Creation of a Canopy Height Model from mini-UAV Imagery

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Introduction & Motivation

The arrival of mini-UAV (Unmanned Aerial Vehicle), these small autonomous aircrafts, has opened the doors to a new environmental data acquisition's approach. In forestry, low-altitude imagery from UAV can be used to characterize forest ecosystem structure through a Canopy Height Model (CHM). The greatest asset of these images, compare to traditional remote sensing techniques such as photogrammetry (high altitude flights with metric camera) or Lidar based survey, stay its high spatial and temporal resolutions [Watts *et al.*, 2012].
In this research, authors developed a new workflow for acquiring low-altitude aerial images with a mini-UAV and used them for the construction of a high resolution Canopy Height Model.

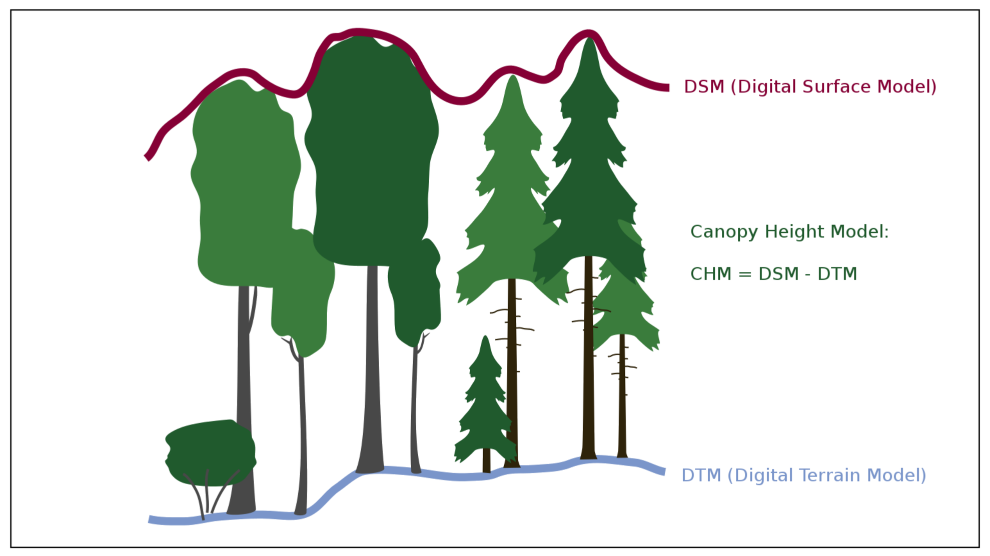


Figure 1: Schema of Canopy Height Model

Material & Method

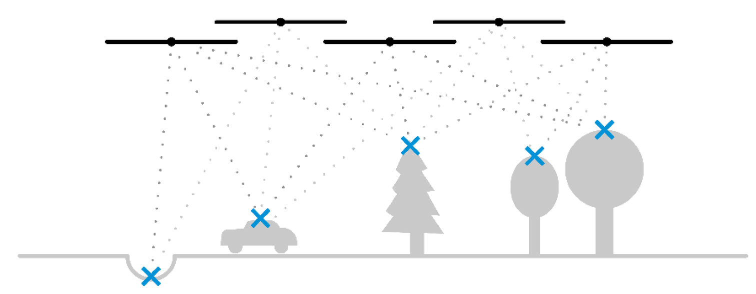
By using the UAV Gatewing X100 (http://www.gatewing.com) and the consumer grade camera Ricoh GRIII (10 Mpixels, 6 mm fixed focal length), 612 aerial images covering the entire study area were collected in one single flight. The flight altitude was 250 m height, providing 8 cm Ground Sample Distance (pixel resolution) and 80% side and forward overlaps.

Figure 2: The Mini-Unmanned Aerial Vehicle used in this research. The X100 Gatewing is a fixed-wing of 2kg flying with an electric motor at the cruise speed of 80km/h. Its flight duration of 40 minutes enable to cover areas of more than 100 ha with high overlap (80%) at 250 m above ground level.

