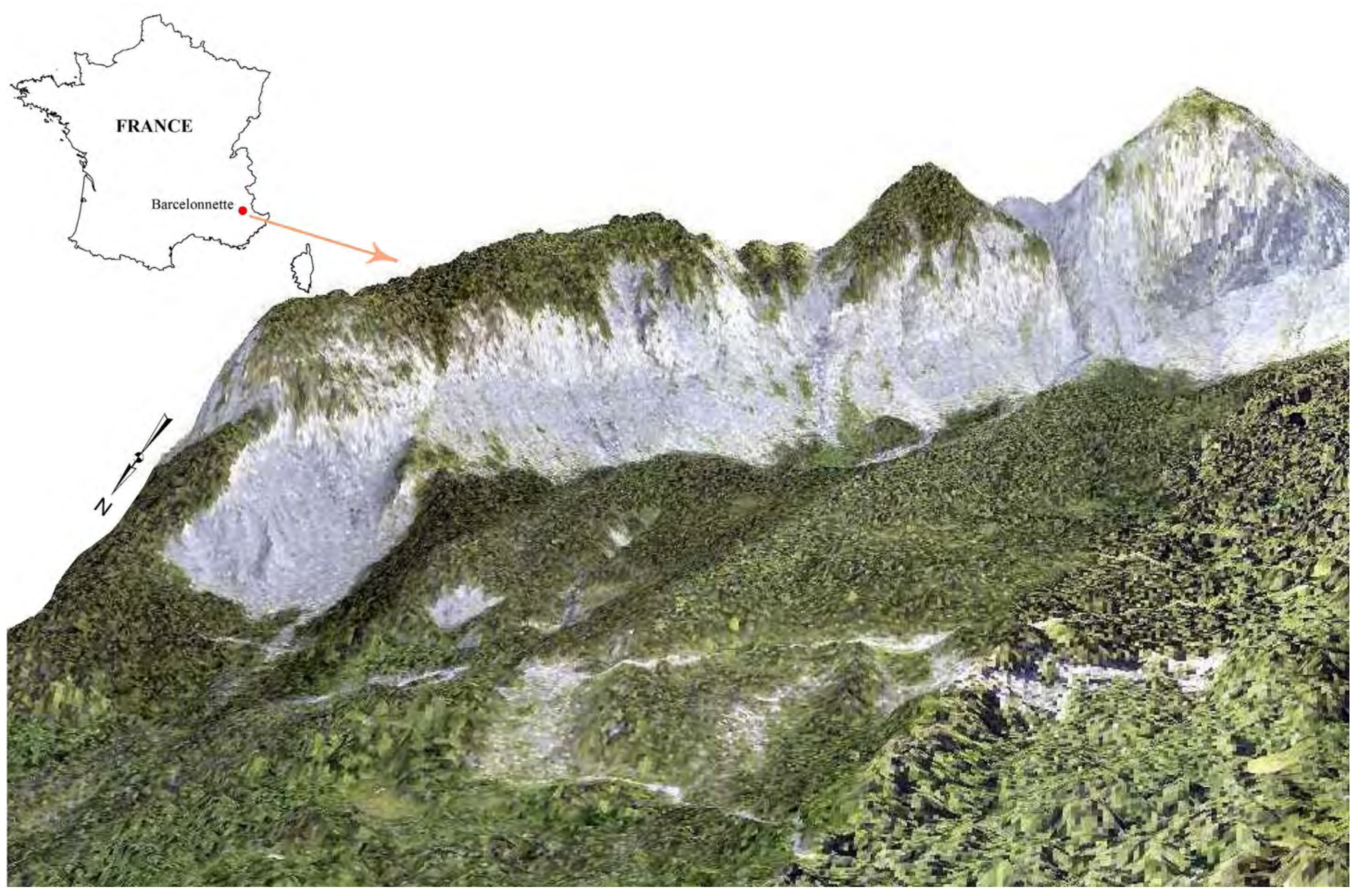

Fig.1 Three dimensional view of the study area on aerial photographs (0.15 m ground resolution).

Fig. 2 The forest predominantly consists of mountain pine (Pinus uncinata) and scots pine (Pinus sylvestris).

