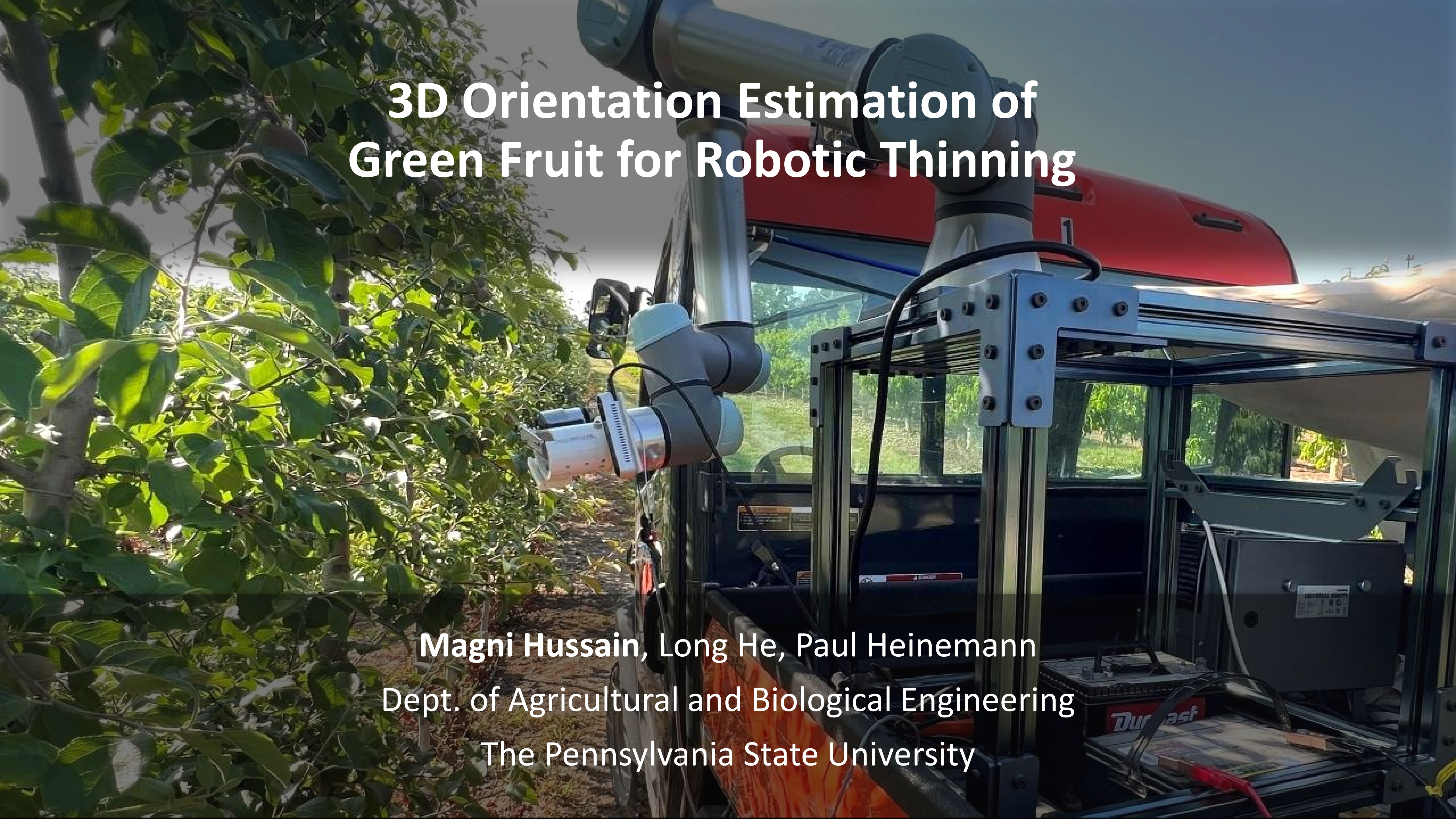

3D Orientation Estimation of Green Fruit for Robotic Thinning

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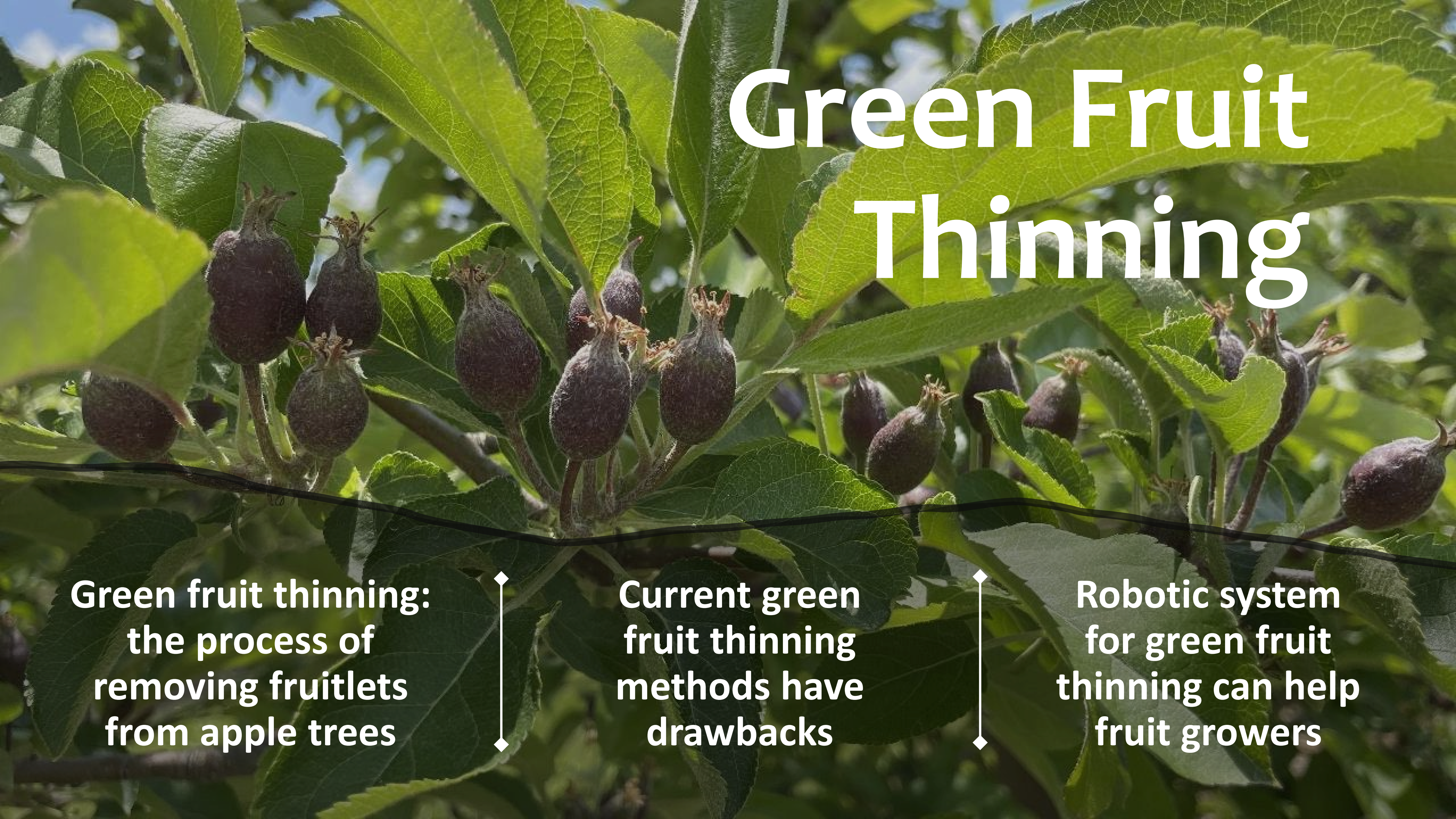
Apple Industry

$3.05 billion in utilized production in US

Several tasks for apple production:

- Harvesting
- Pruning
- Thinning


Green Fruit Thinning
Green fruit thinning: the process of removing fruitlets from apple trees
Current green fruit thinning methods have drawbacks
Robotic system for green fruit thinning can help fruit growers

Robotic Green Fruit Thinning System

Project Goal: to develop a robotic green fruit thinning system for apple production

FRUIT REMOVAL END-EFFECTOR

THINNING VISION SYSTEM

PATH PLANNING & SEQUENCING

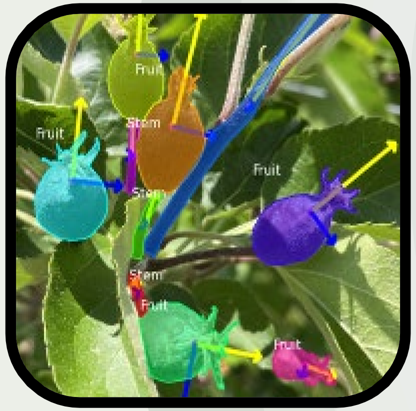
SYSTEM INTEGRATION

PHASE 1 (Fruit Removal End-Effector, Thinning Vision System, Path Planning & Sequencing)

PHASE 2 (System Integration)

