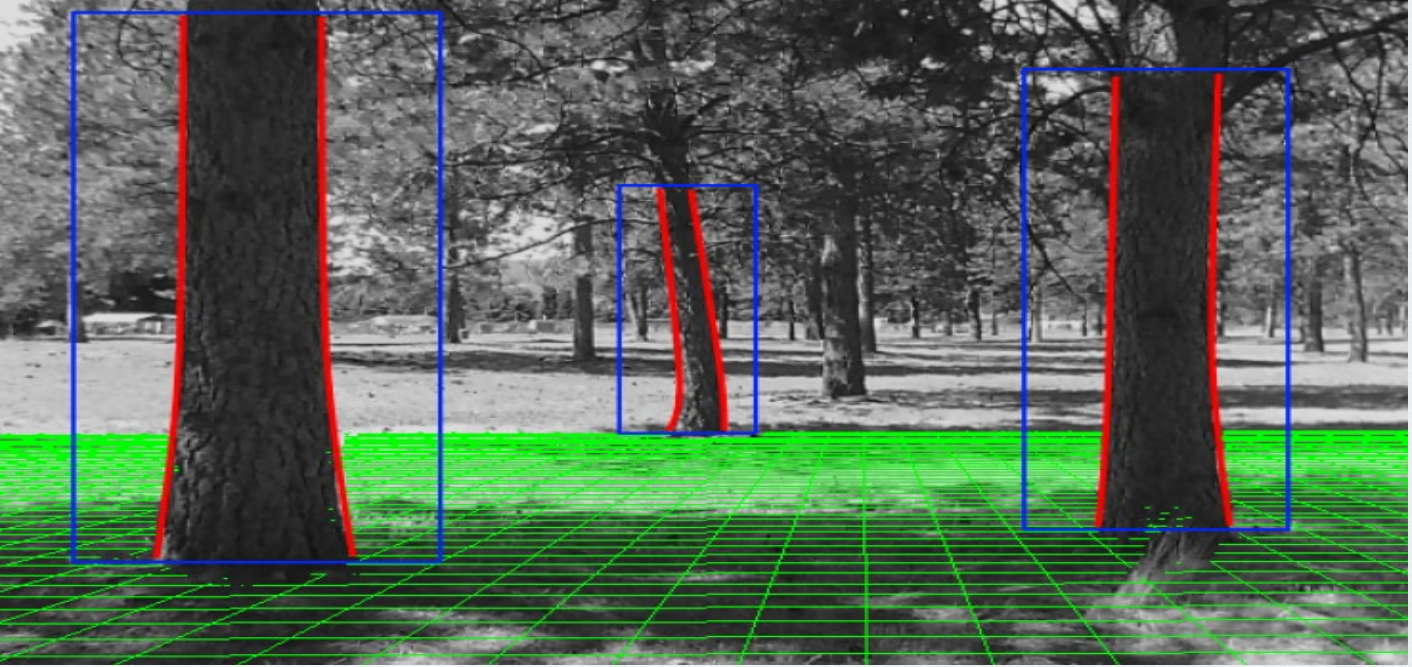

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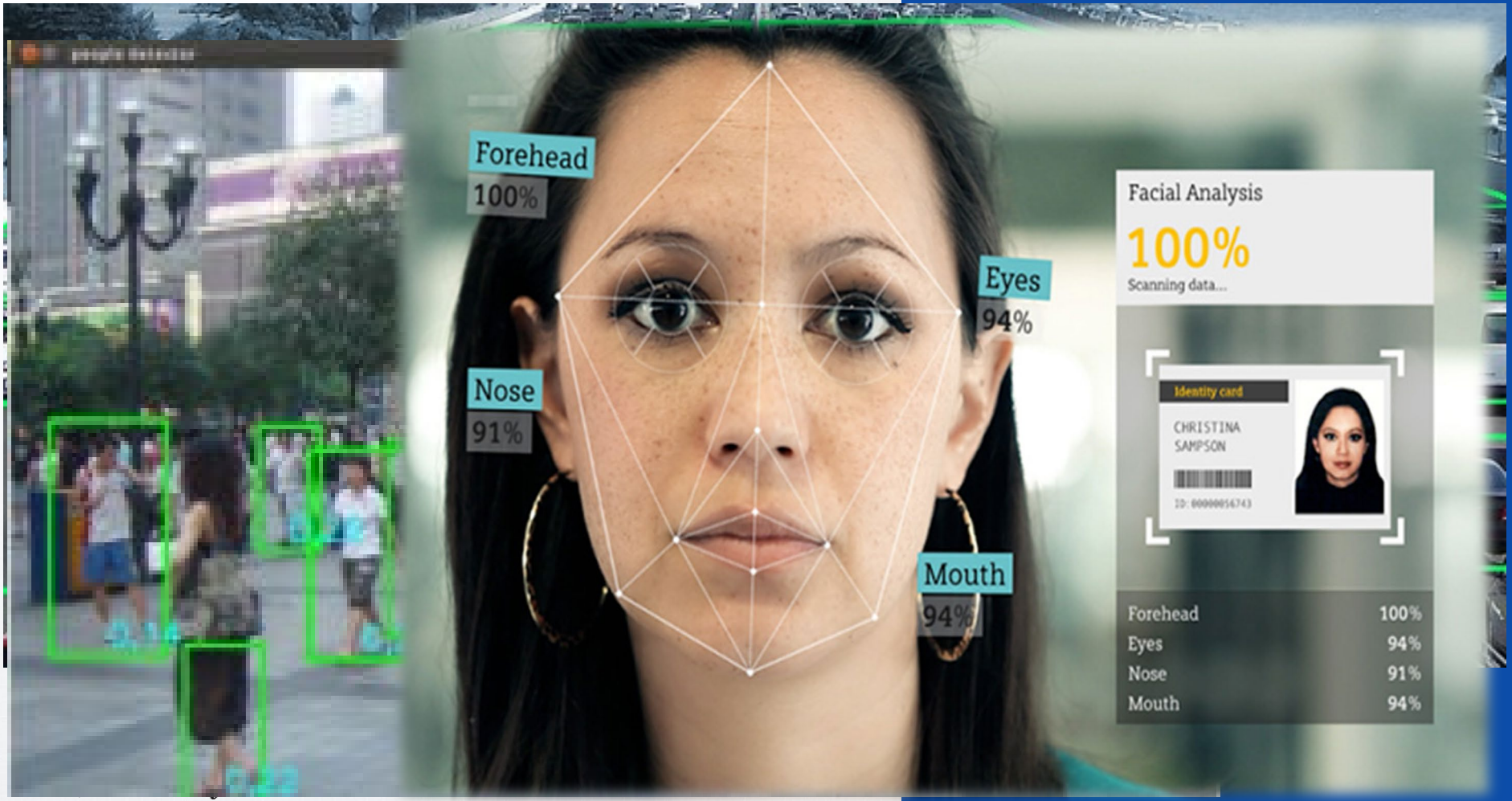
COMPUTER VISION

Real-time Tree Detection and Measurement

Woody Chung and Lucas Wells

WR.COFE 2019 | **Jan. 2019** | **Eugene, OR**

Our Future?


