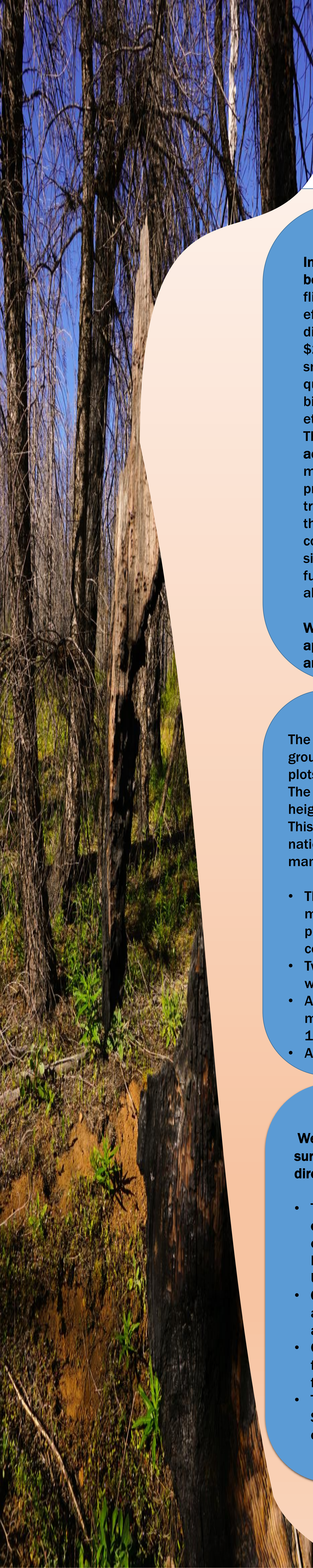
Photogrammetry and Slice Sector Approximation: Applications in Forestry

Zachary Robbins[1], Katie Fanhkauser[2], Demetrios Gatziolis[3], Nikolay Strigul[2]
[1] Portland State University [2] Washington State University at Vancouver [3] U.S. Forest Service



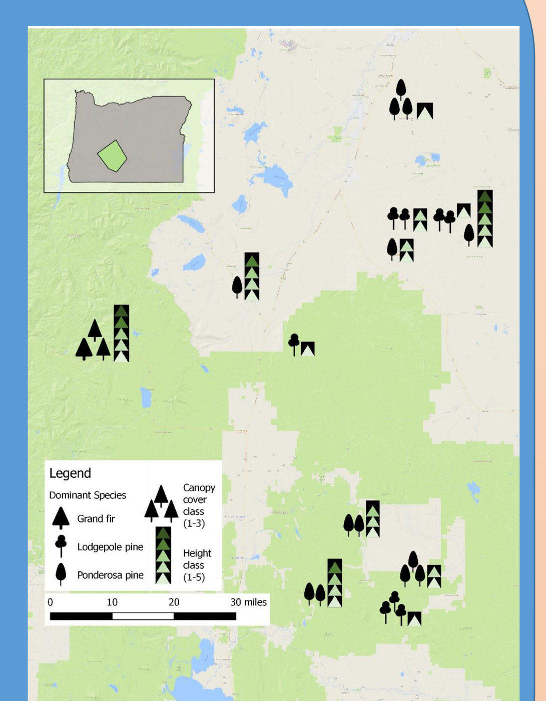
Introduction

Increasingly, crucial measurement of forests (composition, growth, volume, etc) are being handled by remote sensing. However, large scale surveys through LiDAR flights and Landsat satellites are gathered only periodically, limiting the effectiveness of using remote sensing for temporally sensitive applications such as disturbances. Further, the large minimum cost of LiDAR flights (exceeding $20,000), and the data processing associated, can limit LiDAR application in to small experimental scale plots(Gatziolis et al., 2015). Advancing small scale and quickly deployable remote sensing may allow for the capture of forest response to biogeochemical and disturbance patterns, which occur at irregular timescales (Lu et al., 2017).
The consistent evolution of inexpensive photography and personal scale **unmanned aerial systems (UASs)**, colloquially known as drones, poses photogrammetry as a method by which to bridge this gap. **Structure from motion (SfM)** algorithms provide a method by which to create high-resolution point clouds. Calculation of tree metrics necessary for forest management and ecological understanding from three-dimensional (3D) point clouds requires measurement tools that can assess complex structure. **Slice sector approximation** provides an algorithm that allows for simple calculation of tree characteristics such as height and crown diameter. It further can be used to quantify as much detail as presented in the reconstruction, allowing for advanced analysis of crown dynamics and modelling.

