# Vision for Harvesting Machines:
# Real-time individual tree detection and measurement

Lucas Wells[*], Woodam Chung[*], Jenny Perth[†] and Ed Messerlie[†]

[*]Department of Forest Engineering, Oregon State University

[†]Missoula Technology and Development Center, USDA-FS

Forest Engineering Conference 2018

Rotorua, NZ

**Oregon State University**
College of Forestry

# Vision for Harvesting Machines

- Technology overview
  - Camera design
  - Computer design
  - Algorithms
  - Validation
- Applications
  - Markless treatments: diameter and spacing thresholds
  - Virtual boundaries
  - Optimized treatments based on stem maps
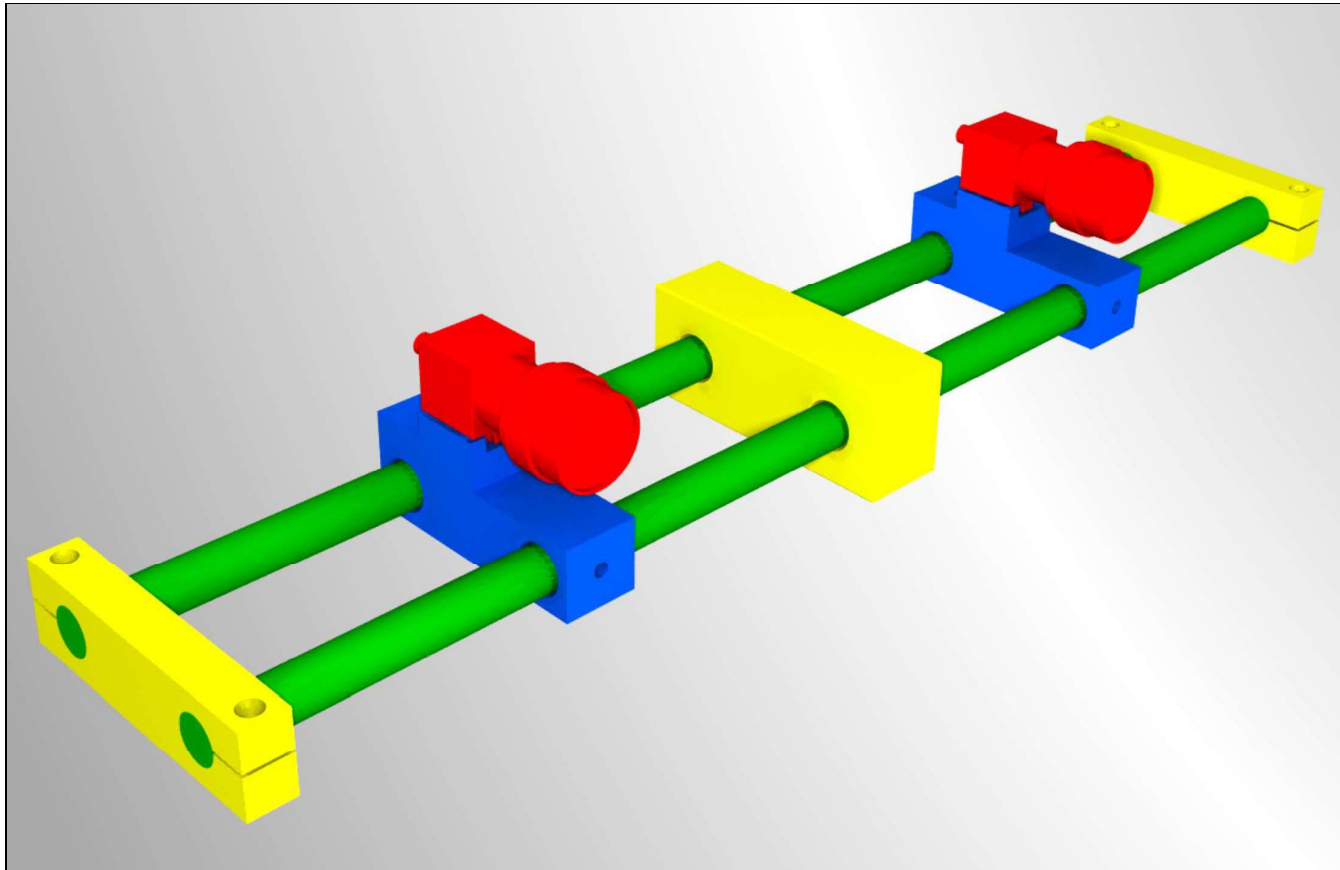  - Autonomous boom control