Forehead
100%
Eyes
94%
Nose
91%
Mouth
94%
Facial Analysis
100%
Scanning data...
Identity card
CHRISTINA
SAMPSON
Forehead 100%
Eyes 94%
Nose 91%
Mouth 94%

Acknowledgement

Collaborators and Funding Source

Jenny Perth and Ed Messerlie

USFS Missoula Technology and Development Center

Funding Source

USDA Forest Service Agreement #16CS-1113-8100-017

Contents

Computer Vision for Harvesting Machines

Technology Overview

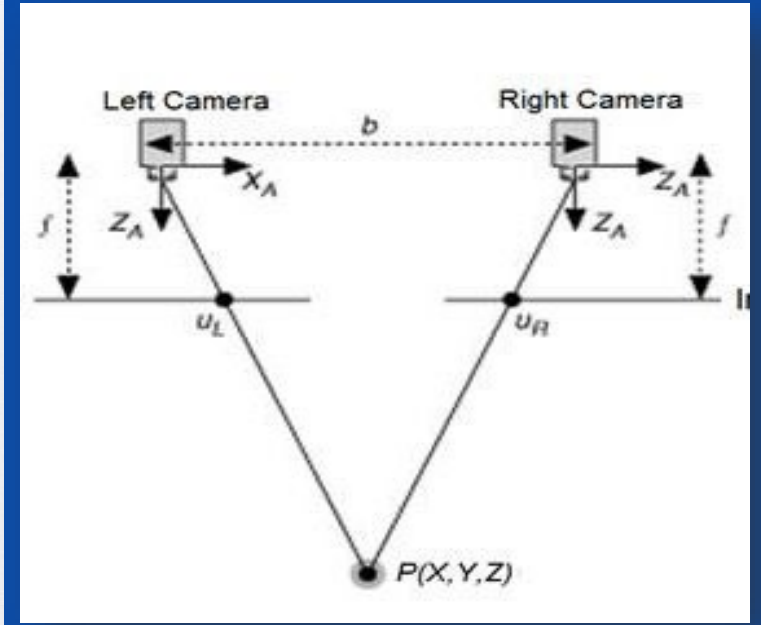
- Camera design
- Computer design
- Algorithms
- Validation

Applications

- Markless treatments
- Virtual boundaries
- Optimized treatments based on stem maps
- Autonomous boom control

Computer Vision

- Computer vision seeks to automate human visual processing tasks
- Stereo vision extracts 3D information from images
  - 3D coordinates for pixels plus color information
  - In real time



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Computer Vision

- Real-time computer vision is difficult
  - Depends on computational complexity and hardware
- Solutions…
  - Efficient algorithms
  - Graphics Processing Units

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Technology Overview

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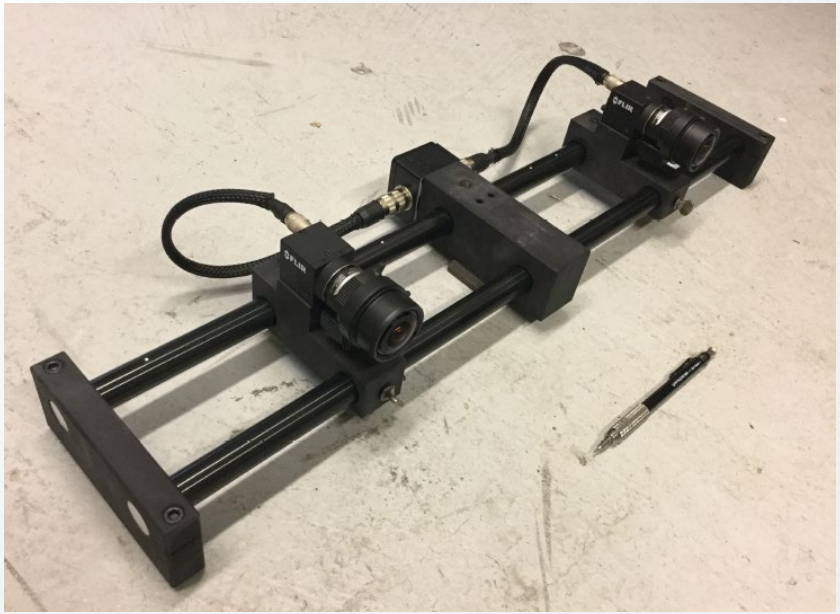
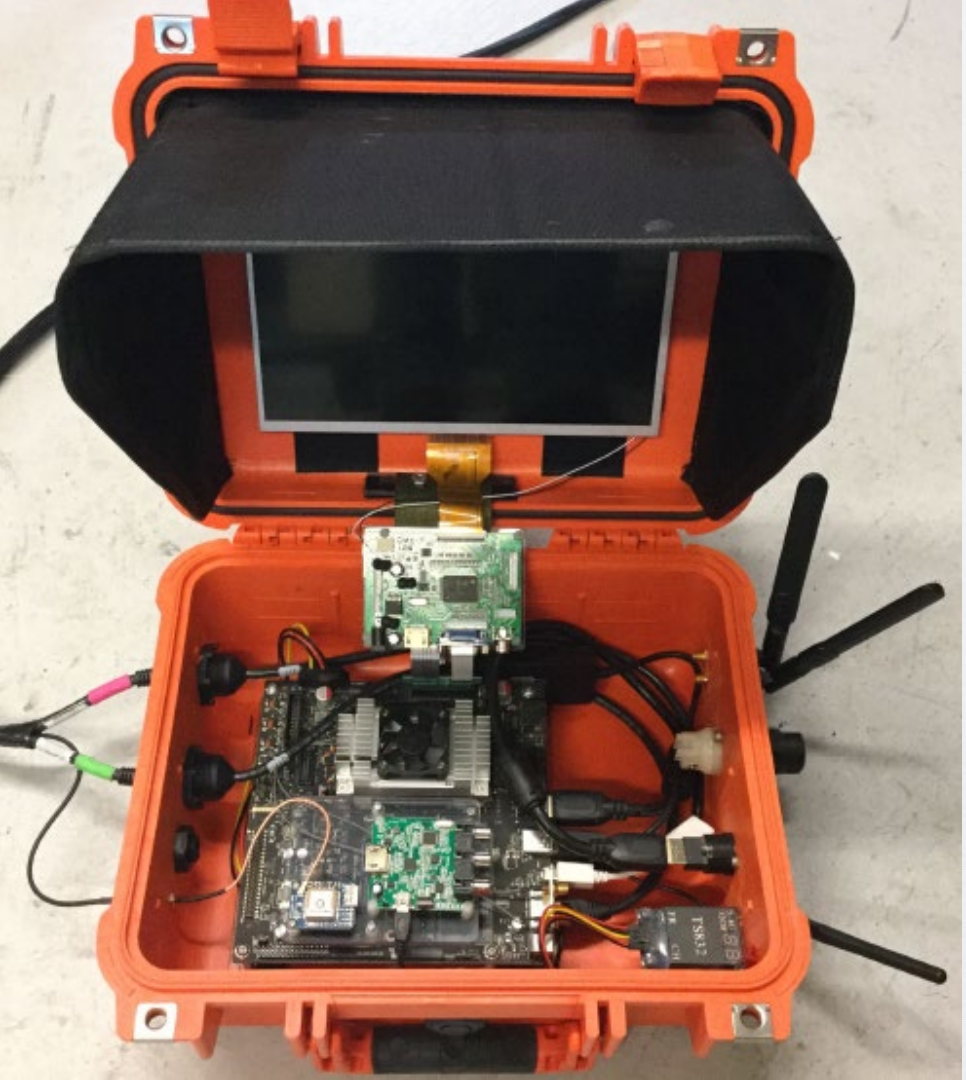
Camera Design