Lidar data

A full-waveform airborne laser scanning system (RIEGL VQ-480) which was developed for surveying mountainous forested area, was used for the study areas.
The system performs on-line full waveform analysis (in hardware) to extract discrete returns from the waveforms. The mean point density was 160 points/m^2

Table 1: The airborne laser scanning characteristics

Acquisition (month/year)	July- 2009
Laser scanner	Riegl VQ480i
IMU system	iMAR FSAS - record 500Hz
GPS system	Topcon legacy - record 5Hz
Laser pulse repetition rate	300 kHz
Measurement rate	Up to 150 000 s^{-1}
Beam divergence	0.3 mrad
Laser beam footprint	75 mm at 250 m
Field of view	60°
Scanning method	Rotating multi-facet mirror

Description of pit-free algorithm

The algorithm comprises three stages. The first stage normalizes the height of the Lidar data by replacing the elevation of each point (i.e., the original z coordinate) with its vertical height above the ground. The pre-processing was implemented via batch-scripting the lasheight modules of LAStools.

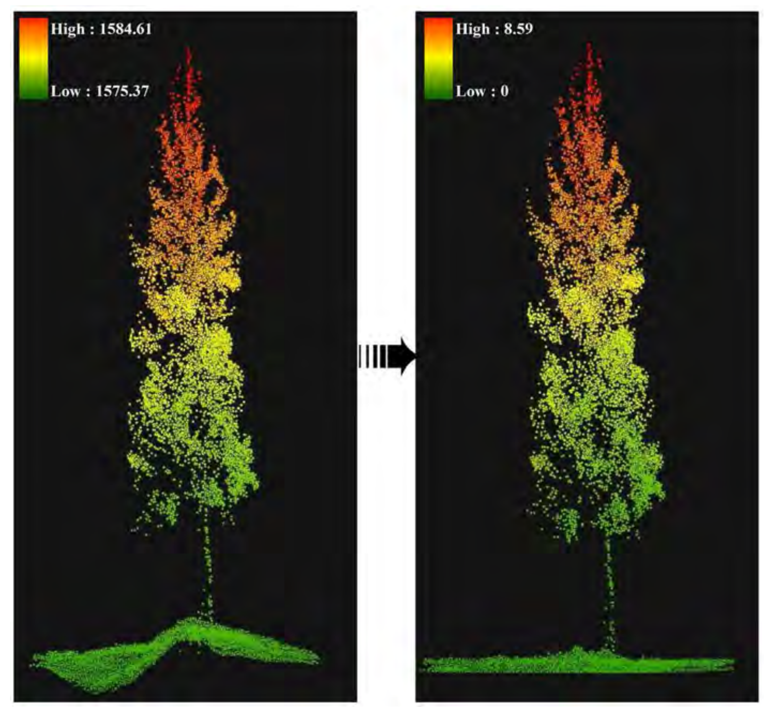

Fig. 3 Raw Lidar points (left) and height normalized points (right) of one individual tree.

The second stage constructs a standard CHM from all first returns and – most importantly – a number of partial CHMs from only those first returns that correspond to higher-up vegetation hits. The third stage combines all the standard and the partial CHMs into one CHM by keeping only the highest value across all CHMs for each x and y raster position (pit-free CHM with ground resolution of 0.15 m). These processes are easily implemented in the command line with a batch script using a combination of the efficient blast2dem and lasgrid modules of LAStools.

