From Loppers to Lasers, Labor-Saving Engineering Advances for Grapes and Apples Leaves it Pretty Open

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- Tony Koselka, Vision Robotics Corporation

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Introduction

- An important practice of the U.S. speciality crop production is “dormant pruning”
- However, it is one of the most costly and labor-intensive operations

Introduction

- For grapevines, accounts for 20% of direct vineyard production costs —the highest expense among direct cost
- For fruit trees, dormant pruning accounts for 20-22% of total labor costs —the second largest labor input after harvesting

Introduction

- The main reasons are due to its dependency on:
  - A large number of seasonal labor
  - Increasing labor cost
  - Uncertainty of the availability of labor

Why is the Automated Pruning?

- To mitigate the need for large, skilled workforce:
  - Develop innovative technologies for automating the pruning of grape and apple
  - Use modern sensors, computers and robotic manipulators.

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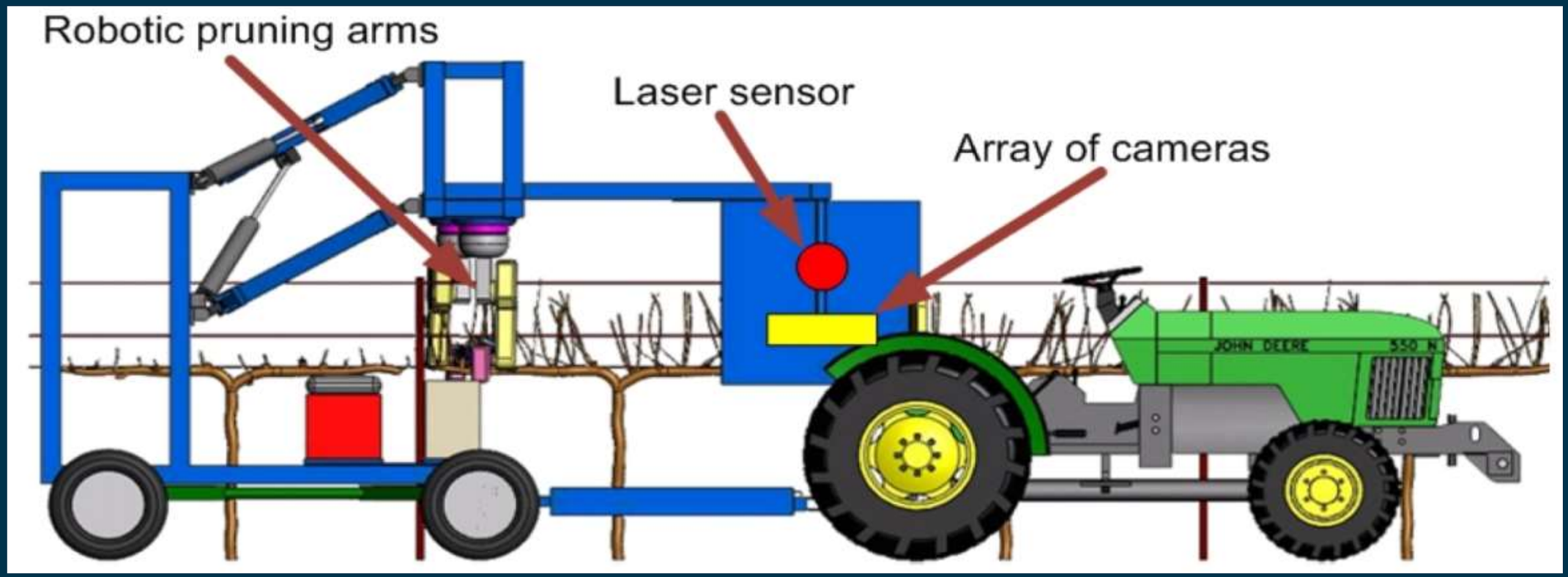
How Automated Pruning Will Affect the Farmers?