Technology Overview



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

Stereo Camera System



Computer Design

Technology Overview

NVIDIA Graphics Processing Unit

- GPS with external antenna mounted on camera
- 5 meter POE Gigabit Ethernet cables
- Transmits video to remote displays

Algorithms: Stereo Correspondence

Technology Overview

Left

Right

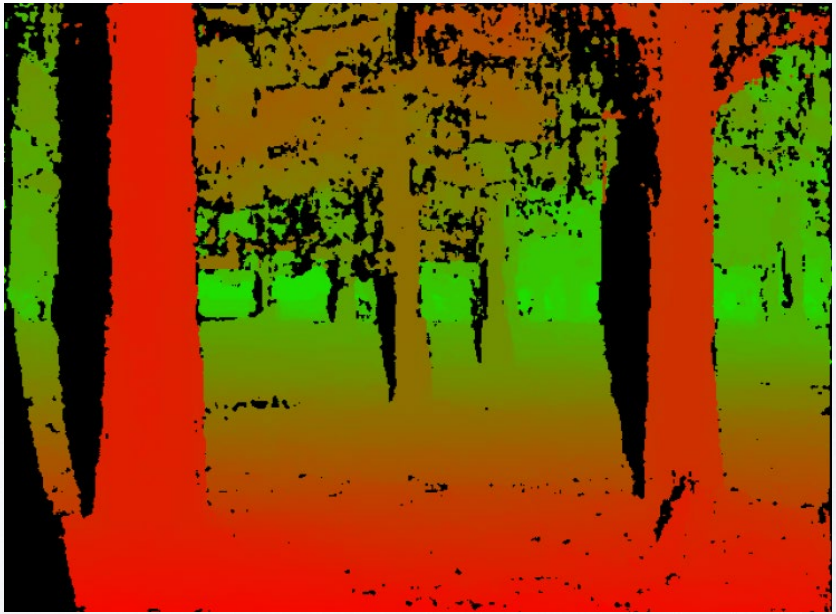
Algorithms: Stereo Correspondence

Technology Overview

Disparity

Algorithms: Stereo Correspondence

Technology Overview

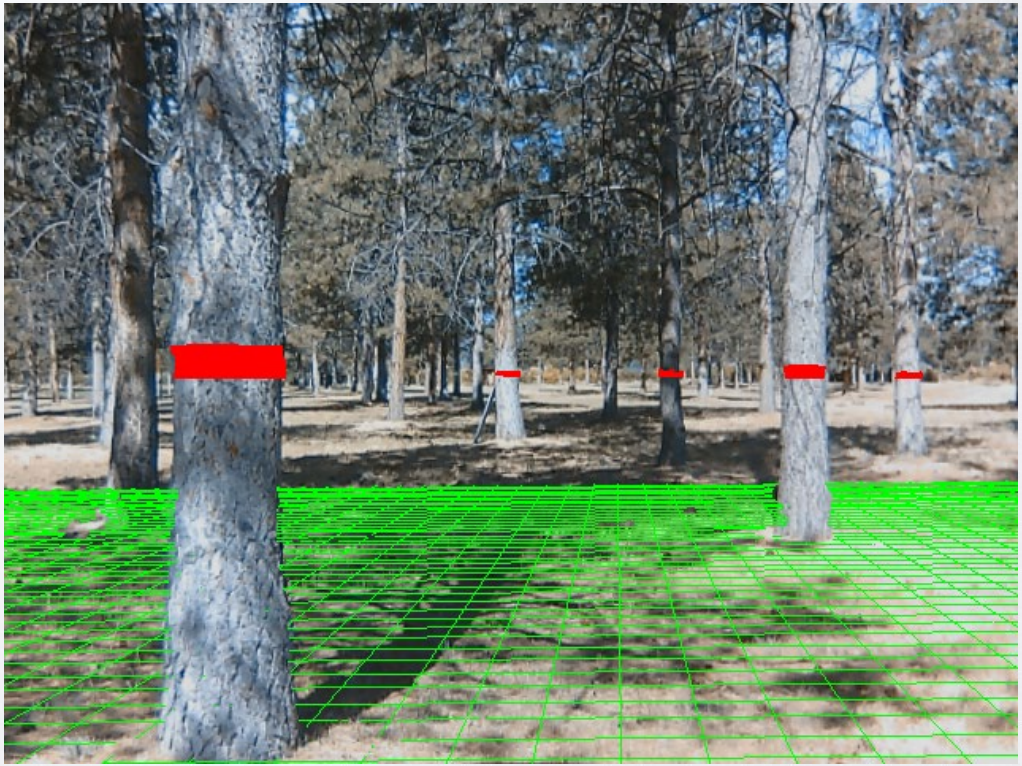


- Semi-global block matching
- Post processing
  - Right-left consistency check
  - Median filter