We employed a small scale UAS and photogrammetry and executed slice sector approximation in order to compare the method measurements made using LiDAR and traditional manual methods to compare the efficacy.

Sites

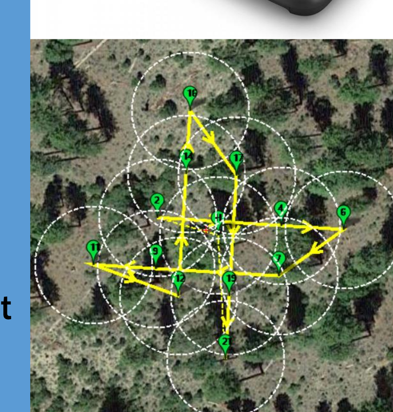
The United States Forest Service collected detailed ground field data on 50 circular, 1/5th acre (53ft radius) plots in central-southern Oregon in the summer of 2015. The plots were first stratified by canopy cover and tree height class using LiDAR data collected in spring 2015. This method is designed to capture information about national forest plots in various stages of growth and management.



- The plots vary by height profile, canopy cover, and management activity, including burning, logging, pruning, and/or natural regeneration, but are mostly comprised of pine species.
- Two of the plots are predominantly ponderosa pine, while the third is primarily lodgepole pine.
- All three cover classes are represented and the maximum height between plots ranges from 55 to 114 ft.
- All plots are located on relatively flat topographic land.

UAS Flight

We deployed a UAS to collect still color images above the survey area of focus following pre-programmed flight directions.



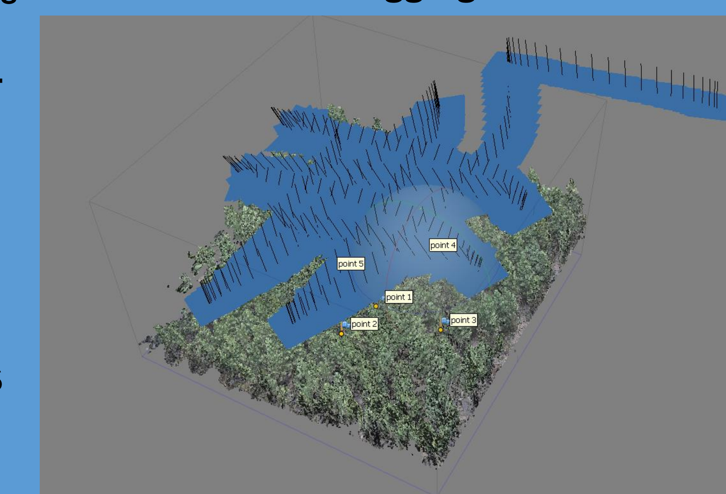
- The goal of this data collection is to **get sufficient overlapping photographs** (approx. 80% planer and side overlap) to create 3D structure.
  Flight and camera instructions are programmed into the UAS using **Mission Planner** software.
- **Ground control points (GCPs)**, are placed among the plot and their locations are computed by measuring azimuth and slope-adjusted distance from the center.
- Once the ground data is established, the UAS is launched from a level clearing near the plot and follows the autopilot flight.
- The UAS used for this method consists of a 3D Robotics Solo platform with a gimbal and a GoPro Hero 4 Silver camera.

Point Cloud Reconstruction

The process of creating **three-dimensional models** from still images relies on the principles of photogrammetry and **structure-from-motion (SfM).** SfM is a process that identifies features across series of images and determines their precise location in three dimensional space.

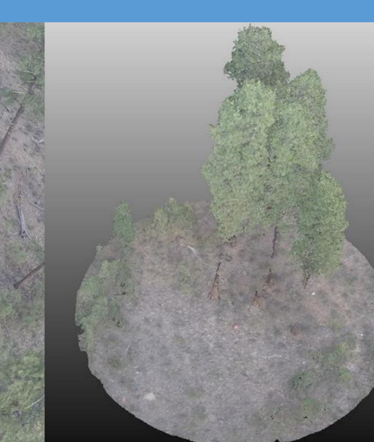
- Each of the images are **geotagged** using the known GPS location from the flight plan.
- Each image is examined for **visual identification of the ground control points** and the corresponding coordinates are assigned to that pixel.
- Image-specific depth map computations based on these known locations then **produce a reconstruction in the form of a dense point cloud.**

