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EIMA International 2021 — A GREAT EIMA, AS USUAL — The Digital Preview (EDP) 11/15 novembre 2020 — The Event 3/7 febbraio 2021

Study of Canopy-Machine Interaction in Mass Mechanical Harvest of Fresh Market Apples

Dissertation presented to Washington State University, Pullman, WA, USA

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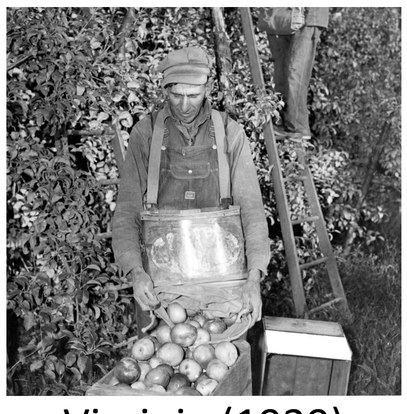
WASHINGTON STATE UNIVERSITY

1 Research Motivation

Apple Crop in Washington State:

- ❑ No.1 agricultural product
- ❑ >63% of the US annual production
- ❑ ~3.4 billion kg production in 2019
- ❑ Harvested manually worldwide



Virginia (1939)

Washington (2019)

https://www.nal.usda.gov/exhibits/speccoll/exhibits/show/2016-calendar/item/8760

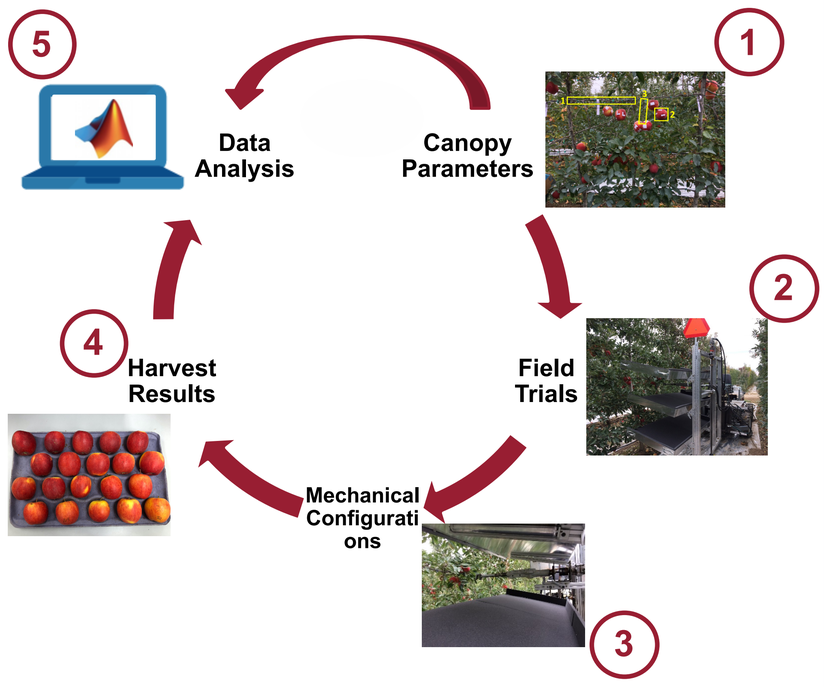
Significant Challenges:

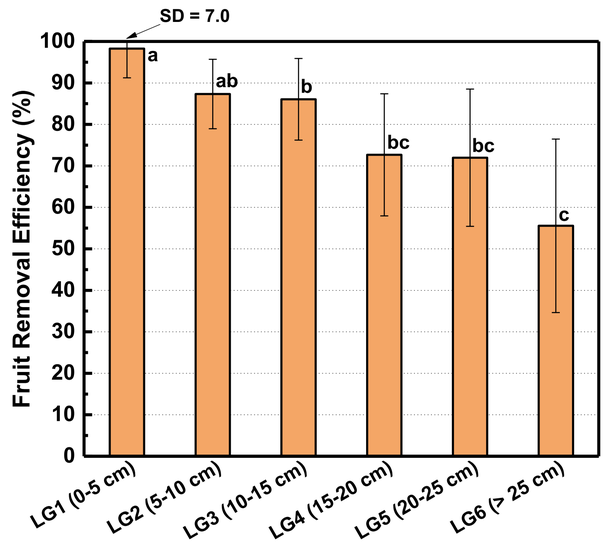
- ❑ Uncertain labor availability
- ❑ Rapidly increasing costs

2 Key Canopy Parameters and Pruning Strategies for Improving Efficiency

Obj #1: To identify the most relevant canopy parameters affecting the harvest efficiency

- ❑ Supervised machine learning algorithm weighted *k*-Nearest Neighbors
- ❑ Principal components analysis
- ❑ Key parameters: fruit load/density, branch basal/end diameter, and shoot length/diameter