11 milliseconds on GPU

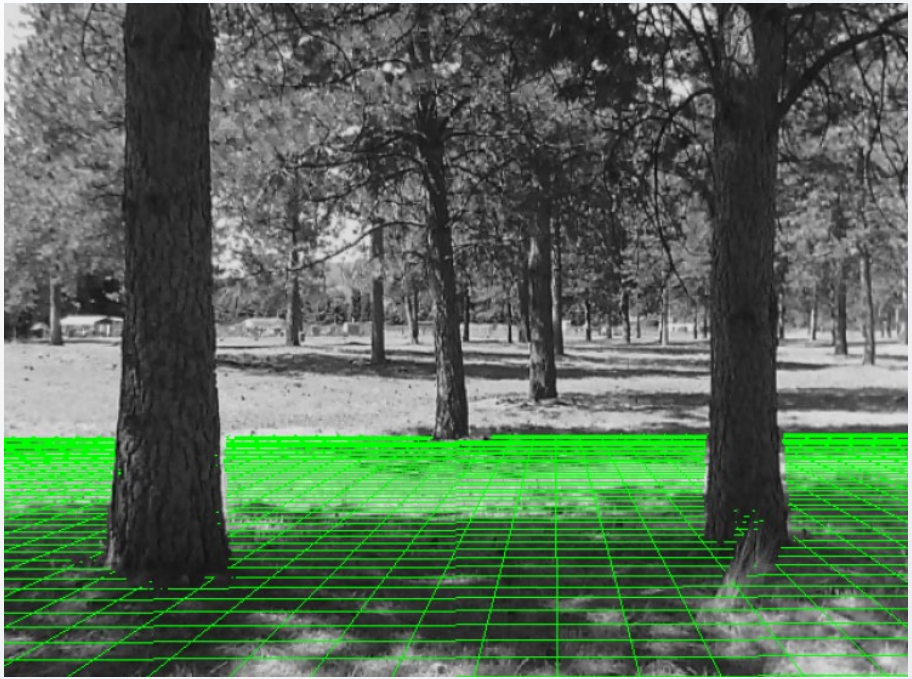
Algorithms: Ground Plane Detection

Technology Overview



Algorithms: Ground Plane Detection

Technology Overview

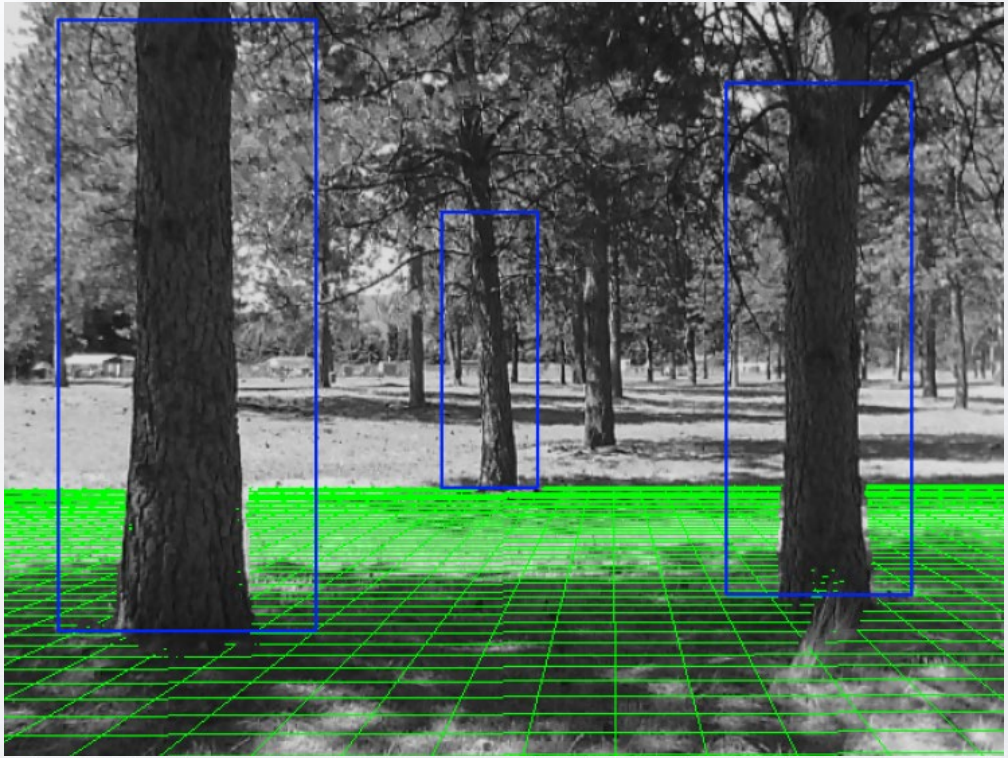


- Plane fitting (6 parameters)
- Random Sample Consensus (RANSAC)
- Unequal selection probabilities based on previously detected plane
- Motion constraints to filter unlikely plane hypotheses

