Highly portable lidar mitigates occlusion in tropical forests through high density sampling schemes and novel deployment methods

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Highlights: Highly portable lidar can be deployed at varying heights to capture tropical forest sub-canopy and canopy information while mitigating occlusion. Hybridized reconstruction and voxelization approaches may offer improved biomass estimates from lidar acquisitions.

Key words: *Tropical, terrestrial, lidar, occlusion*

Introduction

Remote sensing captures important ecosystem characteristics at large spatial scales and meaningful temporal and spatial resolutions. Tropical forests are particularly challenging for airborne and spaceborne remote sensing resources due to overall height, the density and vertical stratification of vegetation, the variable moisture content and frequent cloud cover. Terrestrial lidar has proved a useful validation tool for airborne and spaceborne observations of temperate forests, as well as an increasingly effective independent characterization and measurement tool. However there are limiting logistic challenges to deploying lidar in tropical forests, including the difficultly in accessing and traversing these environments and other conditions which are hazardous to equipment such as frequent rainfall, heat and humidity. Even when deployment can be achieved, the dense understory of tropical forests introduces a large amount of occlusion, limiting the range of lidar pulses and therefore the overall spatial coverage of the lidar scans. In addition, occlusion limits information which can be found above the sub-canopy, including tree heights and crown structures.

Recently developed highly portable lidar can overcome many of the logistic challenges to deployment of terrestrial lidar in tropical forests, and additionally can facilitate mitigation of occlusion both horizontally and vertically.

Methods

The Compact Biomass Lidar (CBL) is a highly portable, rapid-scanning, eye-safe, time-of-flight, 905nm discrete lidar based on the SICK LMS151 and built by the University of Massachusetts Boston in collaboration with Rochester Institute of Technology. The CBL samples at an azimuth and vertical angular resolution of 0.25^o and has a maximum range of 40m. In 2014 and 2015 the CBL scanner was deployed in La Selva National Park to acquire scans of long-term Carbono vegetation monitoring plots. In 2015, scans were taken on a 5m resolution grid of the 50m x 100m Carbono A2 and A5 sites (231 scans per site at a height of 1.5m). In addition, scans were taken at 3m, 6m, 9m and 11m height on a 10m x 10m resolution grid for a 20m x 20m sub-plot within the A5 Carbono plot. These variable-height scans were facilitated by mounting the CBL on a portable telescopic radio-mast tripod. Finally, a series of 1.5m scans were taken *ad hoc* to provide full angular coverage of trees with buttressed root structures within the 20m x 20m variable height sub-plot. The scanner was aligned to magnetic North and levelled prior to each scan to aid the co-location process.

Scans were co-located (relatively positioned in a Cartesian co-ordinate system) by a two-step process. The first step was an unsupervised X,Y and Z positional transformation based on the relative position of the scans according to the three-dimensional sampling scheme. The second step was a supervised, iterative process between sequentially paired scans, starting with the plot center scan as a reference. Calibration targets and GPS are not practical in dense, high-occlusion tropical environments, so co-location remains a challenge. Inertial Movement

Units (IMU) combined with traditional surveying techniques may offer the best avenue for automatic co-location of scans, though the semi-supervised approach employed here was still acceptably efficient.

Quantitative Structure Modelling (QSM) [1] was applied to the individually extracted trees for woody biomass estimation. An automated approach to stem detection previously designed for use in temperate forests was tested for its efficacy when initialized with scans of different heights.

Buttress volume was estimated by mesh formation from Poisson resampled point cloud segments which were extracted by analysis of trunk diameter stabilization, and manual filtering of unrelated ground points between roots. The resulting mesh was reductively facetized to form a closed polygon, the volume of which was then measured.

Information gain with horizontal and vertical view angle was assessed in terms of contributions to tree structure at varying heights; unique view angle analysis; and occlusion mitigation assessed with a combined pulse-tracing and voxelization method. Stabilization of the QSM output with combinations of source scans contributing to the extracted point cloud was also utilized as a metric of information quality.

Thus a hybridized approach to biomass estimation was investigated, utilizing QSM for trees of Diameter at Breast Height (DBH) greater than 10cm; voxelization for a volumetric estimation of vegetation associated with stems under 10cm DBH; and volumized polygons for buttress roots.