Oregon State University
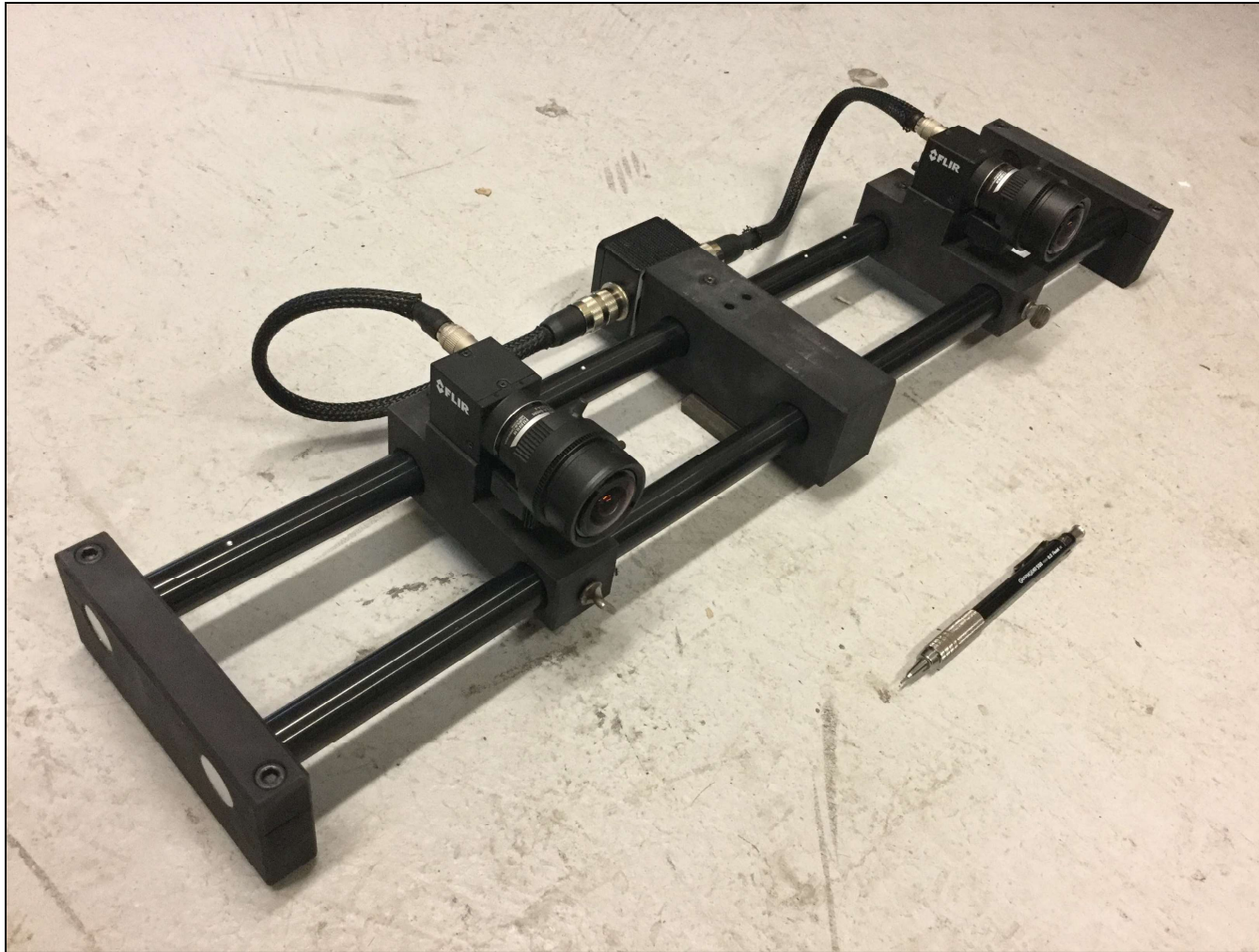College of Forestry

# Technology Overview

# Camera Design

- Purpose-built stereo camera
- Adjustable baseline
- Rugged/durable design
- Low cost