- This research will lead to a mechanical pruner that uses a 3D imaging and decision system for:
  - Data acquisition and 3D modeling of the trees (obtain estimated information such as the radius, angle, etc.)
  - An automatic pruning using the rules acquired from experts that describe the optimal pruning on the estimated data of the tree-model



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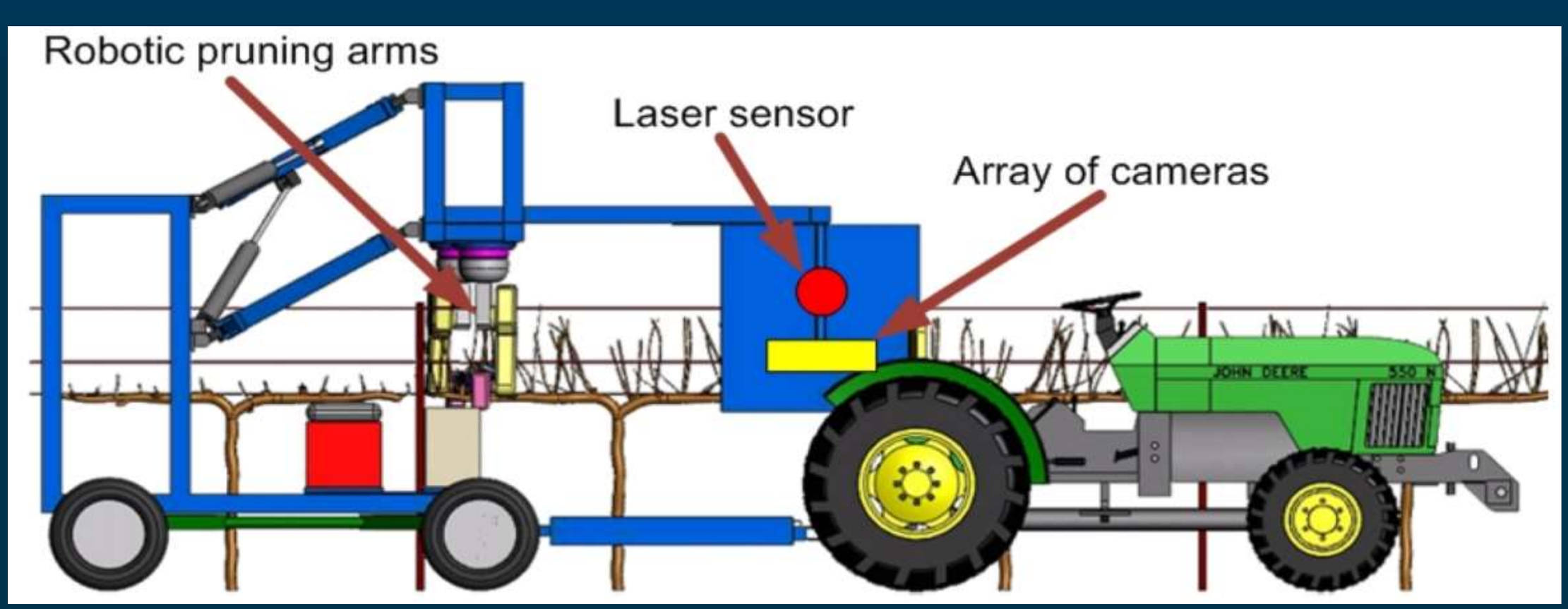
Towards Automated Pruning

- A 3D imaging and decision system requires:
  - Data acquisition
  - Reconstruction and modeling of the tree (estimate information: radius, angle, etc.)
  - Evaluate the model (compare estimated data with the ground-truth data)
  - Apply the pruning rules –from experts -- that describe optimal pruning rules



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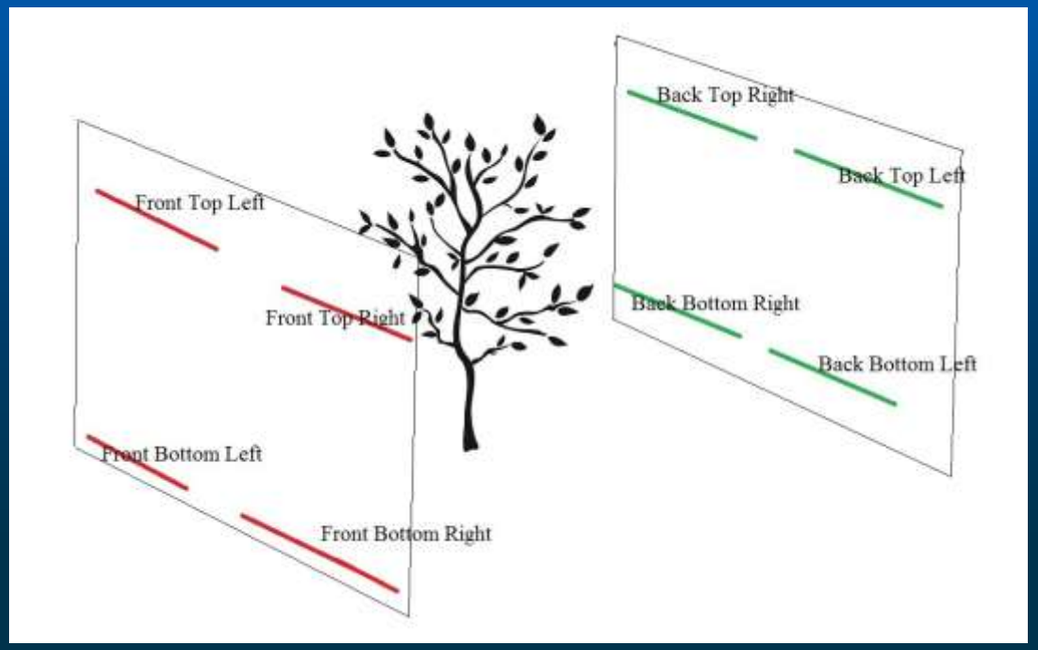
Automated Pruning I: Data Acquisition