Green Fruit Thinning Vision System

Purpose: to detect target green fruit and generate target end-effector positions



Segmentation & Orientation Estimation

Fruit and Stem Pairing

Fruit Clustering

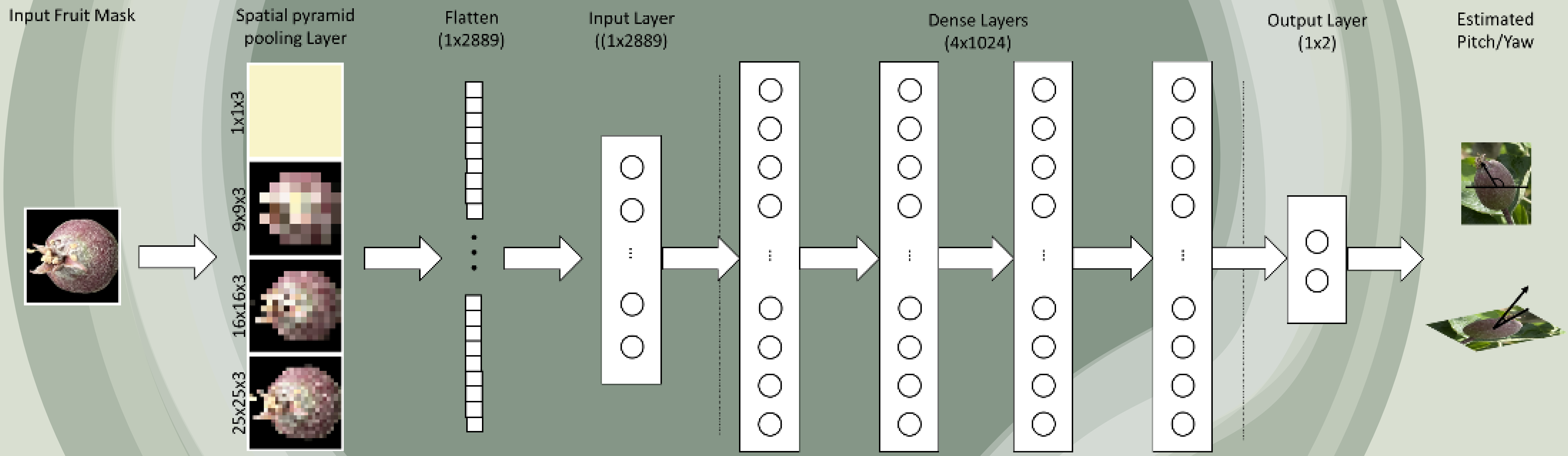
Thinning Decision-Making

Target End-Effector Position Generation

3D Green Fruit Orientation Estimation

Goal: to estimate yaw and pitch of green fruit from 2D masks for proper orientation of end-effector

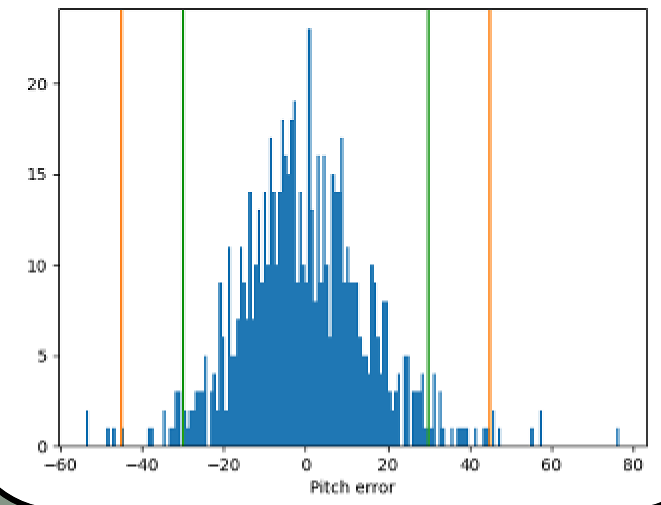
METHOD:
DNN-based using spatial pyramid pooling

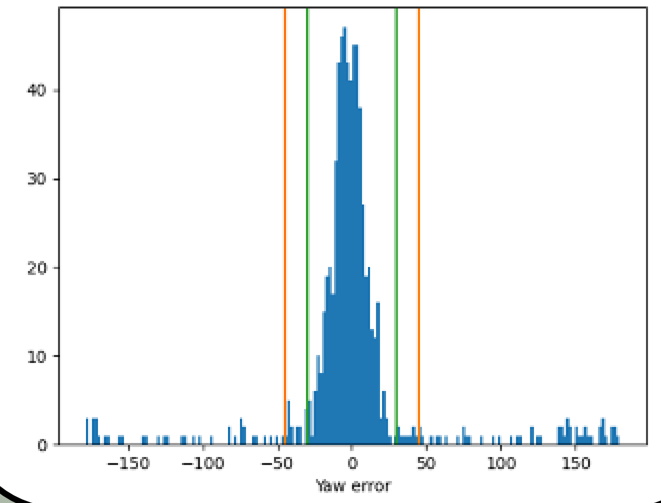


DATASET:
524 images of GoldRush, Fuji, and Golden Delicious
Train/Val/Test Split: 70/15/15

3D Orientation Estimation Results

	PITCH	YAW
% ERRORS WITHIN 30 DEGREES	93.4	84.2
% ERRORS WITHIN 45 DEGREES	98.4	87.6
% ERRORS GREATER THAN 90 DEGREES	N/A	8.7





- Differences between pitch and yaw performance likely due to tighter relative yaw constraints
- Majority of estimates accurate enough for proper encapsulation by end-effector

Conclusions & Future Work

3D orientation estimation achieved the following results:

- Yaw – 84.2%
- Pitch – 93.4%

Improvements to neural network structure could improve performance

Future work:

- Evaluate 3D segmentation performance
- Use 3D data for clustering and thinning decision-making

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Ag Robotics & Sensing Lab

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