Oregon State University
College of Forestry
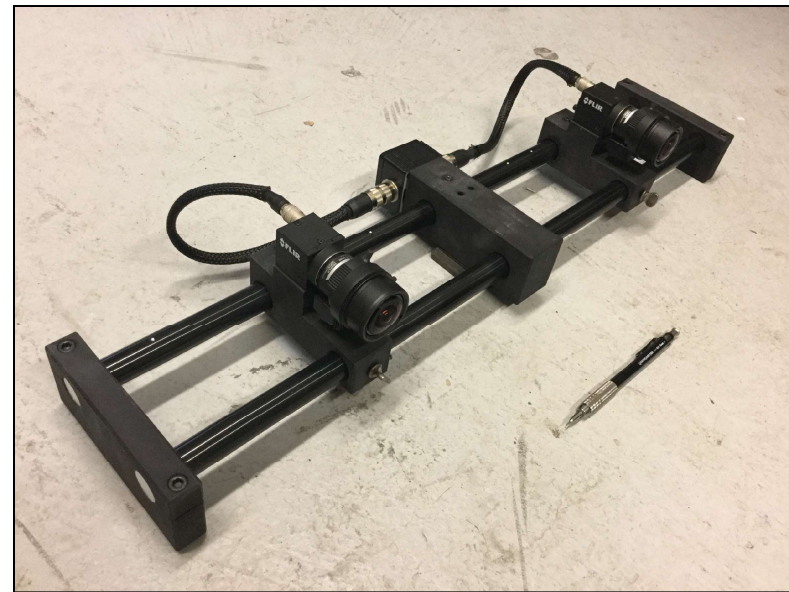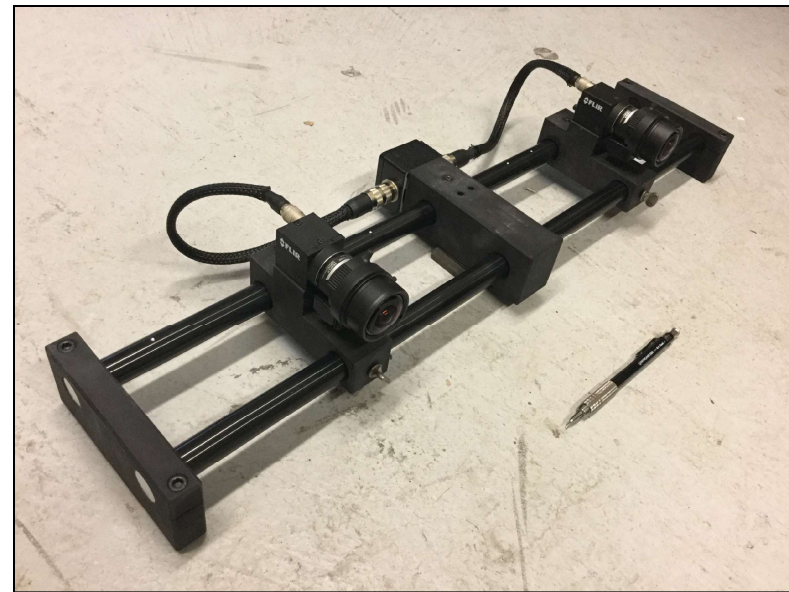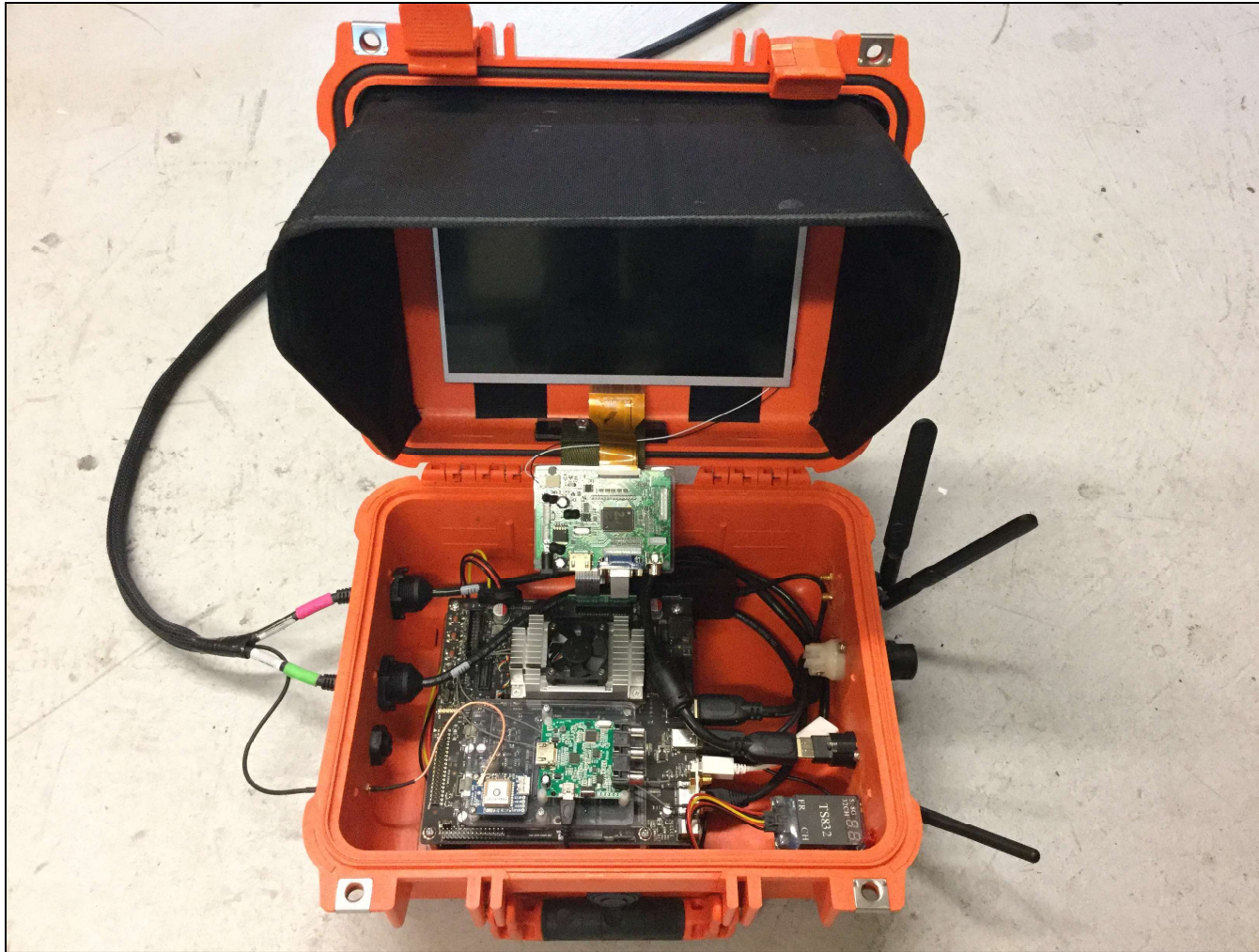
# Camera Design

# Camera Design

# Camera Design

Cameras can be indexed at 4 positions optimized for depth error minimization given stem density (i.e. 1000, 500, 250, 100 TPA)



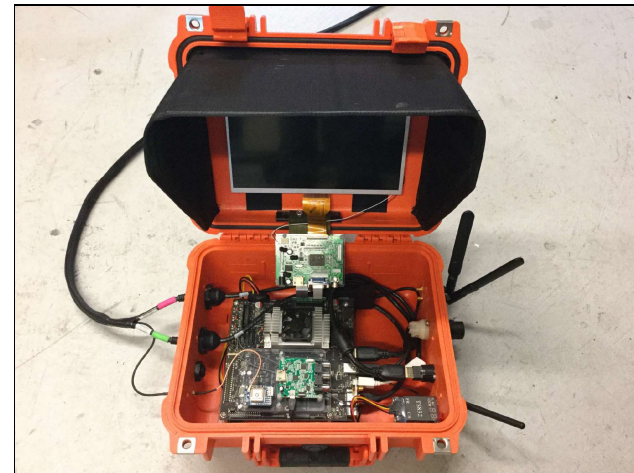Oregon State University
College of Forestry