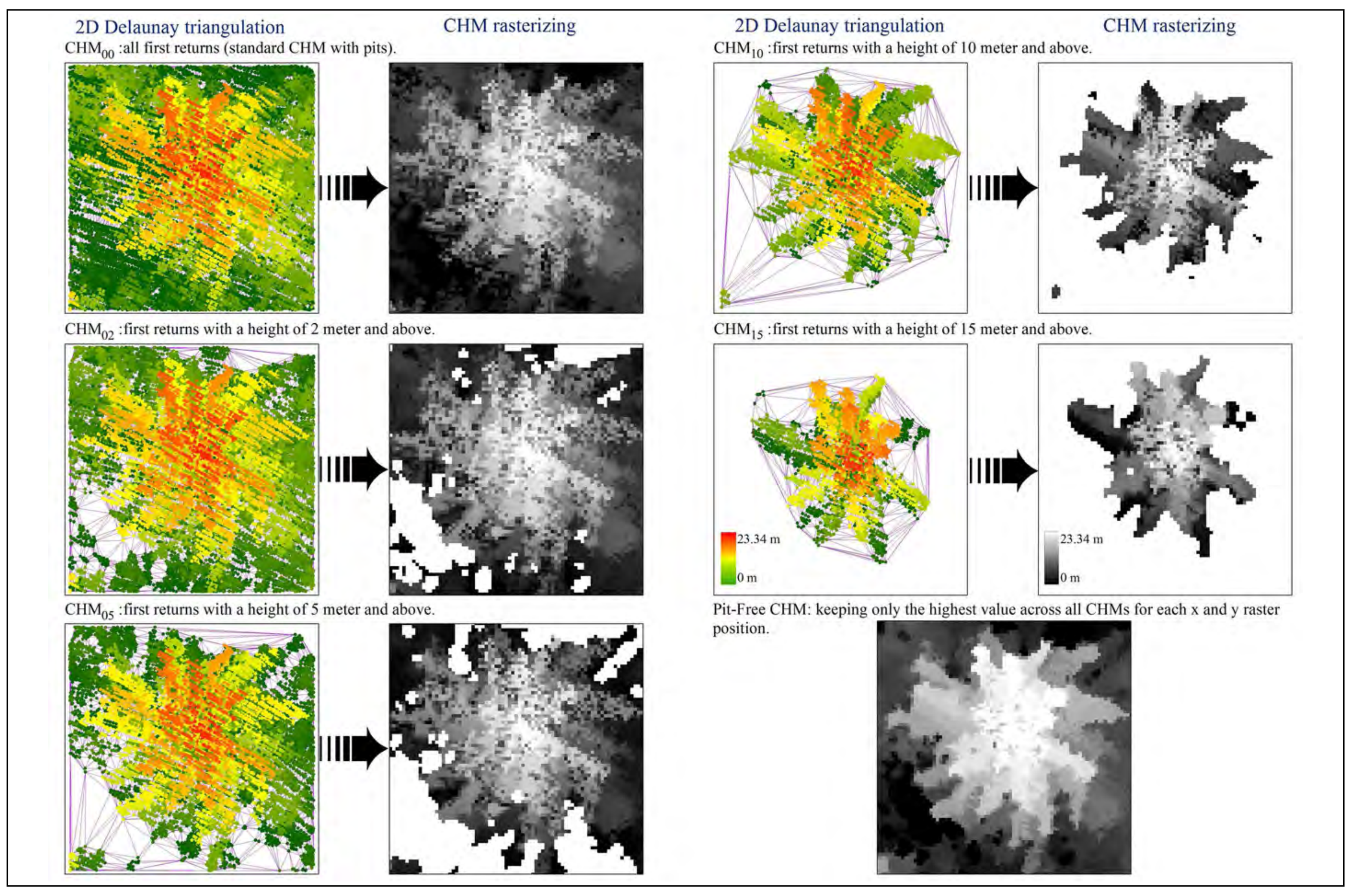

Fig. 4 The generated TINs, rasters of partial CHMs and the pit-free CHM for an individual tree. The partial CHMs are generated by rasterizing only those triangles with all three edge lengths are below a certain threshold.

Result and conclusion

In order to demonstrate the robustness of our algorithm as to generating a pit-free CHM, a lower-density version of Lidar data (7 point/m^2) is created artificially from the original Lidar survey by applying simple point thinning using the first only and the keep_every_nth filter of LAStools (CHM with a ground resolution of 0.50 m).
Our pit-free CHMs derived from both Lidar datasets were evaluated by visual comparison with the standard CHMs smoothed with a 5×5 Gaussian filter.
Based on our results, the pit-free algorithm is visually superior to the Gaussian smoothing filter. The results show that the algorithm not only effectively removed the pits but also preserved the edges of canopy gaps and crowns for both the high and the low-density dataset.

