UAV photogrammetry approach for above ground biomass in forest blowdowns Julia Carr & Jake Slyder, Carnegie Museum of Natural History and Powdermill Nature Reserve



Lucky to be hit by a tornado

In 2012, a tornado came through southwestern PA. Powdermill Nature Reserve, the ecological field station of the Carnegie Museum of Natural History, has used this storm as a research opportunity to study forest regeneration. In each of the four major blowdowns, researchers from across the world have set up long-term studies.



Most visible is an experiment to est the effect of salvage logging n forest regrowth, where each plowdown was divided in half, vith one half salvage logged (left). This research requires highly detailed, repeated measurements that could be directly compared in the upcoming years.

PROJECT GOAL

Create rapid, repeatable methods for extracting accurate tree level information across large sites.

Turning a toy into a tool

Remote sensing makes it possible to conduct repeated surveys across wide areas. Unmanned aerial vehicles (UAVs) are a simple, inexpensive, customizable option for surveying at the site wide scale.

For this study, a DJI Phantom 3 Professional equipped with a RGB camera was used to survey four study blowdown sites. Flights were taken at 80m, with 90% forward overlap and 90% side overlap. Images were brought into Pix4D, a photogrammetric software, which creates composite orthomosaic imagery, digital surface models and true color 3D point cloud (top above). For easy manipulation, all files were then brought into ArcGIS. Photogrammetric point clouds can use many pre-existing tools created for LiDAR datasets.

Finding trees in the forest

Previous studies primarily identified tree locations through local maxima in the canopy height. However, this approach may over-count large, branched trees in a deciduous forest, and under-count small trees under the canopy.

Instead, our identification tool searches for the vertical tree trunks, and then models individual trees through an iterative growth algorithm. To get the best geometric model, we use point cloud data from early-April flights, before the leaves come on. These tree models are then used to measure forest level biological information, like basal area and biomass.

. Identification and segmentation: automatically finding and delineating trees in the point cloud

Here we propose a two-step approach, first identifying tree locations (seed points), and then segmenting the point cloud into distinct trees.

Both tools take advantage of the natural geometry of trees. The identification tool is able to ignore complexity in branching or ground debris by searching for the vertical tree trunks. The segmentation tool then iteratively grows the tree from those seed points.

ACCURACY ASSESSMENT

To test the accuracy of the tools, we manually identified and segmented trees forty test plots across the four sites, and assessed the recall (sensitivity), precision (positive prediction value), and F-score (balanced ratio of precision and recall).

To account for user judgement in manual identification, each manual tree was assigned a confidence value.

2. Biological Information: what is the biomass? **CAN THE SEGMENTED POINT CLOUD REPLACE FIELD MEASUREMENTS?**

Biomass is often estimated using diameter at breast height (DBH, or approx. I.4m) measured in the field and allometric equations. Here we estimate these measurements from the point cloud.

Due to inconsistent point coverage, we estimated DBH across eight 50cm slices from 1m to 4m. When there was a large density of points in a certain direction from the centerpoint (branch), or when points are isolated (noise), we removed these points as outliers. We estimated DBH as twice the average distance from all remaining points to the centerpoint. We calculated basal area with these DBH measurements and compared those values to field measurements (right).







DENTIFICATION ACCURACY

The tool identified almost 9,000 trees across the four sites. Trees in the accuracy assessment plot that were missed were primarily trees of low manual identification confidence (that is, lacking a distinct form or point density)

This preliminary model overestimates DBH. (1:1 line shown in blue) However, many of the major overestimates (highlighted in red) are actually split trunks, where the true basal area will be larger than the field measurement.

SEGMENTATION ACCURACY Out of the 395,097 points in the test plots, 91% were correctly segmented (true positive or true negative).

Most errors were concentrated in specific trees.

False negatives (top left) were scattered throughout, primarily occuring when there was a gap greater than the growth distance in the point cloud.

1.9% of the points were correctly segmented as a tree, but assigned to the wrong tree. This only occurred when one branch (center left) either overlaid a smaller tree, or a tree/branch leaned into another tree.

False positives (bottom left) were primarily concentrated around areas of low, down debris. 75% of the false positives were from only 8 trees, and all associated with debris or broken branches.

How much field work is needed to get a good biomass estimate?

The point cloud provides a good estimation of tree location and general structure and volume. However, biomass calculations also depend on species abundances. We tested the amount of field sampling necessary to consistently estimate site-wide biomass using the following steps:

- I. Identify trees in the point cloud within pre-existing permanent sampling plots and determine their species and DBH in the field.
- 2. Create proportional 'card deck' for relative species abundance.
- 3. Randomly select **N** trees from field data
- 4. Calculate the 'true' biomass from field species.
- 5. Use card deck to randomly assign species, and calculate biomass from random species
- 6. Sum the true and random biomass estimates for 100 repititions
- 7. Calculate average and standard deviation of the percent change between 'true' and 'random' biomass estimates for different **N** values

A framework for further study

- UAV photogrammetry is a spatially and temporally scale-appropriate method for tree level monitoring.
- Photogrammetric point clouds can provide precise, tree level identification and geometric information
- Leaf-off flights provide a good model of both the ground and the trees themselves.
- Site wide monitoring is possible with relatively little field measurement

Future directions

CANOPY AND BLOWDOWNS

With the woody structure fully mapped, point clouds from early, mid, and late summer can be segmented to study canopy structure. The combination of leaf-on and leaf-off data can show the effects of the tornado and provide a direct comparison between the damaged and undamaged forest.

GROUND CLASSIFICATION

One of the major limitations of the photogrammetric point cloud was in the ground classification. Local complications in terrain often caused major errors. For example, in one study site, the ground identification was vertically scattered. This was actually due to the presence of a --previously unknown-- collapsed mine shaft (visible below). Future ground classifications will take into account any obvious local topography, masking on a first classification run, and then re-classifying to get a better measurement.

collapsed mine shaft

Get in touch.

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