# Computer Design

# Computer Design

NVIDIA Graphics Processing Unit

- Executes all algorithms at 5Hz

- GPS with external antenna mounted on camera

- 5 meter POE Gigabit Ethernet cables

- Transmits video to remote displays



Oregon State University
College of Forestry

# Algorithms: Stereo Correspondence
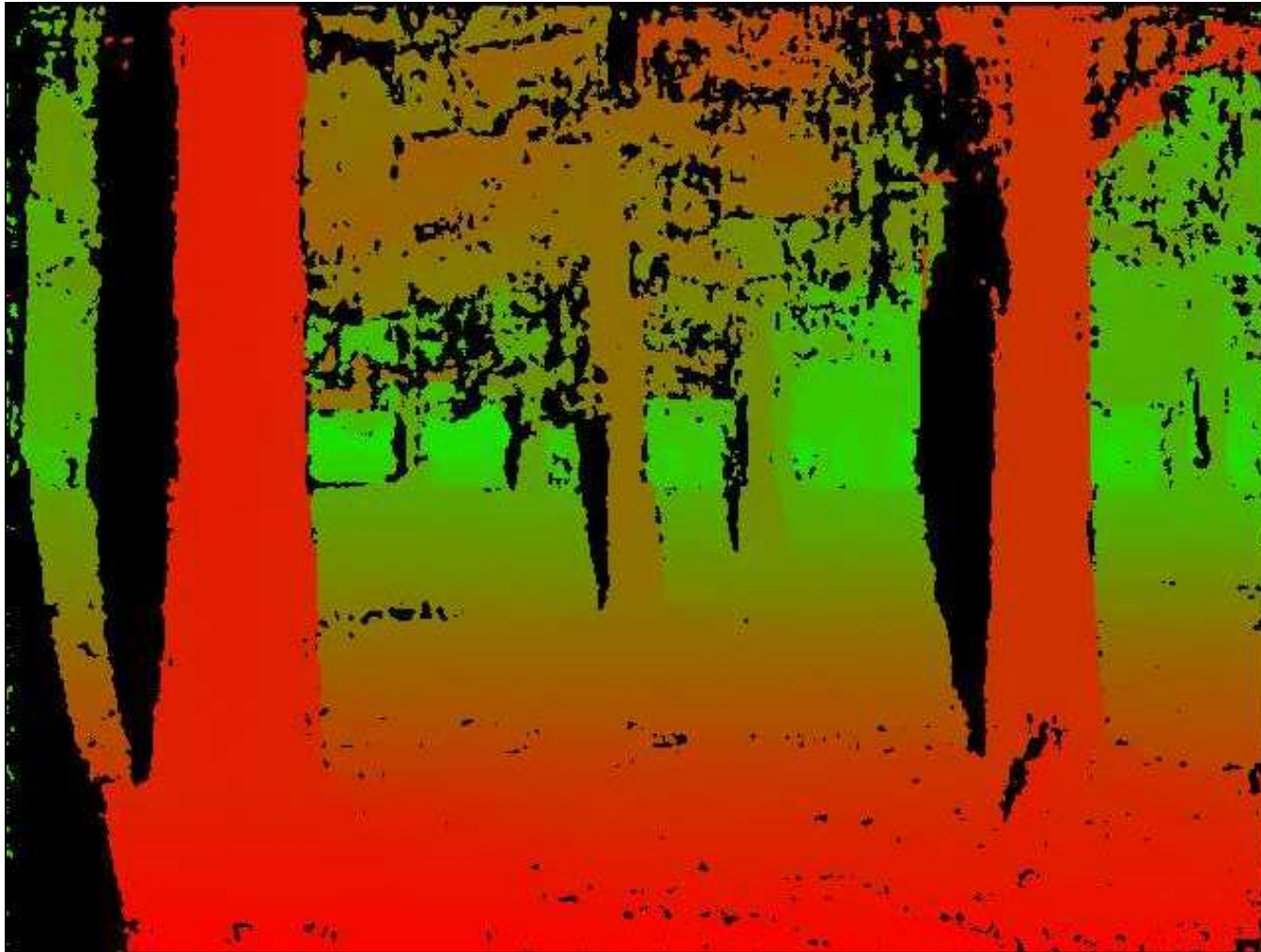
Left and right stereo images
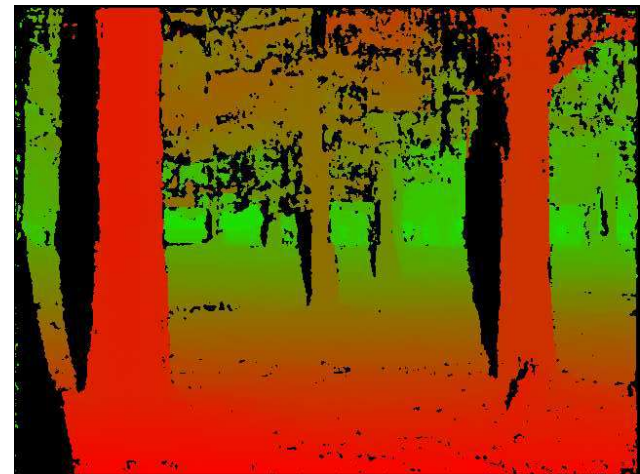
# Algorithms: Stereo Correspondence