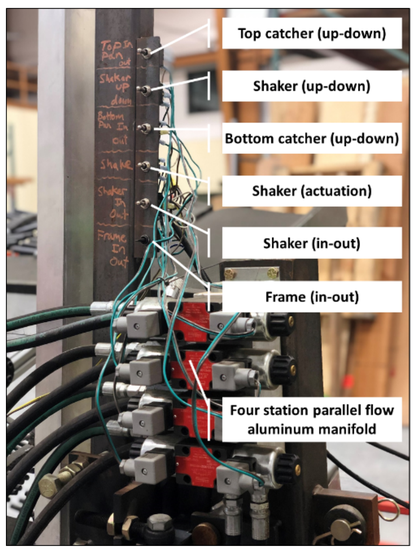




Obj #2: To study the influence of a precision canopy management on the harvest efficiency

- ❑ With increased shoot length, fruit removal efficiency (FRE) dropped from 98% to 56%
- ❑ FRE ≥85%, when shoot length ≤15 cm, or shoot index (shoot index = shoot diameter/length) ≥0.03
- ❑ No noticeable pattern for fruit quality

3 Field Evaluation of Harvesting Technologies



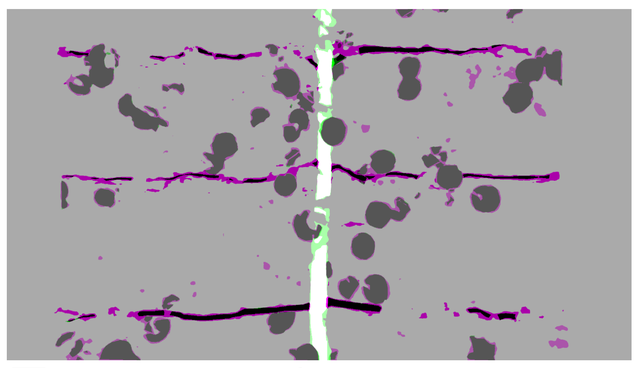
Obj #3: To perform a comprehensive evaluation of different harvest systems

- ❑ 3 vibratory shaking methods: continuous non-linear/linear, and intermittent linear
- ❑ 3 shake-and-catch harvesting system: hand-held (84% of FRE), hydraulic (87%), and semi-automated (90%)

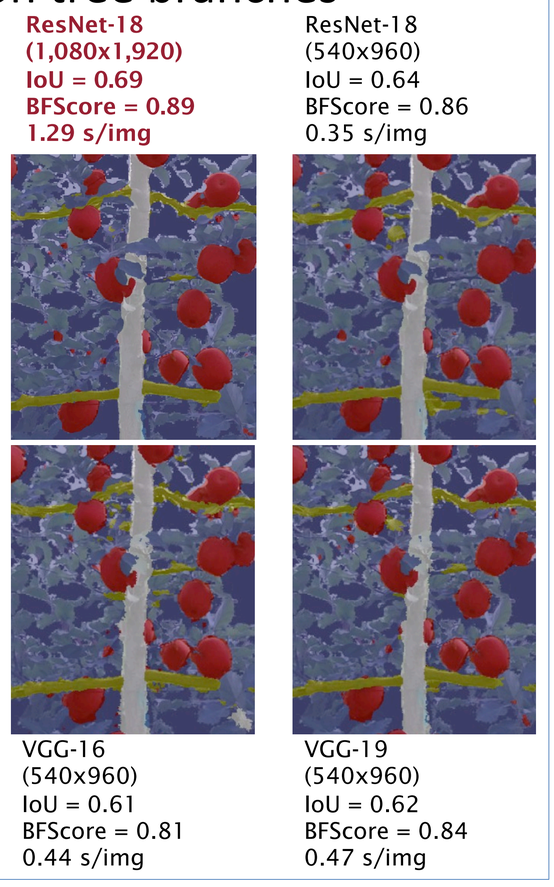
4 Computer Vision for Mechanical Harvesting

Obj #4: To develop a machine vision system for identifying shaking locations on tree branches

- ❑ Kinect V2
- ❑ 785 RGB-D images



- ❑ Tree trunk/branch identification
- ❑ Semantic segmentation
- ❑ Convolutional neural networks: Deeplab v3+ ResNet-18, VGG-16/19



5 Final Remarks

This research aimed at creating a benchmarked knowledgebase for maximizing the efficiency of a vibratory shake-and-catch harvesting system for the mass harvest of fresh market apples. It was focused on gaining an understanding on canopy-machine interactions for supporting:

- ❑ The creation of machine-operation-friendly canopy management strategies, and
- ❑ The optimization and automation of shake-and-catch harvest systems design to achieve a highest possible overall harvest efficiency