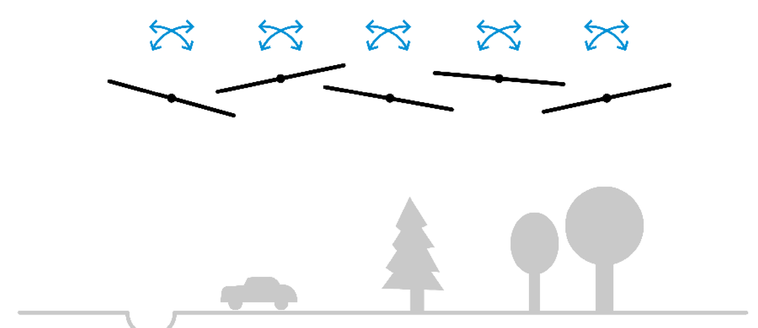
Figure 3: Pilots with Ground Control Station and Checklist

For digital photogrammetry processing, authors compare two software solutions. The first one is Agisoft Photoscan . The second one is an open source toolbox for photogrammetry developed by the National Geographic Institute of France: MicMac [Pierrot-Deseilligny et Clery, 2011].

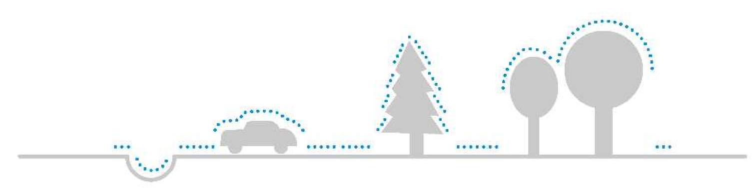
Photogrammetric Workflow



AreoTriangulation is performed for each Tie Points by the means of Bundle Block Adjustment



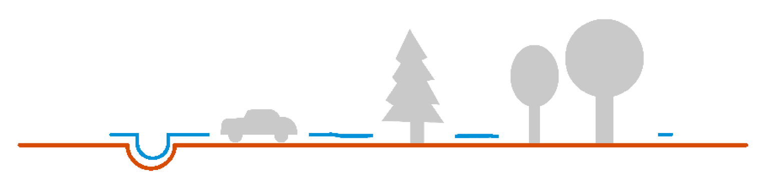
Bundle Block Adjustment compute tie point position and camera poses (position and orientation)



Multiview dense matching operates on each pixels and results on a dense point cloud

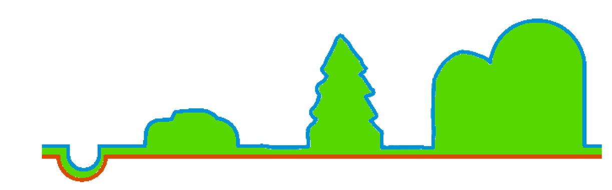
DSM[a] is interpolated from dense point cloud

[a] Digital Surface Model



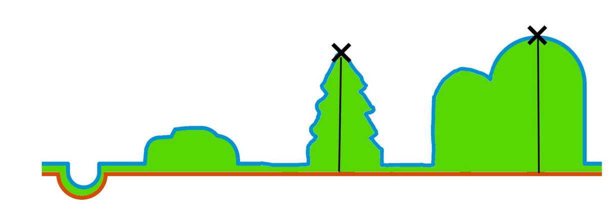
Co-registration of the DSM with a low resolution topo-DTM[a] is performed by surface matching for the non forested part

[a] Digital Terrain Model



Combination of DSM and DTM produce the CHM[a]

[a] Canopy Height Model



Accuracy is investigated comparing CHM with field measurements:

$$H_{CHM} - H_{field} = \Delta H \quad (1)$$

Validation of the two Canopy Height Models (one for each software) was achieved by comparing field measurements of the tree heights (n=137) with the CHMs.

Results

The resulting CHMs (Figure) of 25 cm resolution enable the computation of single tree height with an RMSE of 2.1 meters. According to authors, these residuals have four origins;

- The Digital Terrain Model used with its poor resolution and unknown accuracy has marred the precision of the Digital Surface Model.
- 3D reconstruction from images is tricky for objects such as forest canopy because of leaves movements and the repetitive texture of canopy in broadleaf forests that both hinder the process of dense matching
- The result of DSM and DTM co-registration for forested area is not scientifically rigorous, due to the lack of ground visibility (vegetation height =0) on the DSM
- field measurements of the tree height are prone to error

Although, even though the two softwares are presenting a lot of operational differences, the two resulting CHMs are not significantly different.