Method 1:
LASER SCANNER



Method 2:
Microsoft Kinect 2

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Comparison Between Kinect and LIDAR

- Advantages of Kinect over LIDAR:
  - Light-weight
  - Inexpensive ($200)
  - Accurate, high resolution output in both outdoor and indoor environments

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How to use Kinect for Data Acquisition?

Original Tree

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Automated Pruning II: 3D Reconstruction

Indoor Environment

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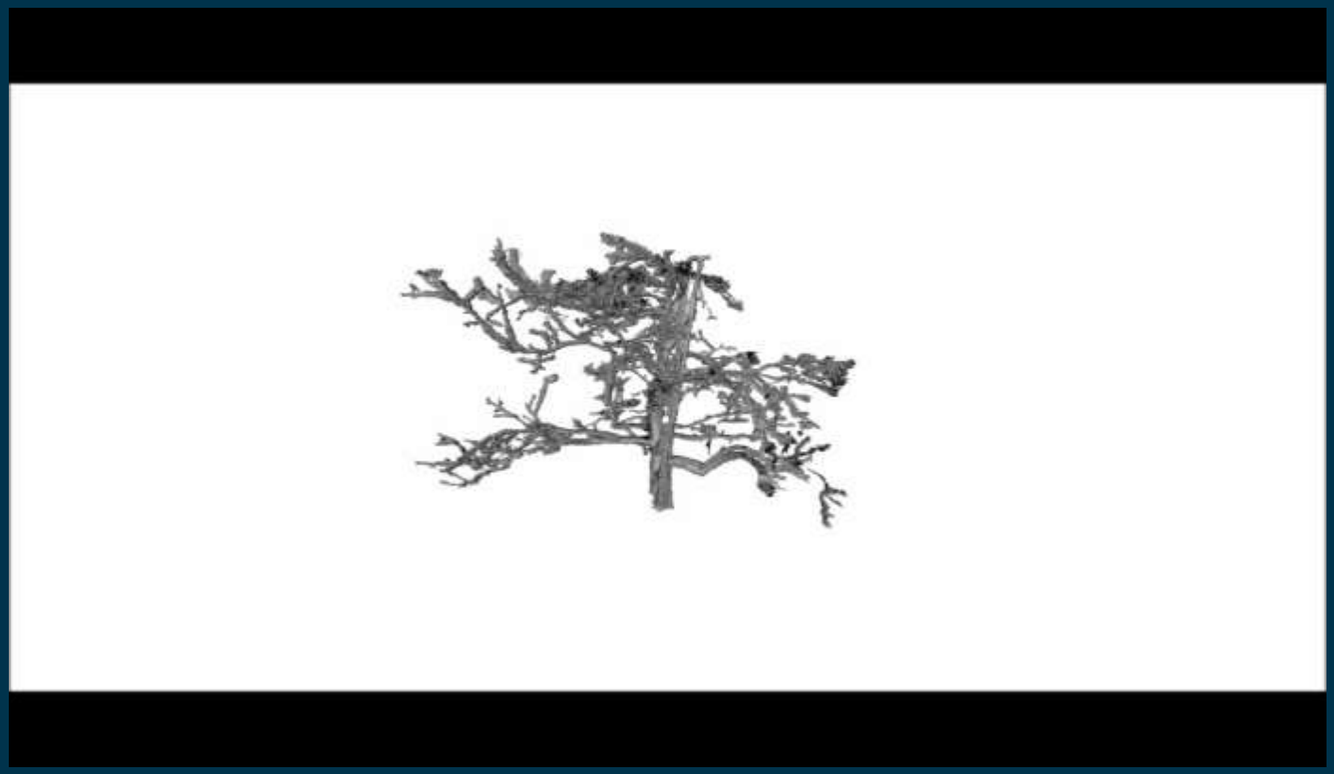
Automated Pruning II: 3D Reconstruction