Geotagging



Photo

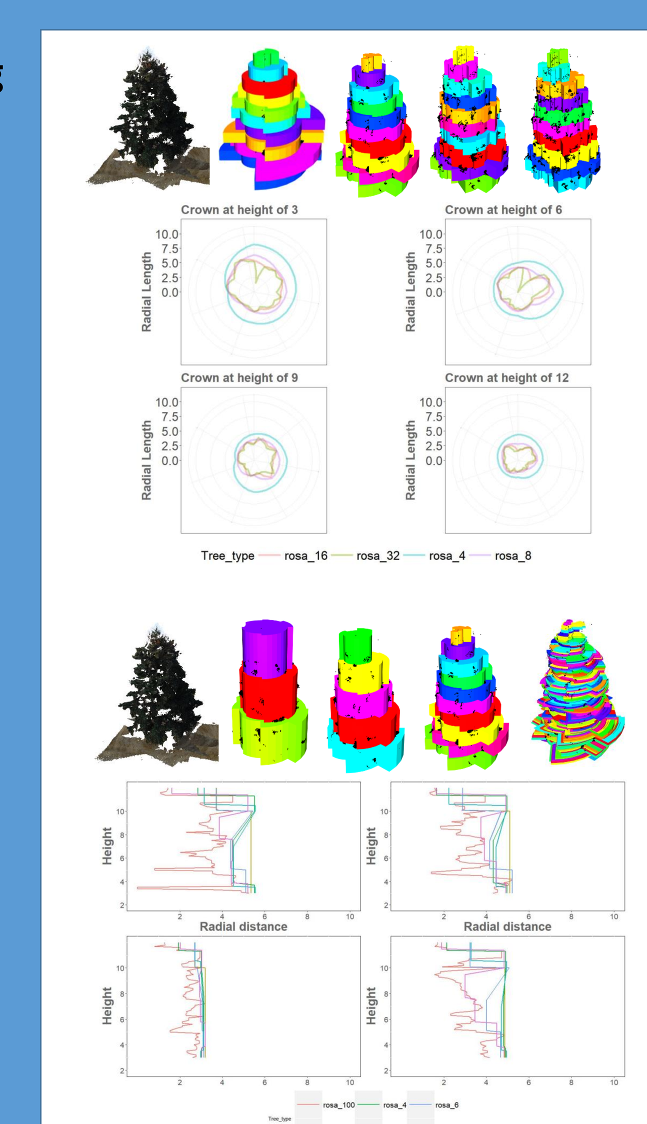
Reconstruction



Slice Sector Approximation

Slice sector approximation applies two-dimensional **(2D) non-parametric clustering** to find tree locations and approximate the crowns around them.
Different combinations of slices and sectors can be used based on the crown definition needed

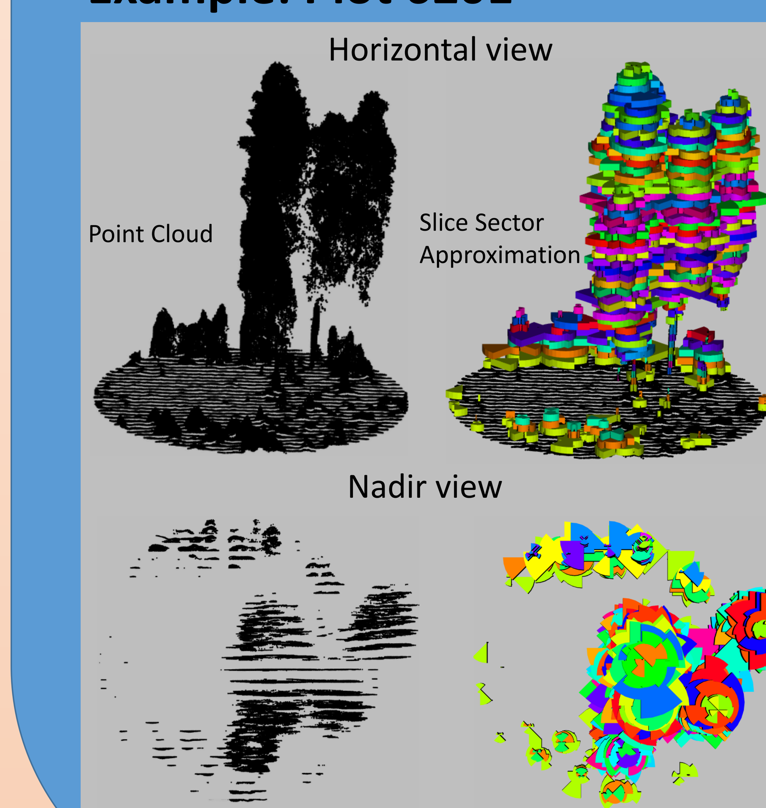
- This is achieved by dividing the point cloud into equal vertical slices and then compressing each slice to **a 2D map.**
- To each layer's 2D map of points, a mean-shift algorithm is applied, **grouping points into clusters.**
- **Mean shift algorithms** works by clustering the number of points likely to occupy a given area based on user defined parameters
- The mean coordinate position of this cluster is defined as the tree center
- The distance of the cluster groups from these centers is used to **define the crown length** at a given azimuth sector.
- Through many vertical iterations of this you get **an outline of the crown shape.**