20 milliseconds on GPU

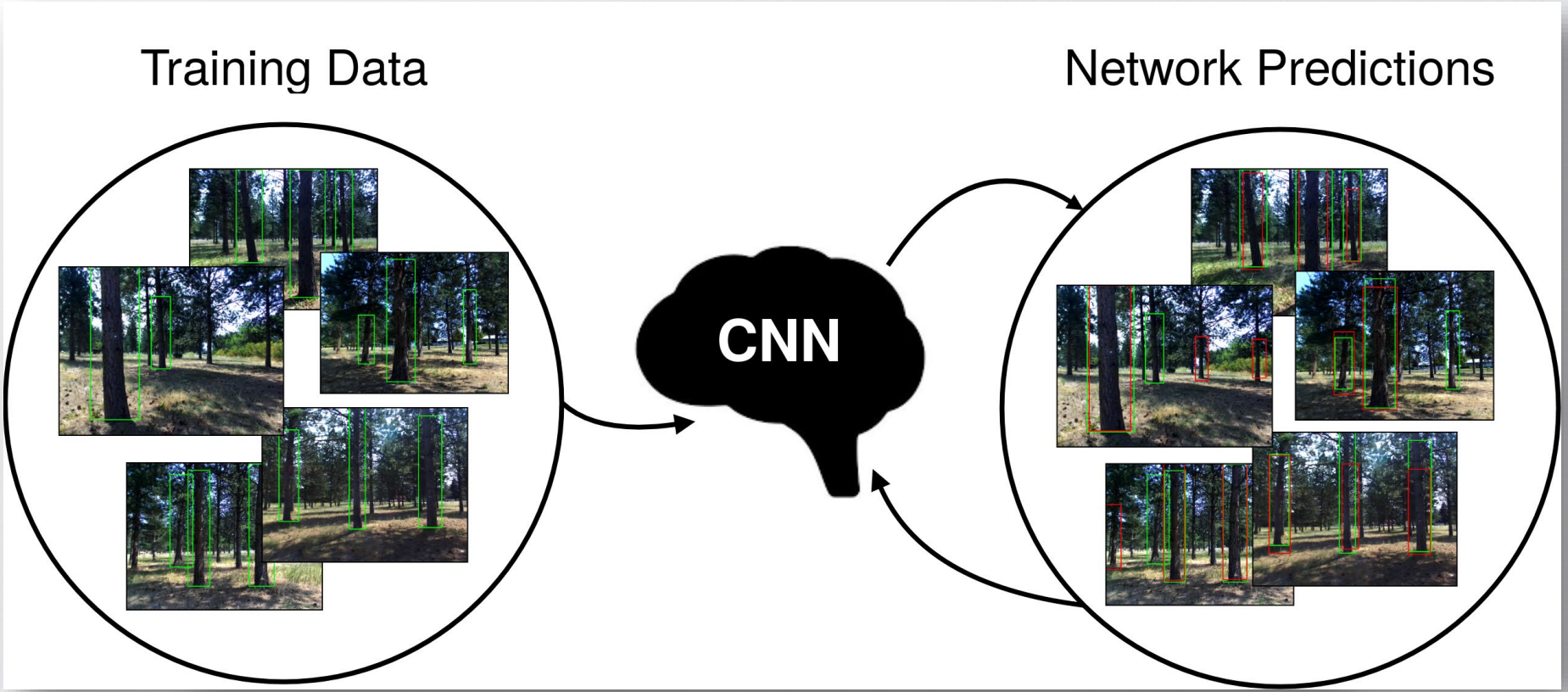
Algorithms: Stem Detection and Classification

Technology Overview



Algorithms: Stem Detection and Classification

Technology Overview



Algorithms: Stem Detection and Classification

Technology Overview

- AOI: From ground to canopy base height
- Convolutional neural network to define bounding boxes using a training data set (e.g., 300 images).
- Outputs: Center of bounding box, width, height, probability of being a tree stem.

10 milliseconds on GPU

Algorithms: Stem Detection and Classification

Technology Overview

- AOI: From ground to canopy base height
- Convolutional neural network to define bounding boxes using a training data set (e.g., 300 images).
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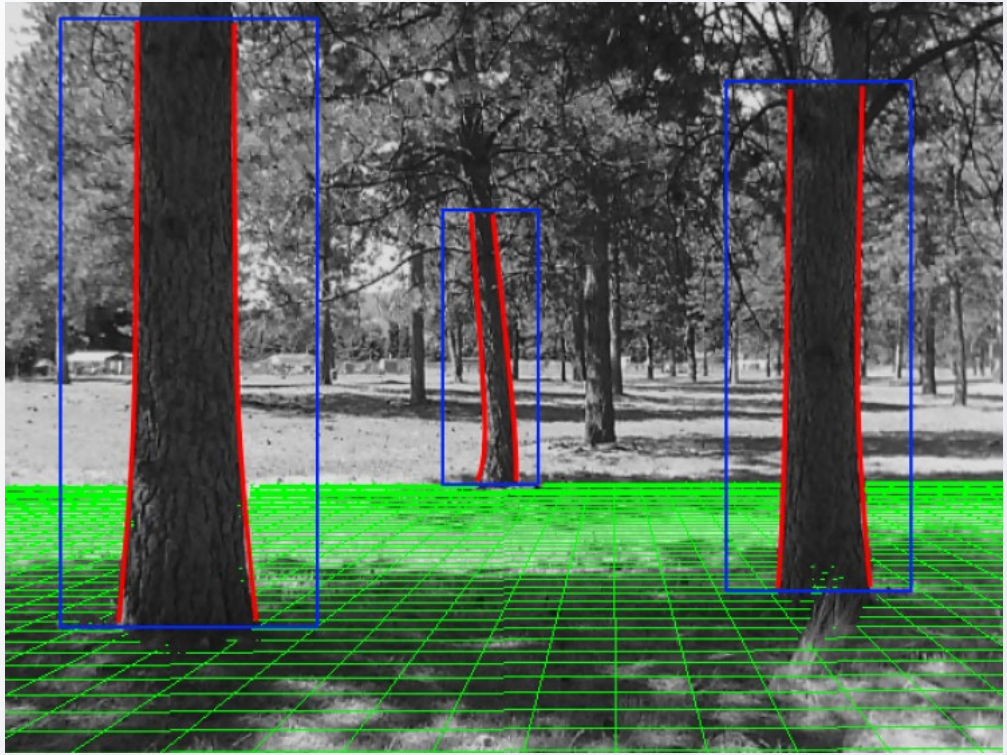
10 milliseconds on GPU