Outdoor environment: Meig Orchard



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Automated Pruning II: 3D Modeling

Original tree

Red indicates detected trunk

Colors indicate detected branches

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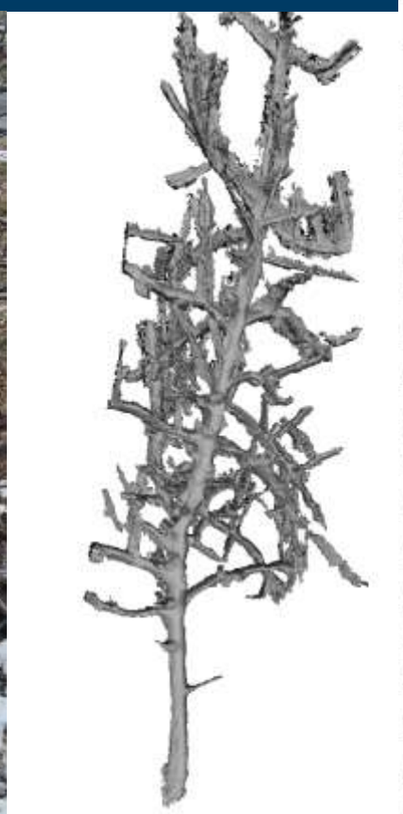
Automated Pruning III: Evaluate the Model

- **Where we currently stand:**
  - We collect real data from orchards (Meig, Penn-state university, Paramount).
  - We obtain pruning rules from experts
  - We obtain the ground-truth data from experts
  - We setup a Ground-truth annotation for verification



Ground Truth

Tree	Pruning Severity	Branch	Diam
A9.01.050	1.25	30	4.4
A5.04.09	1.25	1	9
A5.04.09	1.25	2	9.8
A5.04.09	1.25	3	6.8
A5.04.09	1.25	4	16.2
A5.04.09	1.25	5	4.6
A5.04.09	1.25	6	8.1
A5.04.09	1.25	7	8
A5.04.09	1.25	8	13.9
A5.04.09	1.25	9	3.3
A5.04.09	1.25	10	9.2
A5.04.09	1.25	11	17.3
A5.03.51	0.75	1	4.4
A5.03.51	0.75	2	4.1
A5.03.51	0.75	3	7.1
A5.03.51	0.75	4	12.4
A5.03.51	0.75	5	6.6
A5.03.51	0.75	6	11
A5.03.51	0.75	7	7.4
A5.03.51	0.75	8	8.1
A5.03.51	0.75	9	5.5
A5.03.51	0.75	10	8.7
A5.03.51	0.75	11	5.6