# Algorithms: Stereo Correspondence

## Disparity map

# Algorithms: Stereo Correspondence

- Semi-global block matching
- No sub-pixel disparity estimation
- Post processing
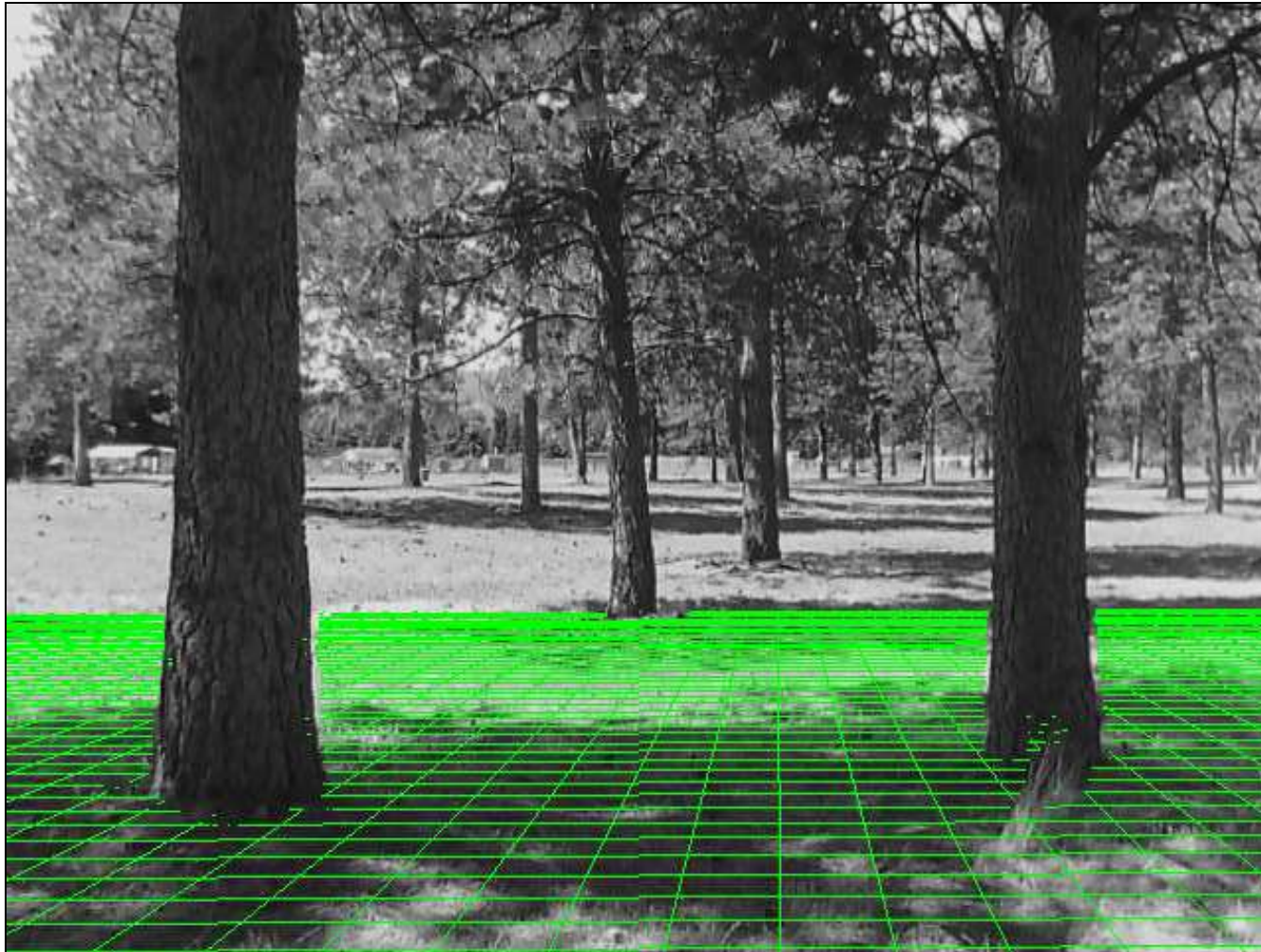  - Right-left consistency check
  - Median filter
- 11 ms on GPU

Oregon State University
College of Forestry

# Algorithms: Reconstruction

RGB point cloud
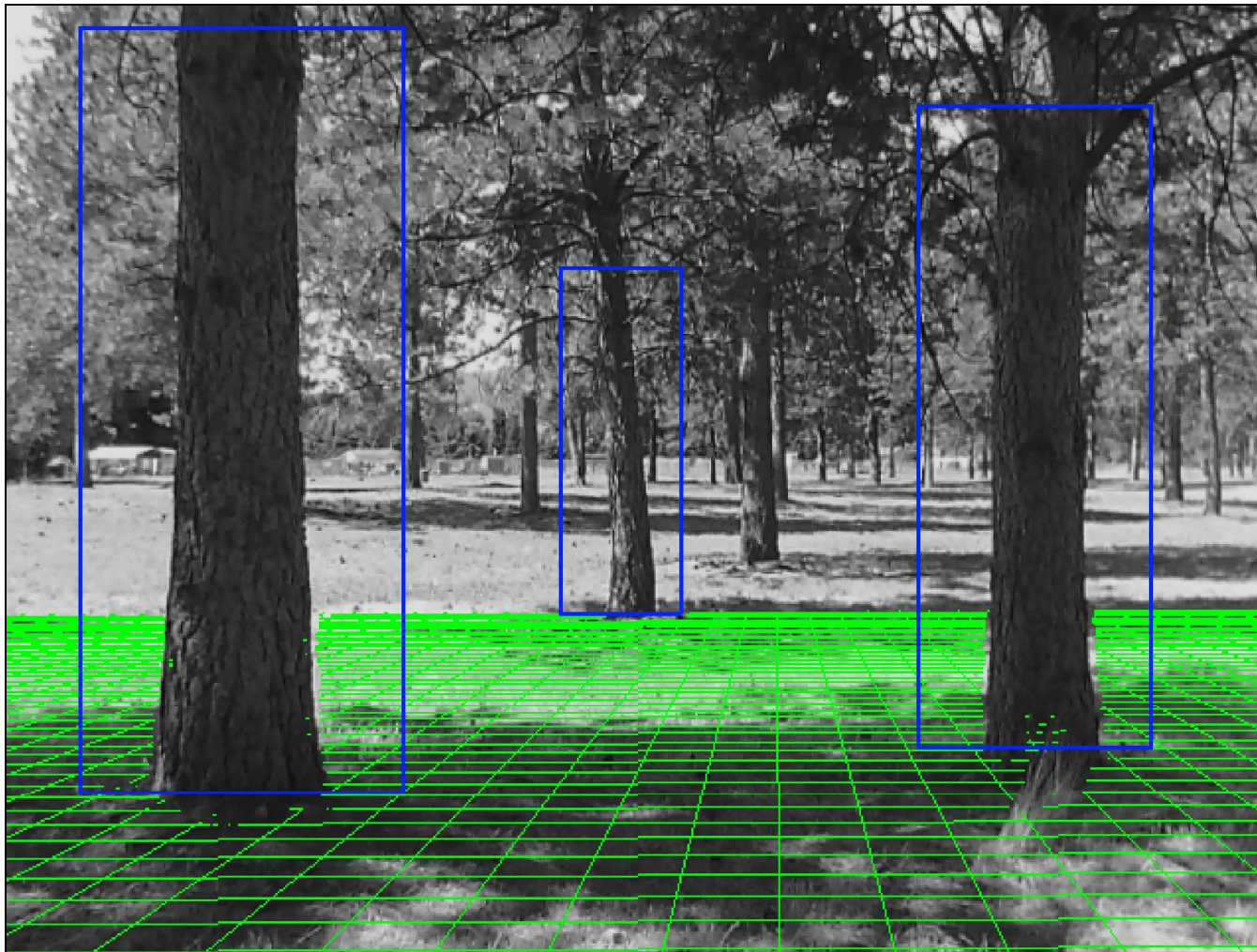
# Algorithms: Ground Detection

