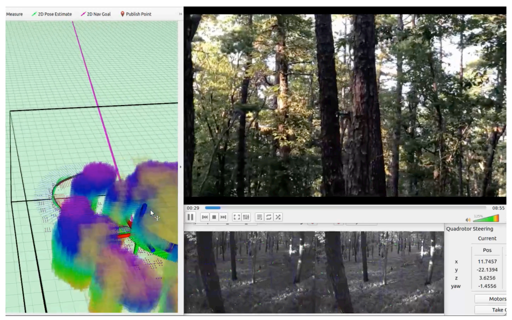
NRI: ROBOTICS, SCIENCE AND TECHNOLOGY FOR FORESTRY (USDA/NIFA #584401)

PI: Pratik Chaudhari, Co-PIs: Vijay Kumar, Patrick Corey Green

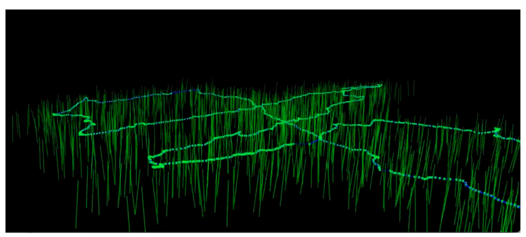
LARGE-SCALE MAPPING AND ODOMETRY

Autonomous flying

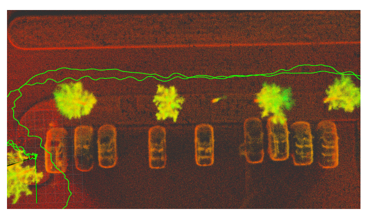


Over-canopy reconstruction

Semantic mapping

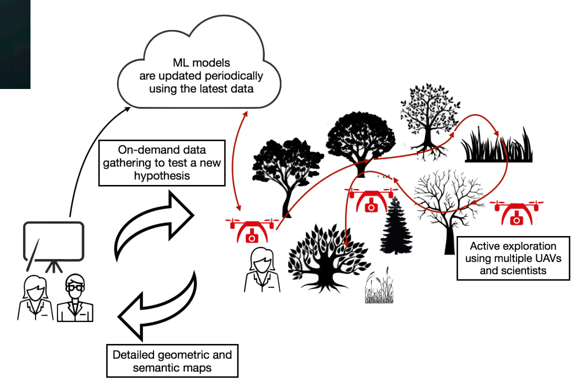


LiDAR odometry (~0.01% drift)



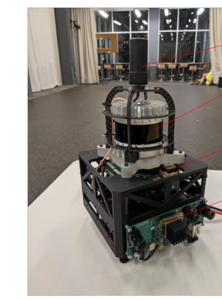
OUR VISION AND RESEARCH GOALS

Sampling	Coverage Rate	Resolution	Labor
Over the canopy measurements	Fast	Low	Minimial
Under the canopy UAVs	Moderate	Medium	Modest
Ground measurements	Very slow, but necessary	High	High



- Large-scale mapping using multiple UAVs
- Fine-grained semantic understanding of unstructured environments
- Pairing human-collected ground measurements with UAV data

PLATFORMS



FALCON 450
~35 min flight time, LiDAR, stereo vision, flexible compute (NUC, or Xavier NX)

SENSOR TOWER
LiDAR, RGB global shutter camera, RTK GPS, thermal camera; onboard compute for data acquisition and compression

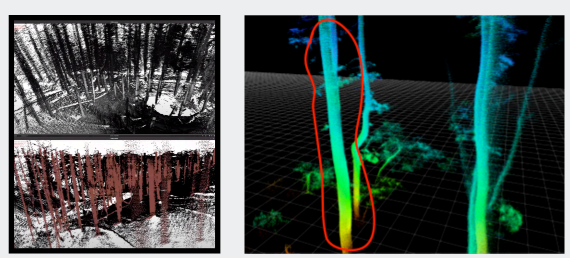
FORESTRY ESTIMATES

Would like to accurately measuring the DBH (diameter at breast height), main stem taper profile, and height of the trees.

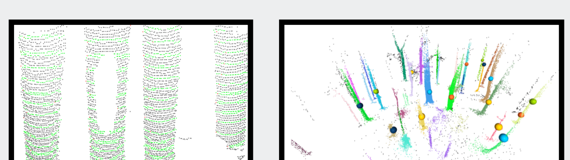
	CM	Inches
Median DBH Error (Hand Carry)	0.650	0.256
Mean DBH Error (Hand Carry)	1.050	0.413
Median DBH Error (Flight)	1.450	0.571
Mean DBH Error (Flight)	1.669	0.657
Median Profile Error (Hand Carry)	0.900	0.354
Mean Profile Error (Hand Carry)	1.255	0.494
Median Profile Error (Flight)	1.350	0.531
Mean Profile Error (Flight)	1.663	0.655

Measurement error with respect to ground truth obtained from Virginia Tech

1. Home-brew tool for labeling point clouds, train a semantic segmentation network from range images



2. Estimate control points and diameter in real time, accumulate profile estimates, re-cluster for correcting height



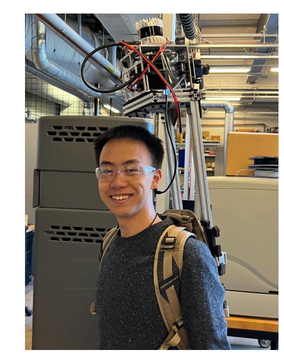
CURIOUS BUT BUSY BEE EXPLORER

Take controls that deteriorate the minimal sufficient representation; when you cannot do so you have learnt the scene

$$\operatorname{argmin} \underset{\substack{p(x|y^t,u^t),\\ p(z|x),p(u|x)}}{\mathbb{E}} \left[I_g(y_{t+1}(u); z) - I(z; x) \right]$$

In preliminary experiments, we instantiated this principle using "slow feature analysis" to explore 2D environments

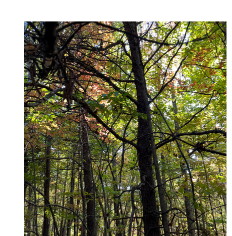
MAP THE PENN CAMPUS



Catalogue the biodiversity and the carbon captured. The 3D map will be matched with Penn's existing database.

KEY CHALLENGES

Planning with very tight tolerances



Extreme contrast changes