Color Coding: Red-White-Blue-Green-Yellow

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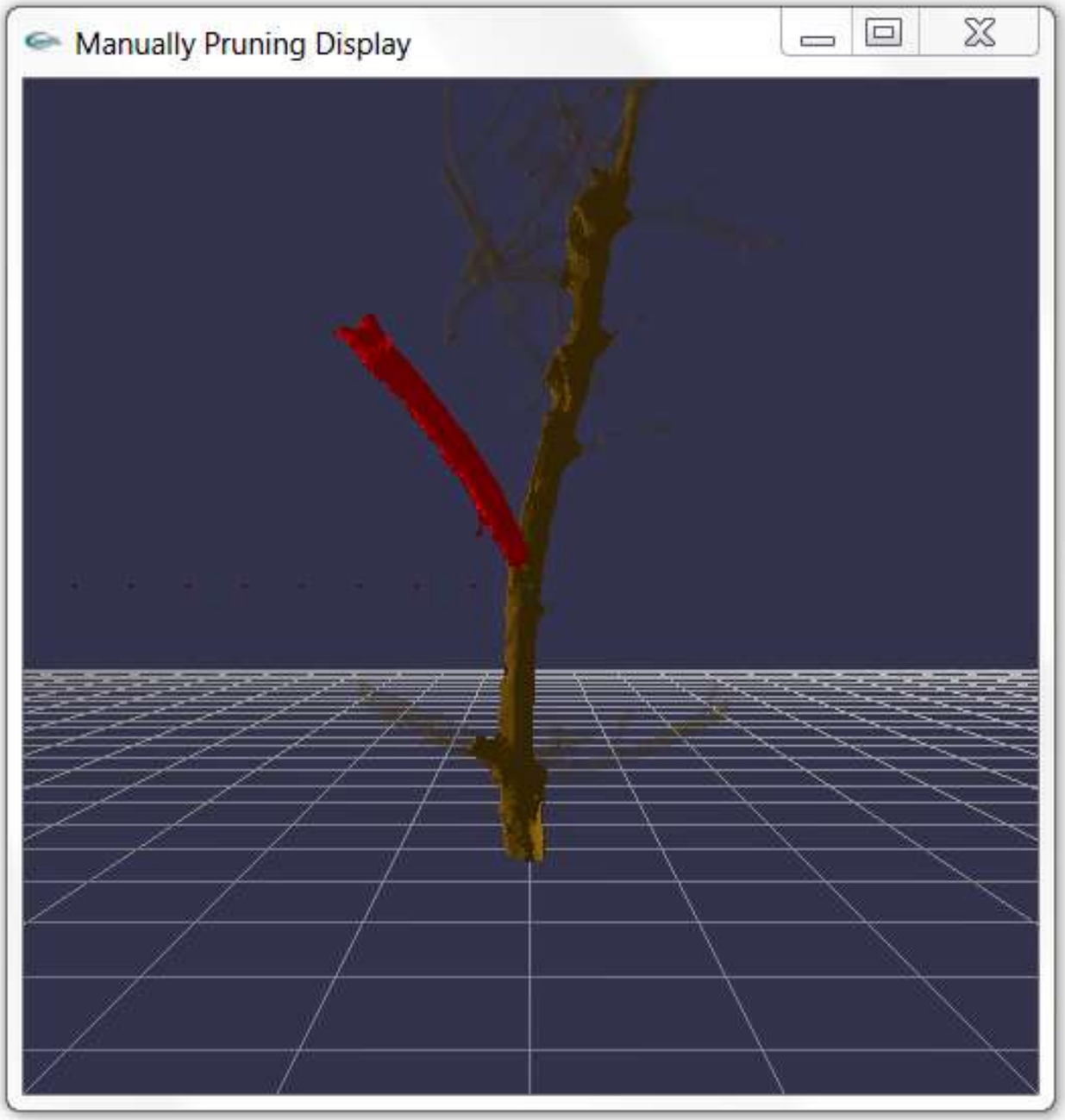
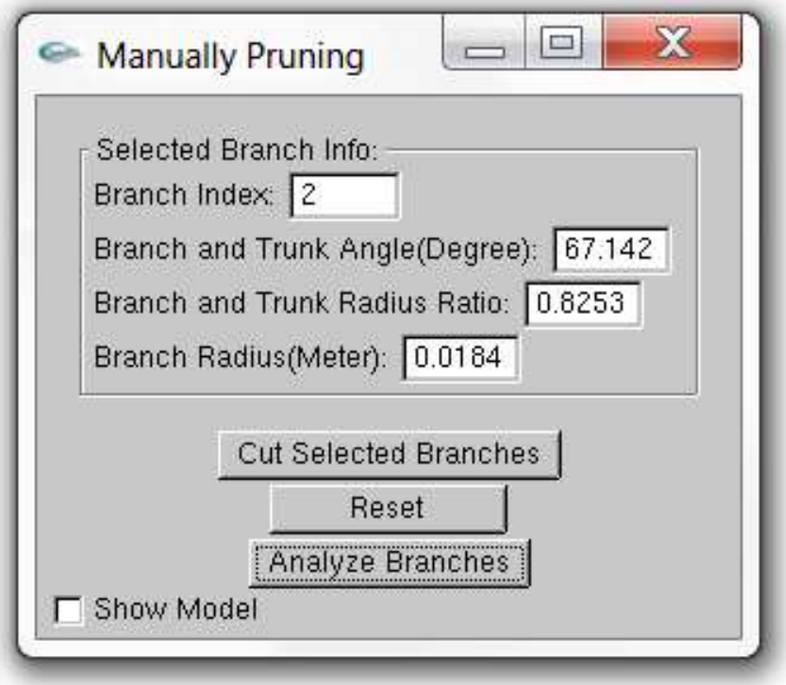
Automated Pruning III: Visualize the Model