# Algorithms: Ground Detection

- Plane fitting (6 parameters)
- Random Sample Consensus (RANSAC)
- Unequal selection probabilities based on previously detected plane
- Motion constraints to filter unlikely plane hypotheses
- 20 ms on GPU for first detection; 10 ms for following detections



Oregon State University
College of Forestry
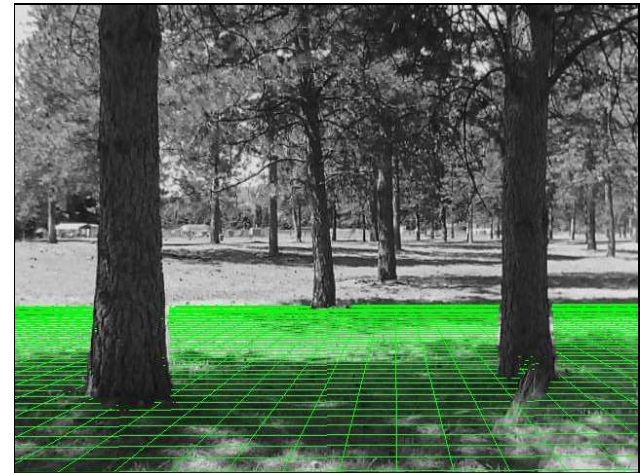
# Algorithms: Stem Detection and Classification

# Algorithms: Stem Detection and Classification

- ROI: 1' above ground plane to canopy base
- Obstacle detection in UV-disparity space: clustering by Hoshen-Kopelman algorithm
- V-space for obstacle height
- U-space for obstacle width
- CNN for object classification
- 2 ms on GPU

Animation



**Oregon State University**
**College of Forestry**
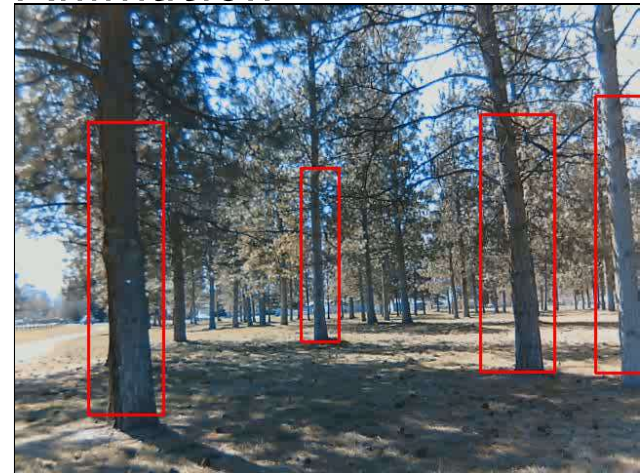
# Algorithms: Stem Analysis
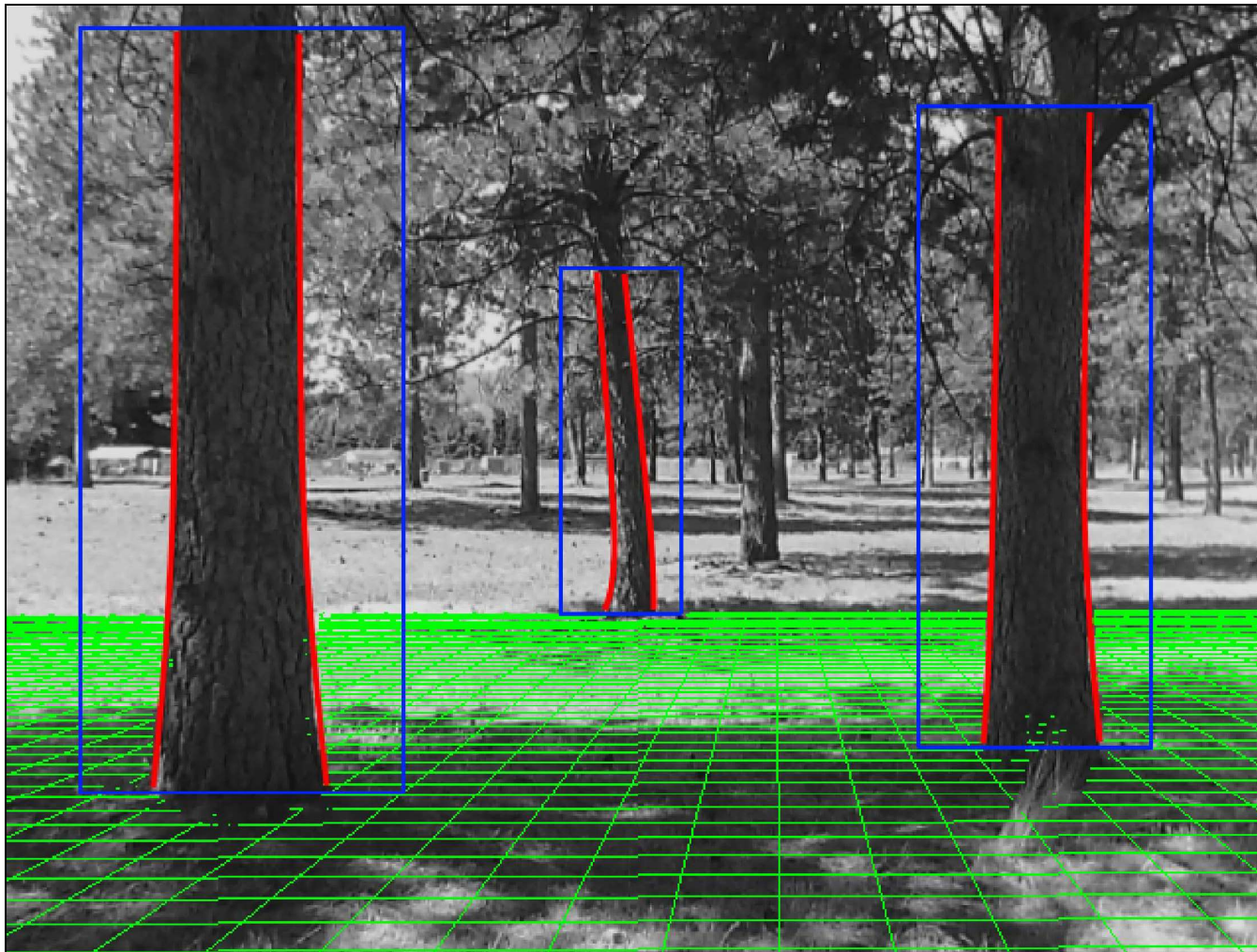
# Algorithms: Stem Analysis

