Development of Robotic Green Fruit Thinning System for Apple Orchards

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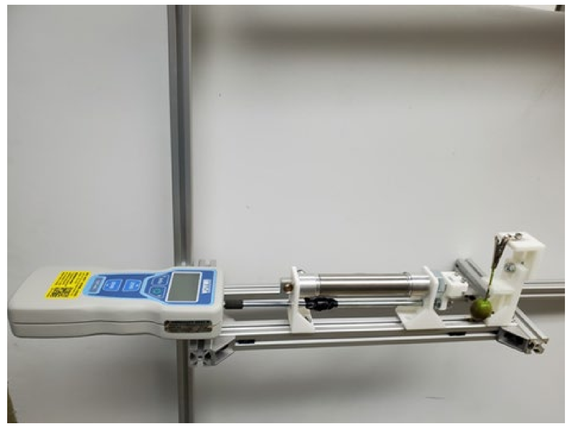
Introduction – Robotic Green Fruit Thinning

- Green fruit is one of the most labor-intensive tasks of apple production.
- A robotic thinning system could reduce the high labor requirement.
- The end-effector and vision system are important components for robotic thinning.
- Green fruit removal dynamics and an end-effector prototype were investigated.
- Green fruit segmentation and orientation estimation algorithms are currently being investigated.

End-Effector – Fruit Removal Dynamics



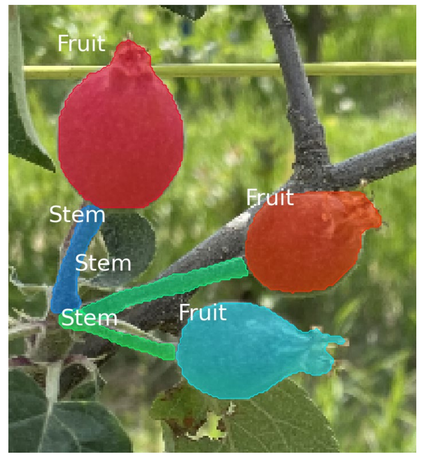
- The dynamics of green fruit removal using pulling and stem cutting methods were investigated.
- Stem cutting required significantly more force than pulling, although pulling resulted in a high occurrence of spur-end stem detachment.
- No correlation between fruit and stem dimensions and required removal force was found.

End-Effector – Stem-Cutting Prototype

- A stem-cutting end-effector prototype was evaluated in thinning experiments using a handheld bar and robotic manipulator.
- Fruit removal success rate was ≥90% for all experiments.

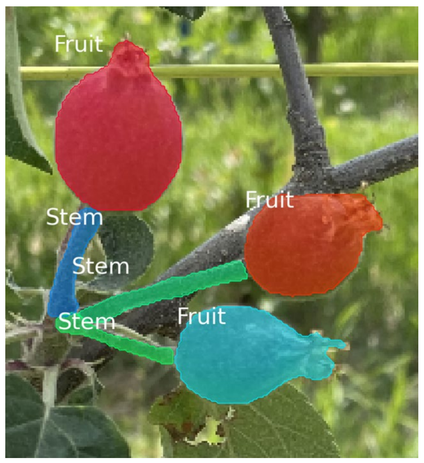
Vision System - Segmentation

Segmentation

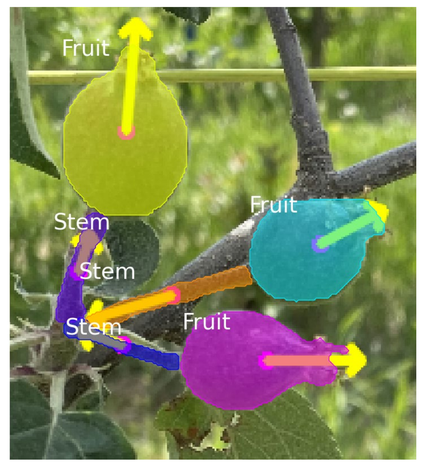


- Mask R-CNN used for green fruit and stem segmentation.
- 365 training images, 78 validation images, and 78 test images were used.
- Test dataset average precision scores (IoU = 0.5) for green fruit and stems are 83.5% and 38.7%, respectively.
- Object sizes in images can affect performance.

Vision System – Orientation Estimation



Orientation



- Principal Component Analysis algorithm used to estimate the orientation of green fruit and stems.
- Mean absolute errors for green fruit and stem orientations over 57 images are 15.2° and 3.4°, respectively.
- Occlusions reduce the accuracy of orientation estimations.

Conclusions

- The stem-cutting end-effector prototype is a simple yet effective device that could be used by a robotic green fruit thinning system.
- The green fruit segmentation and orientation estimation algorithms could serve as bases for further development of a vision system for robotic green fruit thinning.
- Future work will be done in path planning for robotic manipulator in robotic fruit thinning system.

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