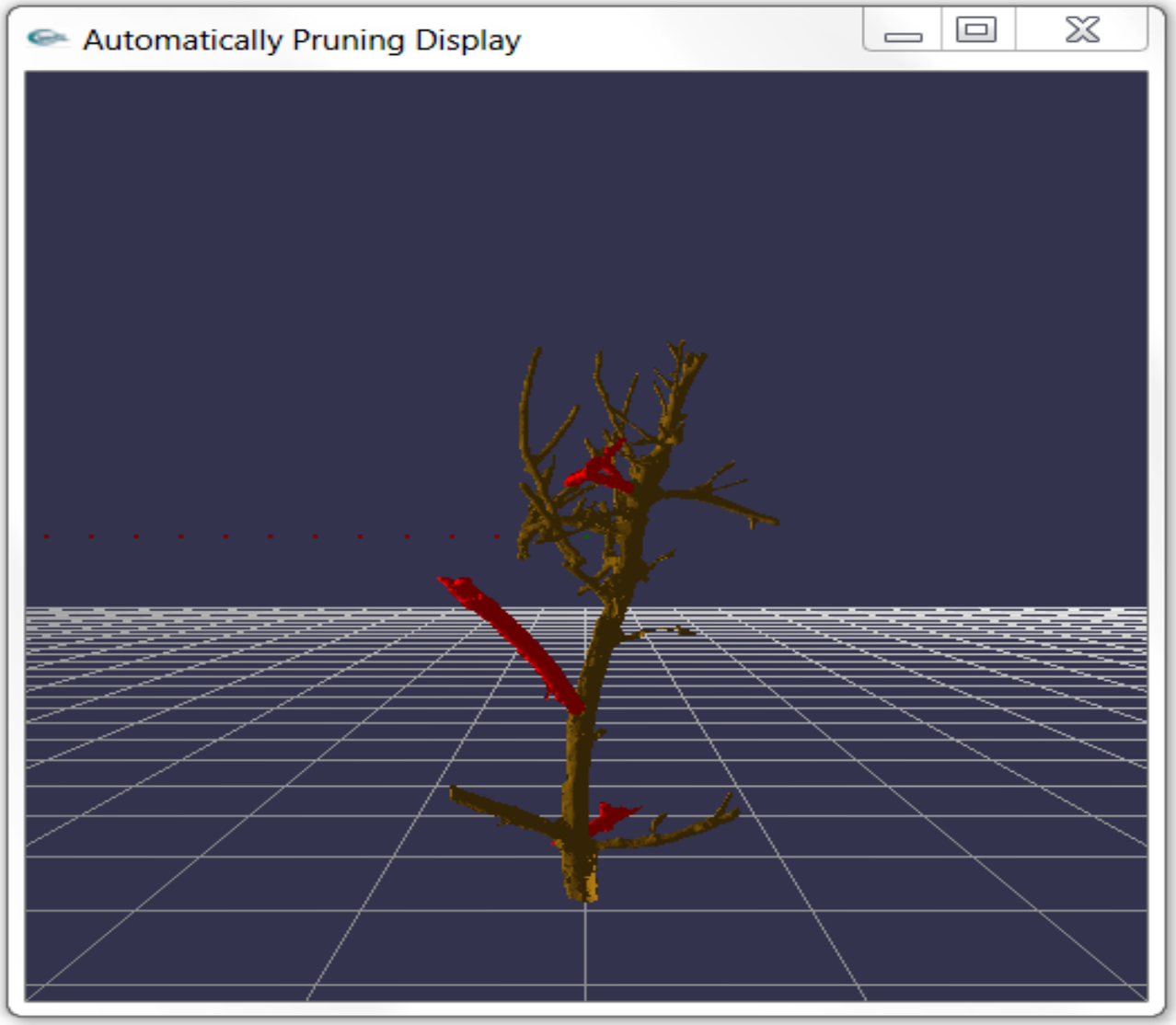
- We build a visualization tool to demonstrate the 3D model before and after pruning based on:
  -
  -