La Selva offers a unique tropical forest data set with extensive high quality field measurements of the vegetation in the Carbono plots to serve as validation data. The large amount of lidar data collected at La Selva has also provided the opportunity to explore the information gain from varying horizontal scan densities (10m x 10m, 15m x 15m, 20m x 20m and randomly resampled grid) as well as three dimensional tree reconstructions utilizing view angle contributions across the horizontal and vertical ranges and tree biomass estimation from QSM with different combinations of vertically distributed scans. The multi height deployment also allows a detailed analysis of the sub-canopy occlusion via the contributions to structure from scans above and below (see Figure 1). Finally the availability of detailed scans of buttressed trees facilitates an analysis of buttress volume estimation with respect to view angles, information density and atypical internal structure.

Results

We will present preliminary findings from ongoing view angle analysis, tree reconstruction by QSM, biomass estimation and atypical tree morphology reconstruction efforts.

Discussion

Highly portable and rapid scanning lidar instruments such as the CBL can augment highly capable, but less portable terrestrial lidars in easily accessible environments, and are serving a role in provide robust independent observations in less accessible environments such as tropical forests. The portability offers a positional flexibility that can mitigate occlusion both in terms of offering higher density of scans in the horizontal plane, and alternative view angles within and above the sub-canopy in the vertical plane.

Occlusion analysis is an important measure to quantify the benefits of highly portable lidar and evaluate the information quality of the data. These assessment techniques are rapidly improving in terms of their resolution and computational efficiency. Eventually, occlusion analysis should allow us to analyze information quality on the fly, and form appropriate scanning schemes responsively in the field. Not only would this truly optimize the benefits of portable lidar, but would guarantee the information quality of the deployment. This relies upon appropriate definitions of information quality, which can be determined by sensitivity analyses on results obtained from information-saturated experiments such as these at La Selva.

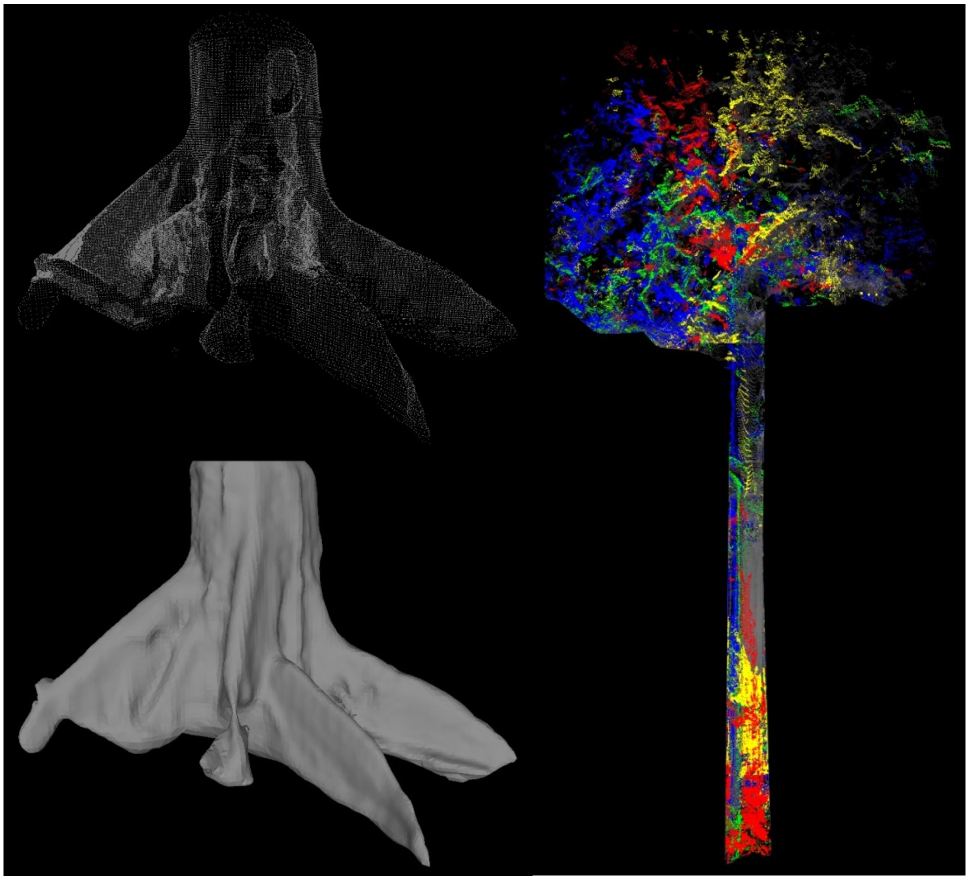

Figure 1: (Anti-clockwise from top-left) Poisson-resampled point cloud extracted from CBL scans of buttress roots of saber tree; surface fitted to k-neighbor mesh of buttress roots; saber tree extracted from 5 CBL scans at varying heights, color of points denotes contribution of individual scans to point cloud

References

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