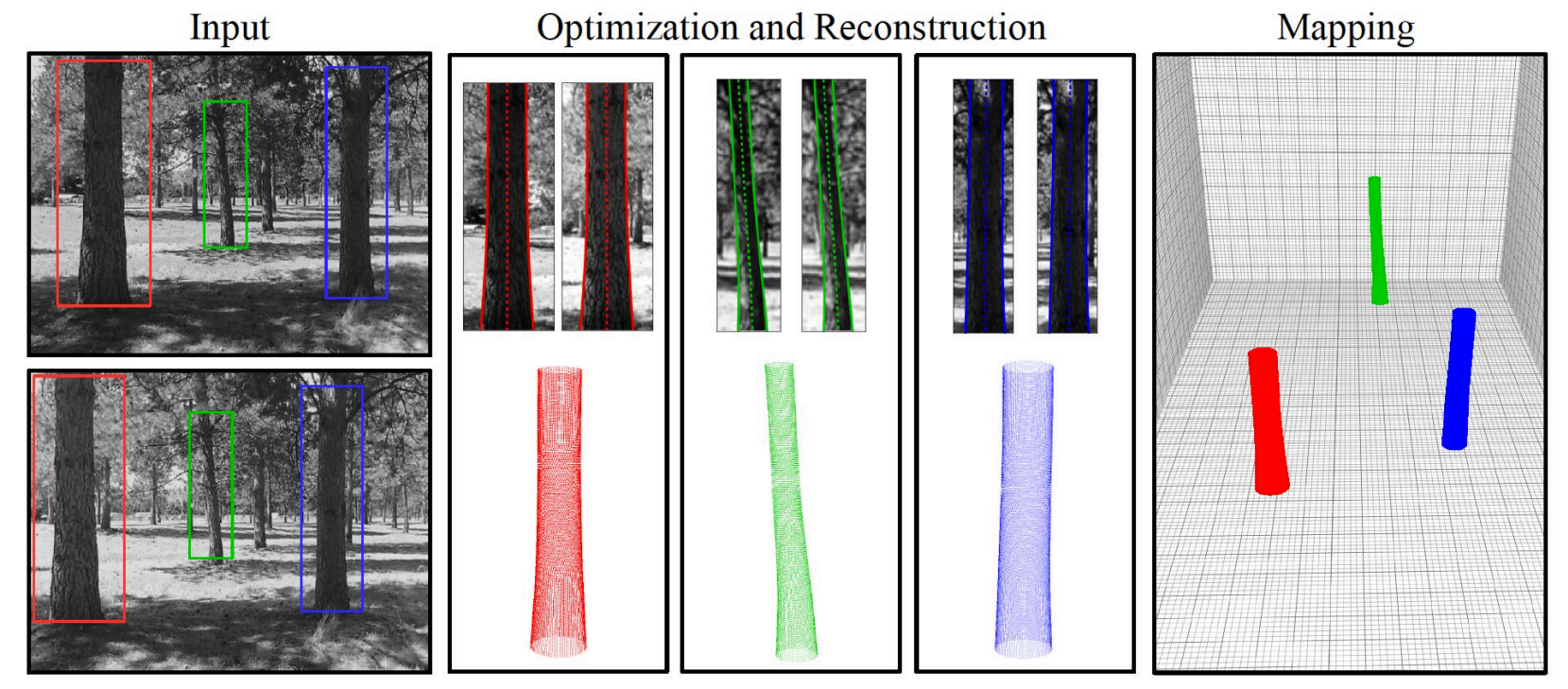
Algorithms: Stem Analysis (Diameter, Taper and Sweep)

Technology Overview



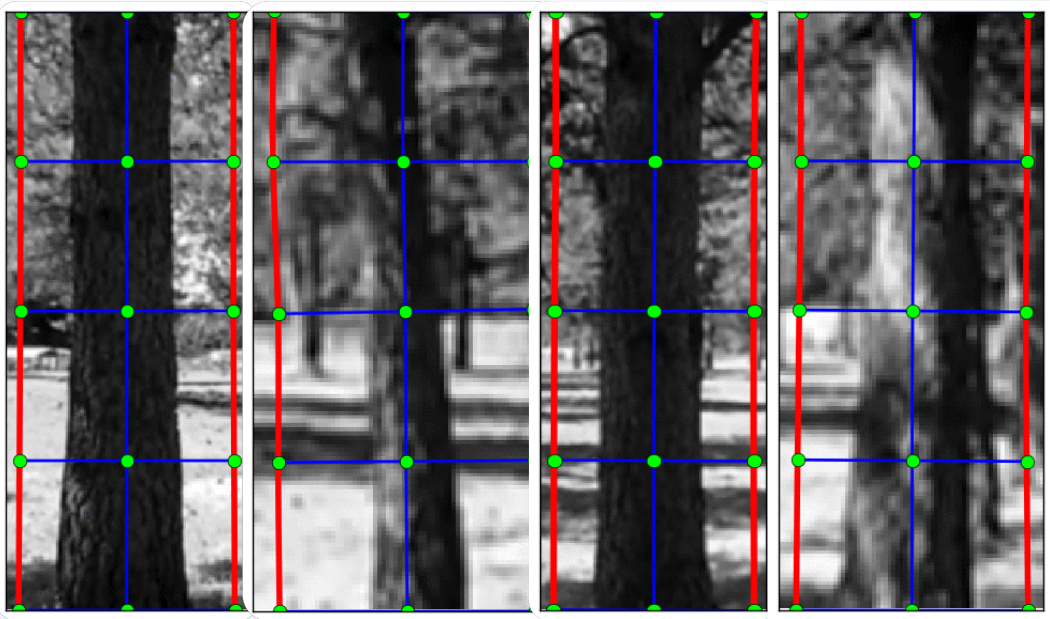
Algorithms: Stem Analysis (Diameter, Taper and Sweep)

Technology Overview



Algorithms: Stem Analysis (Diameter, Taper and Sweep)

Technology Overview



- Parametric stem model (7 parameters)
- Active contour model: energy minimization via gradient descent
- Energy field: Gradients in disparity and color image
- Guaranteed to converge

50 milliseconds on GPU

Algorithms: Stem Analysis (Diameter, Taper and Sweep)