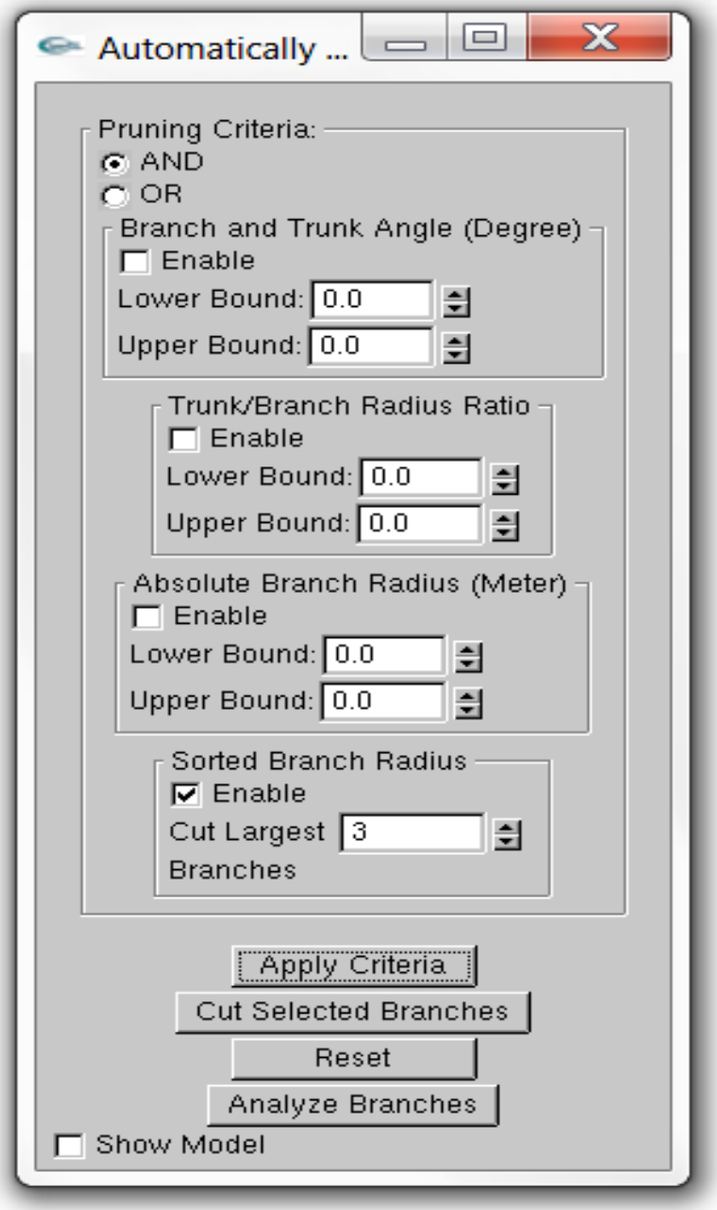




Automated Pruning III: Visualize the Model

Automatic Pruning (Rule-based pruning): selection of the largest 3 branches





How the Automated Pruning Will Affect the Farmers?

- This project will result in:
  - Reduced labor requirements for pruning
  - More precise management of tree architecture

- The proposed robotic pruner will enhance fruit production through improvements in:
  - Production economy (reduce cost)
  - Quality (assist farmers, use pruning rules by experts, save time)
  - Dependability (help when lack of labor)
  - Consistency

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Acknowledgment

- Penn State University
- Paramount Commercial Orchard
- Horticulture Department at Purdue

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Vision Robotics Corporation

Tony Koselka
San Diego, California

Our Systems Understand The Real World

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This Is An Exciting Time For Mechanization

- The components are ready
  - Powerful computers
  - Low cost vision and other sensors
  - Small powerful electric motors
  - Better batteries
- Similar robots and mechanisms in other industries
- A body of work being developed for specialty crops

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Some Tasks Are Easier To Mechanize

- Labor intensive
- Processed fruits and vegetables
- Indiscriminate
- No contact with delicate fruit
- Repetitive
- Long season
- Row crops meet most of this criteria and are largely automated

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Crop Load Estimates for Tree Fruit

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Robots Must Be Fast, Efficient And Thorough

- Robots are expensive
  - Computers
  - Arms
  - Sensors
- Vision Robotics' systems model the plant and work holistically
  - Understanding the plant enables high quality, cost effective operation

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Vineyard Operations Are Being Mechanized

- Harvesters, hedge pruners, shoot thinning, leaf blowing
- Indiscriminate systems
- Quality not equal to hand labor