- Parametric stem model (7 parameters to describe dbh, taper and sweep)
- Active contours: energy minimization via gradient descent
- Energy field: Gradients in disparity and color image
- Guaranteed to converge
- 50 ms on GPU

Animation



Oregon State University
College of Forestry
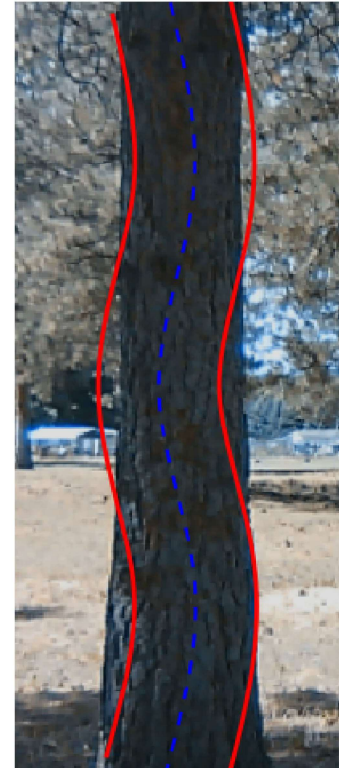
# Validation

RMSE for $n=30$ stems:

- Breast height: 3.73" (9.47 cm)
- Diameter: 0.48" (1.22 cm)
- Distance: 1.56" (3.96 cm)
- Angle: $0.38°$



Oregon State University
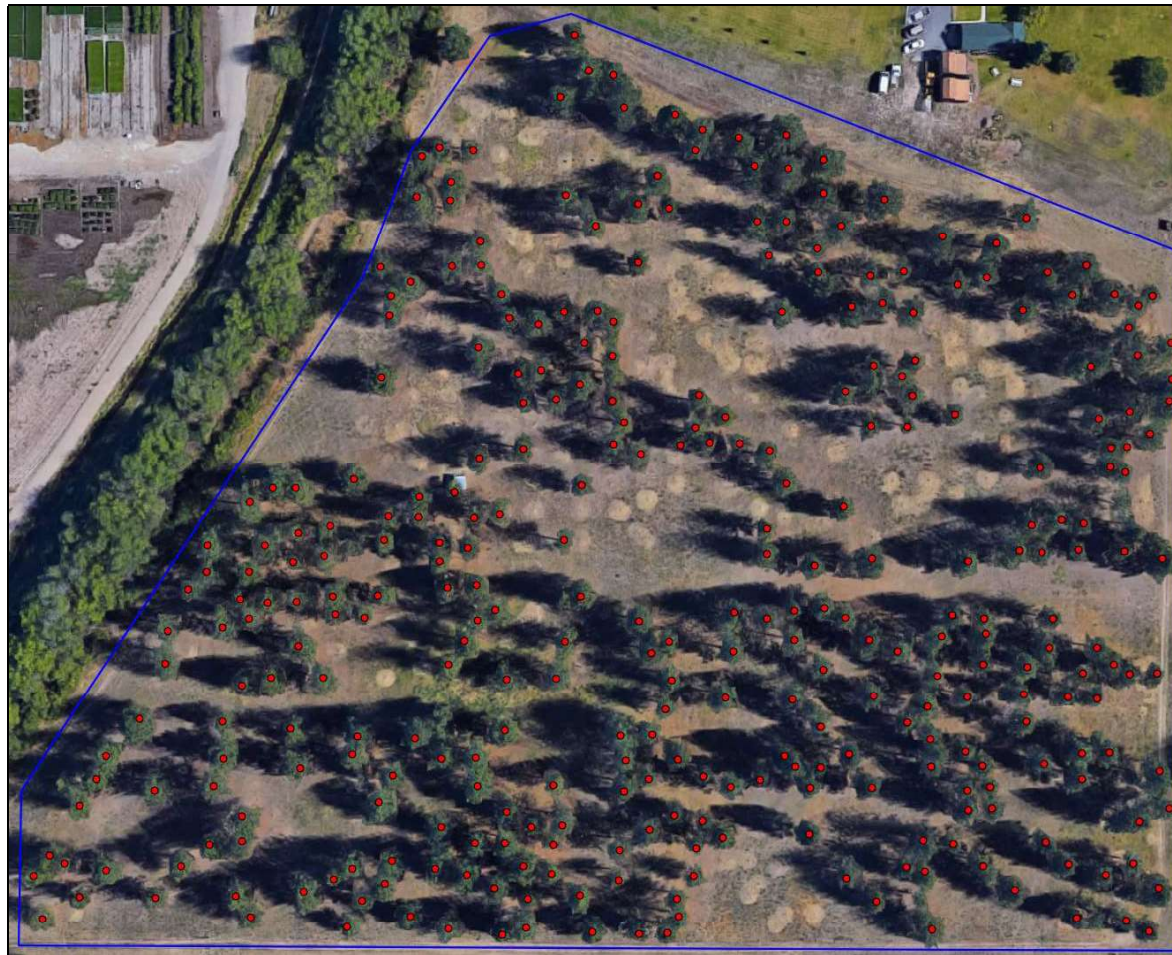College of Forestry