Technology Overview

Validation

Technology Overview

RMSE for stems within 30 feet

- Diameter: 0.48 in (1.22 cm)
- Distance: 1.56 in (3.96 cm)
- Angle: 0.38°

Potential Applications

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Markless Prescriptions

Applications

Provide operator with necessary information to carry out markless prescriptions

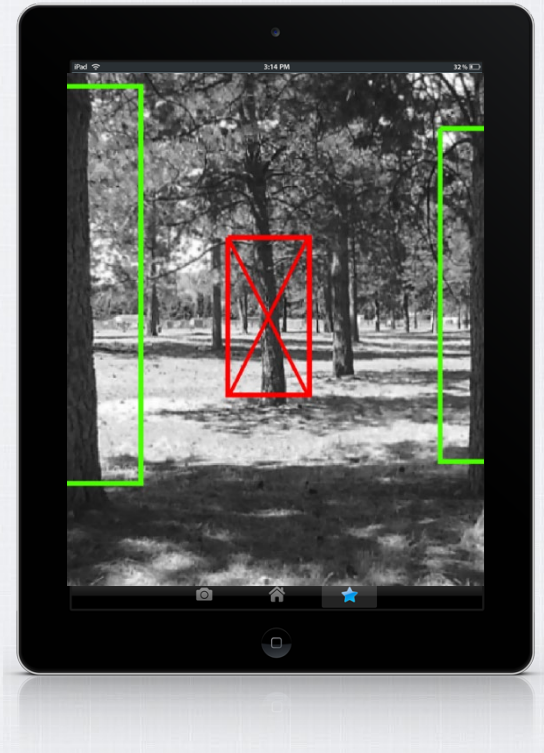
- Diameter
- Spacing thresholds

Provide the operator with cut/leave decisions based on prescription thresholds.