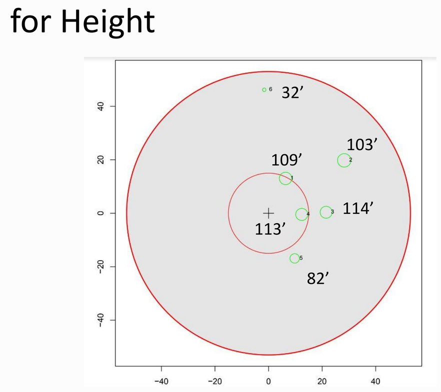
Results

Plot #	No. of Trees: Observed/ Actual	Max Height: Observed/ Actual (% error)	Mean Tree Height : Observed/ Actual (% error)	Adult Crown Coverage Calculated (ft^2)	Adult Crown Percentage
6380	73/73	55/50.7 (8.4%)	37.90/37.5	4192.6	53.4%
6201	6/6	114/121 (5.8%)	96.61/92.2	1696.2	21.5%
6284	17/17	63/66 (4.8%)	48.27/50.1	2572.7	32.8%

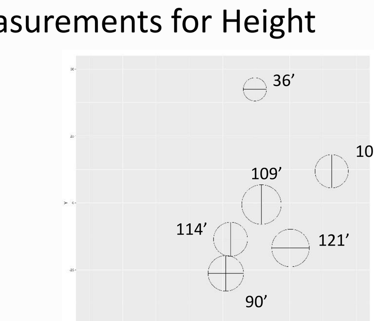
Example: Plot 6201



Traditional Field Measurements for Height



UAS and Slice Sector Approximation Measurements for Height



Conclusions

The use of UAV based photogrammetry and slice sector approximation provides a method by which **to accurately assess small plots** for a number of features using small scale remote sensing, photogrammetry, and slice sector cloud processing. These reconstructions are accurate when compared to field measurement and LiDAR in terms of location, height, and crown area of the trees.

The discrepancy in height we believe is likely a combination of error and **of time between measurements.** Most height measurements are a few feet higher, which is realistic growth in time frame

These **methods do not purport to replace all field data collection** as currently evolved, but instead can be a tool to supplement the data obtained by traditional inventories. On the contrary, **having good field data is often a prerequisite** to building these models. For instance, our slice sector approximation was more quickly optimized to the exact number of trees observed during fieldwork. The **major significance** of this method is **its ability to extract more detailed information about canopy and competition**, which are less readily accessible from the forest floor. Concern should be placed on the fact that user experience in approximation can lead to different outcomes in terms of accuracy. Several approximations may be necessary to avoid trees unrealistically merging with one another.

We are planning to employ this method for parameterization of **spatially-explicit individual tree-based forest simulators.** Slice sector approximation allows for real branch structuring to be incorporated in individual growth models for the first time. **This can vastly improve our understanding of competition dynamics**, as complexity in canopy structure allows for far more accurate light penetration measurement than in traditional conical model.

Citations:
Gatziolis, D., Lienard, J. F., Vogs, A., & Strigul, N. S. (2015). 3D tree dimensionality assessment using photogrammetry and small unmanned aerial vehicles. *PloS one*, *10*(9), e0137765.
Lu, B., He, Y., & Liu, H. H. (2017). Mapping vegetation biophysical and biochemical properties using unmanned aerial vehicles-acquired imagery. *International Journal of Remote Sensing*, 1-23.

Acknowledgments: This work was partially supported by Simons Foundation (283770 to N.S.) and by the US Forest Service grant "Evaluation of Visual Structure from Motion Technology for Forest Inventory Field Operations". KF was supported by the EPA STAR Graduate Fellowship. Z.R. was supported by WSUV NSF REU "Landscape Ecology and Ecosystem Dynamics in the Columbia River Basin: Integrating Terrestrial and Aquatic Perspectives" (PI Dr. Rollwagen-Bollens, WSUV) and the Edward D. and Olive C. Bushby Scholarship.