# Applications

# Markless Prescriptions

- Provide operator with necessary information to carry out markless prescriptions (e.g. diameter and spacing thresholds)

- Provide the operator with cut/leave decisions based on thresholds



Oregon State University
College of Forestry
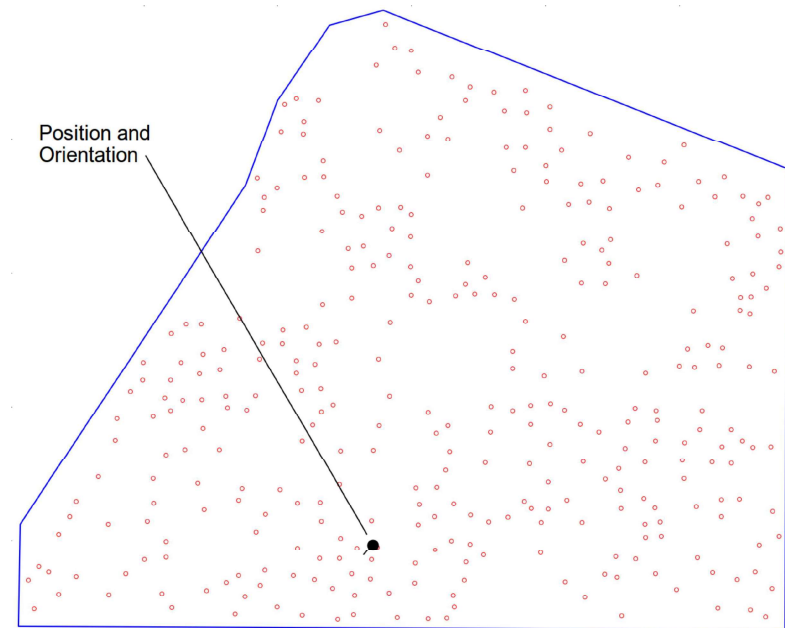
# Virtual Boundaries

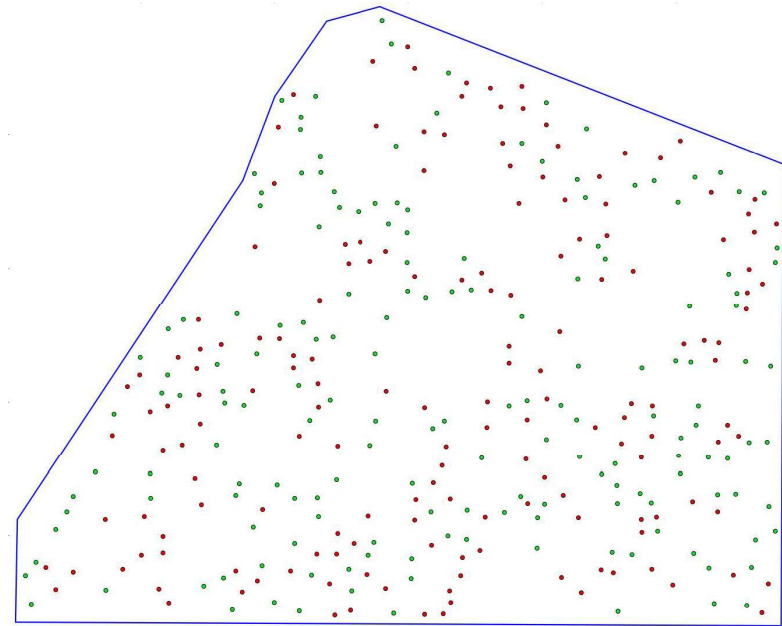Without GPS...

# Virtual Boundaries

Without GPS... Global localization via Particle Filter

- Given:
    - Scaled, non-georeference stem map
    - Distance, angle, and diameter of trees from camera
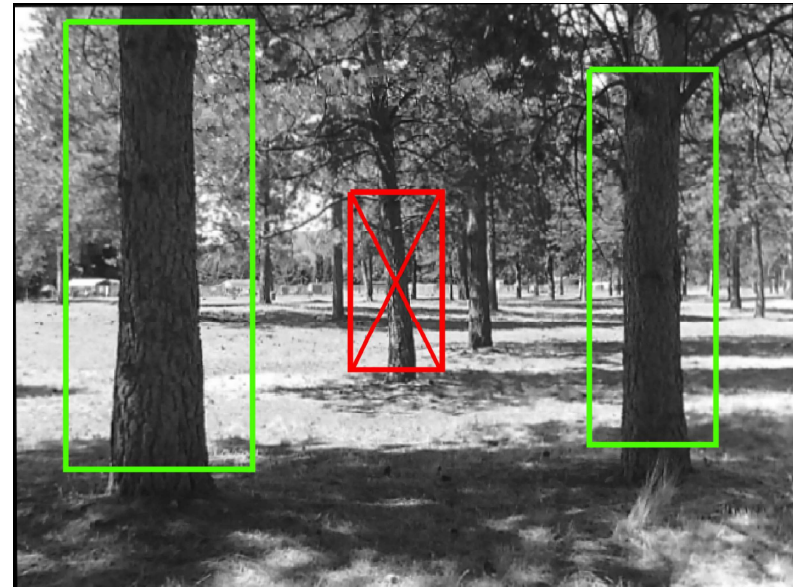- We can localize the machine within the map

Position and Orientation

# Cut-Leave Stem Maps

- Given a stem map with cut/leave assignments

Oregon State University
College of Forestry

# Cut-Leave Stem Maps

- Given a stem map with cut/leave assignments
- We can display the assignments to the operator

# Autonomous Boom Control

- Camera provides the harvester boom end effector a goal position

- Inverse kinematics for optimized joint angle adjustments to reach goal position

- Adjacent detected trees can be used to determine felling direction



Oregon State University
College of Forestry

# Questions?