Markless Prescriptions

Applications

We can display the assignments to the operator



Cut-Leave Stem Maps

Applications

Localization and Mapping

Cut-Leave Stem Maps

Applications

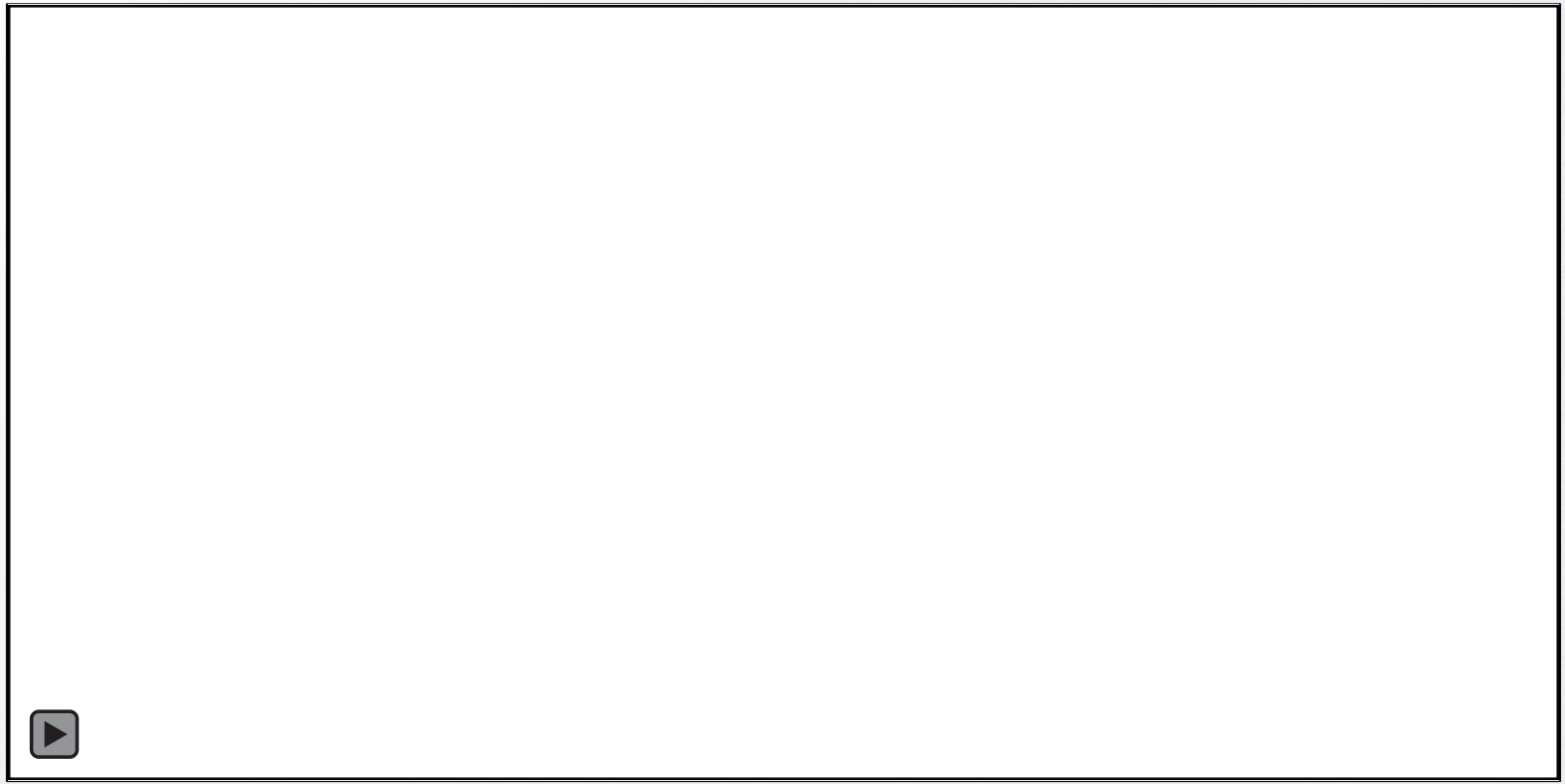
Localization and Mapping without GPS

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

Given a stem map with cut-leave assignments

Cut-Leave Stem Maps

Applications



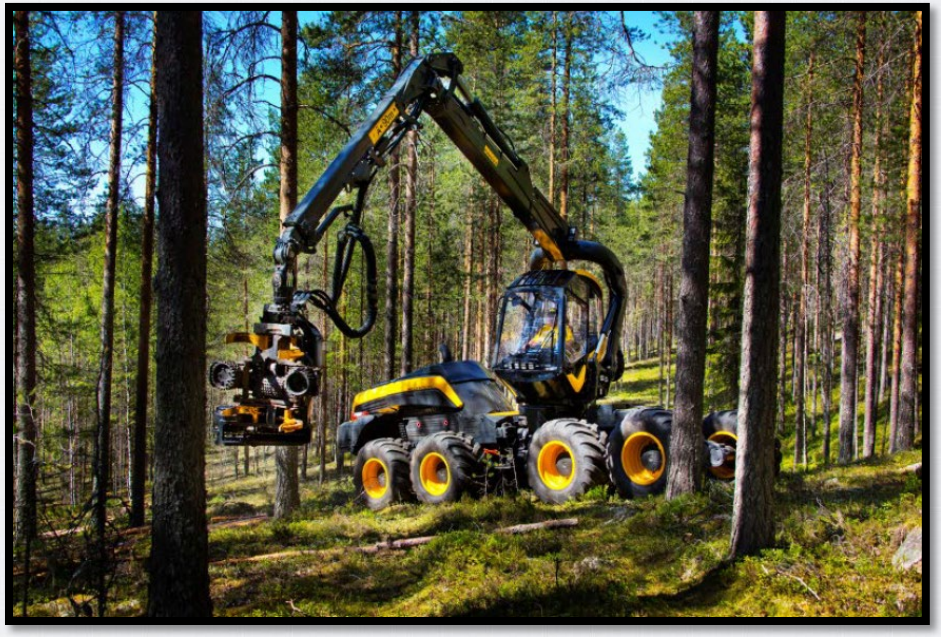
Autonomous Boom Control

Applications

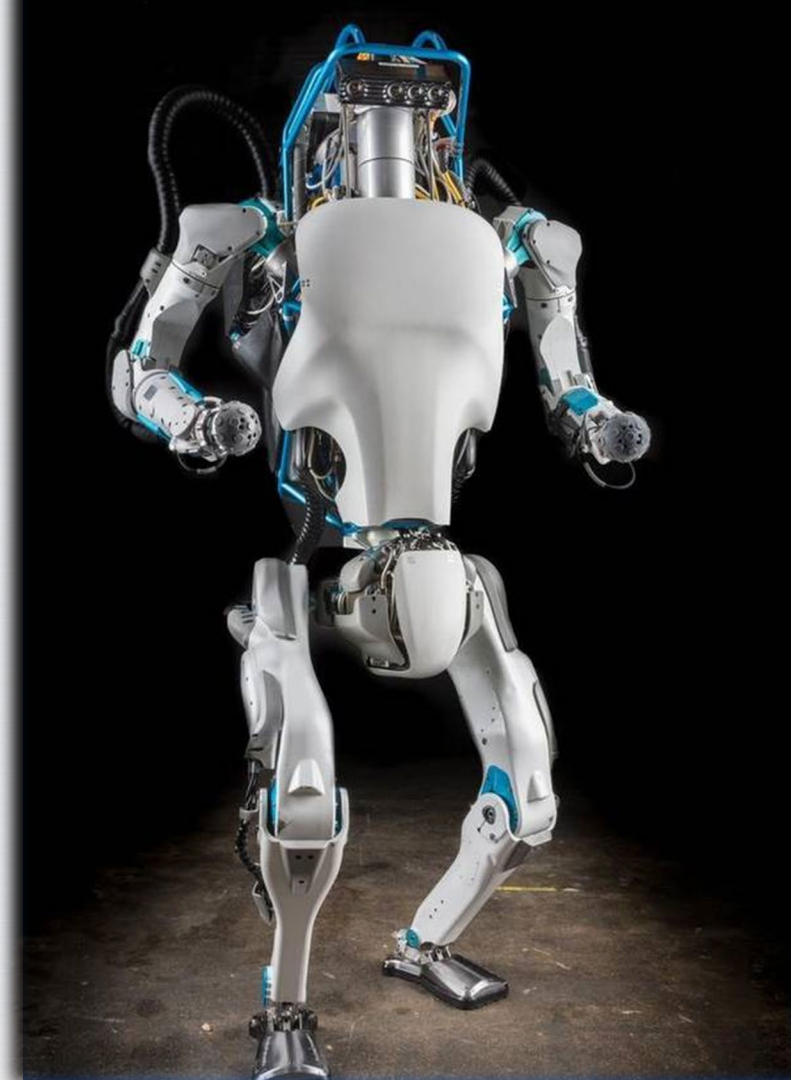
Camera provides the harvester boom end effector a goal position

Inverse kinematics for optimized joint angle adjustments to reach goal position

Adjacent detected trees can be used to determine felling direction



Concluding Remarks



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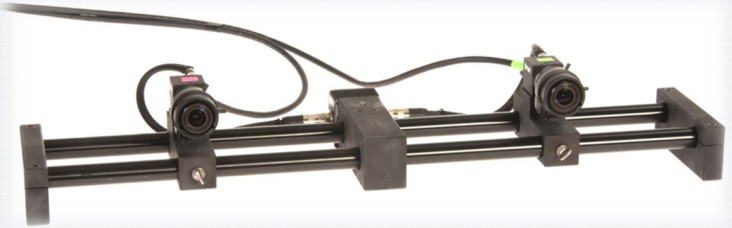
Contributions

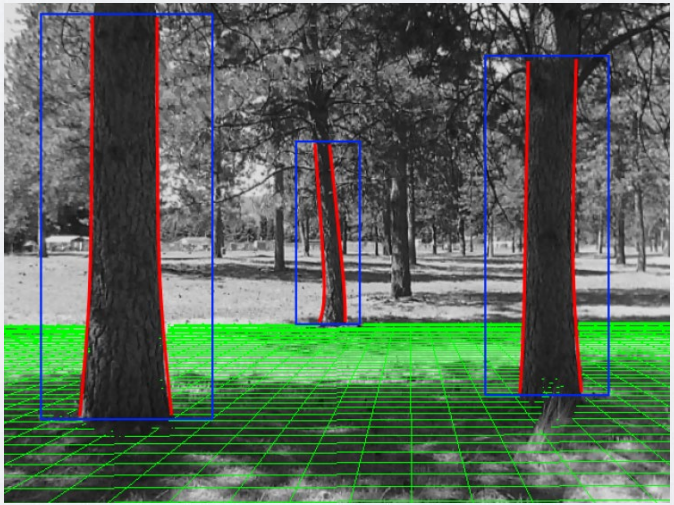
First attempt to develop a real-time vision-based system for tree detection and measurement!

New method for terrestrial forest mapping using readily available and inexpensive equipment

Currently working with an industry partner to continue testing and development



Limitations and Challenges



Ground detection

- Planar surface might fail to represent reality
- What about non-linear surfaces?

Tree detection

- Species classification!
- CNN architecture can be modified for multi-class detection

Adoption in mechanized harvesting

- Where to mount cameras?
- How to present information to operator?

Thank you

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Questions?

Computer Vision

- Computer vision seeks to auto
  visual processing tasks
  - Image sensors are
  - No moving part

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