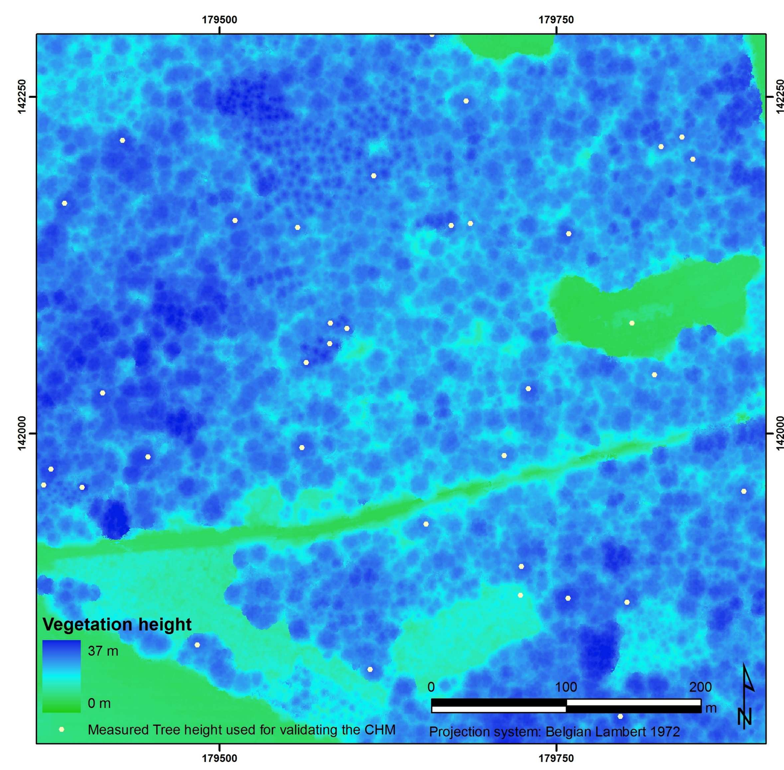


Figure 4: UAV-photo Canopy Height Model (part of the study area). The white circles show the localization of measured tree heights which have been used for validating the CHM.

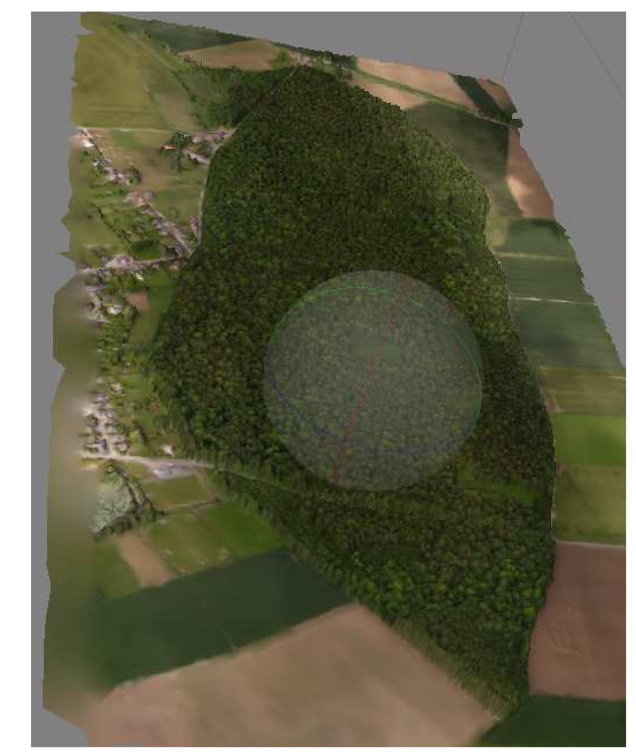


Figure 5: 3D-model of the 130 ha forest of mixed broadleaves stands (Grand-Leez, Belgium).

Discussions & Perspectives

Even if the accuracy of the resulting UAV-photo DEM is not good enough for measuring single tree height with this method, valuable characteristics at the stand level could now be quickly available with such a workflow. Indeed, stand level information such as recruitment state, maturity level (e.g. mean height, dominant height, etc.), and horizontal and vertical structure variability could be analyzed from such CHMs [Véga et St-Onge, 2009, 2008; Miller *et al.*, 2000; Naesset, 2002; Itaya *et al.*, 2004].
This research highlights the fact that UAV photogrammetry which is using consumer-grade digital camera and Structure from Motion software must be improved before being able to provide very accurate Digital Elevation Model of forest canopy. Indeed, measurement of tree height increment based on multi-temporal UAV flights, for example, is not conceivable with a CHM precision of less than one meter. Nevertheless, UAV-photogrammetry is promising approach that may obtain satisfying results for a bunch of environmental research. This is just the *dawn of drone ecology [*Koh et Wich, *2012].*

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