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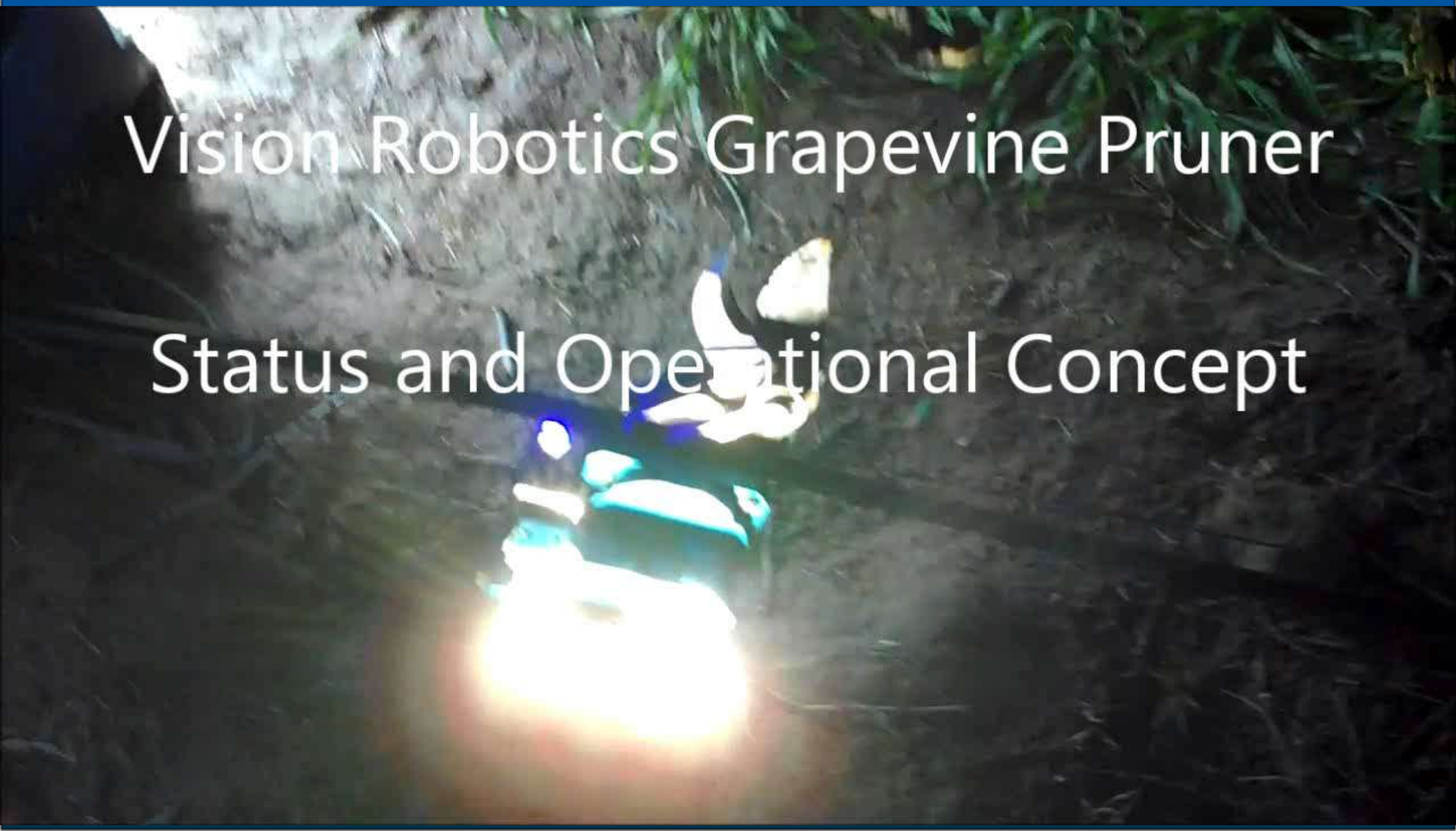
Vision Robotics' Autonomous Grapevine Pruner –High Quality Mechanization



Many Parts Of The Plants Can Be Identified And Modeled

- Crop load
  - Quantity
  - Size
- Plant structure
  - Trunk
  - Cordon
  - Spurs
  - Canes
  - Buds
  - Trellis structure

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The Models Are Detailed And Accurate

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Performance Comparable With Hand Labor

- Bilateral, cordon configurations
  - Spurs ups to 10” long
  - Pre-pruned
- Each pruner
  - $100,000 - $150,000
  - 200 acres per year
  - 1 operator for 4 or 5 systems
  - Multiple sets of pruning rules
  - $200 - $250 per acre to prune

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Vision Robotics' Intelligent Grapevine Pruner Can Be Complete In 18–24 Months

- Schedule based on financing

Questions

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