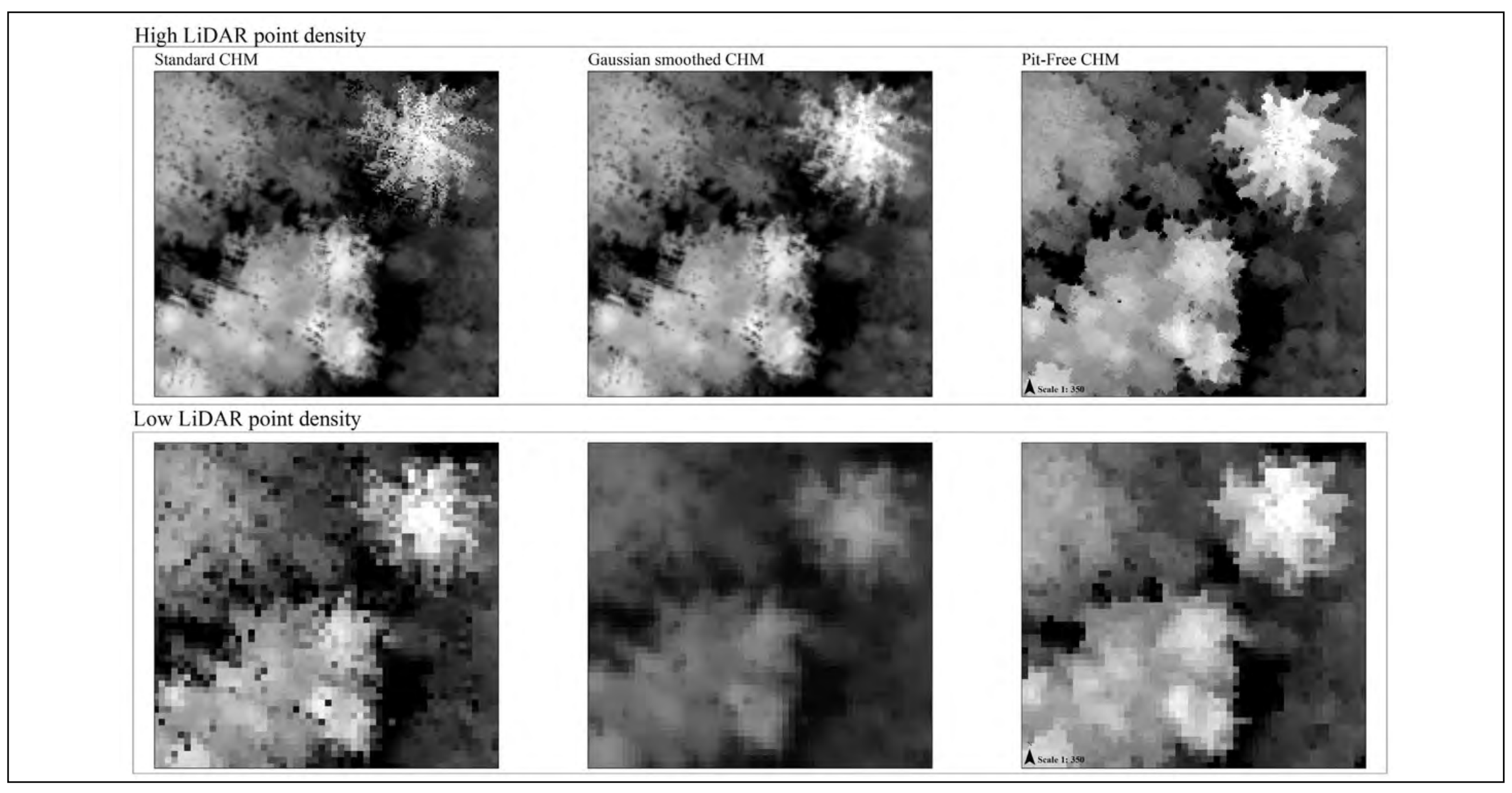

Fig. 5 The performance of the pit-free algorithm compared with the standard CHMs and Gaussian filter for high-density and low-density Lidar data.

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