Automated image processing of pear rootstock seedling vigor using PlantCV

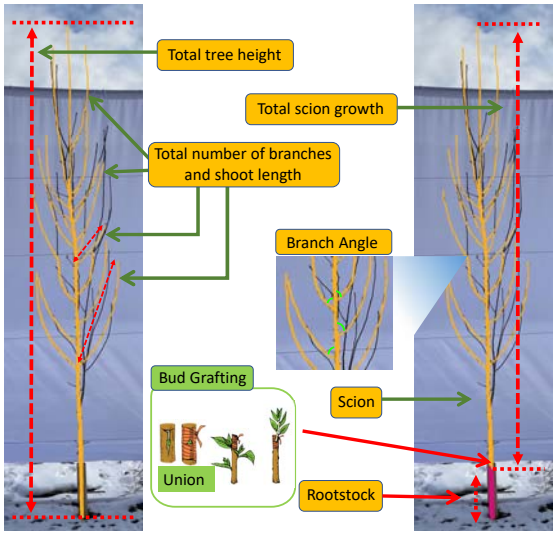
Edwin Polanco, Soon Li Teh, Kate Evans
WSU Tree Fruit Research and Extension Center, Wenatchee, WA 98801. Edwin.Polanco001@umb.edu

Introduction

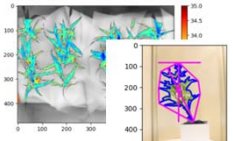
The WSU Pear Rootstock Breeding Program aims to develop dwarfing rootstock seedlings to enable a high-density orchard system capable of improving sunlight interception as well as pesticide, water, and land utility. A total of 556 trees located at Columbia View orchard in Wenatchee were manually measured during winter 2021-2022 to collect vigor-controlling traits related to the effect of pear rootstocks grafted with genetically identical scions, such as:

- Total height & total scion growth
- Total number of branches
- Shoot length & branch angles

Phenotypic data can be extracted by implementing an image processing system to replace the need for time-consuming traditional data collection.



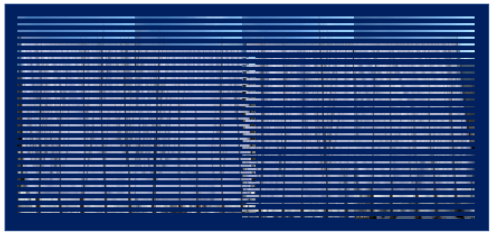
PlantCV is an open-source software package derived from OpenCV for plant-focused image processing, capable of receiving a variety of image types (*e.g., RGB, PSII, VIS, NIR*) as inputs to apply workflows for data extraction.

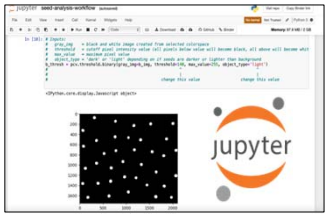


PlantCV enables simultaneous analysis of annotated images to extract morphological traits of pear trees.

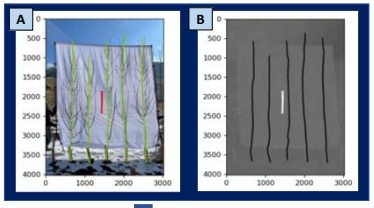
Methods

Jupyter Notebook is a web-based interactive environment enabling workflow development via PlantCV by plotting individual images to visualize the accuracy of object detection.





A collection of 134 RGB images corresponding to six rows of d'Anjou pear scions grafted with pear rootstock seedlings, was captured in winter 2021-2022 and imported for morphology analysis.



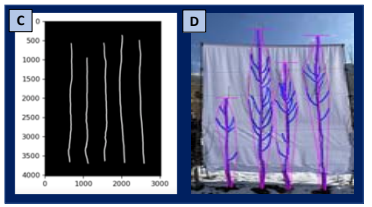
A. A copy of the original collection of images was created to manually annotate objects for analysis.

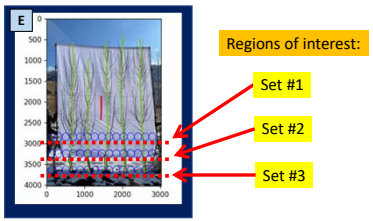
B. The new set of images was converted to a LAB color space and the green-magenta values were isolated to remark the targeted objects.

C. A binary mask for was created by thresholding green-magenta pixels based on annotated images.

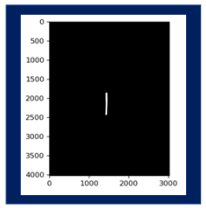
D. The morphology analysis was applied to targeted objects in the original images based on the customized binary mask, and height data were extracted.

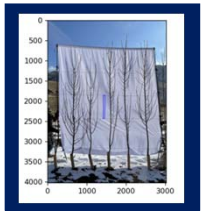
E. Three sets of regions of interest (ROI) were assigned at different levels at the base of the image to collect the data from left to right, and to include smaller trees that were potentially missed due to camera-to-frame distance.

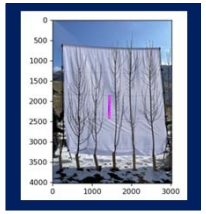




The distance between trellis wires was extracted to correct for inconsistency in camera-to-frame distances, and to normalize all extracted measures.



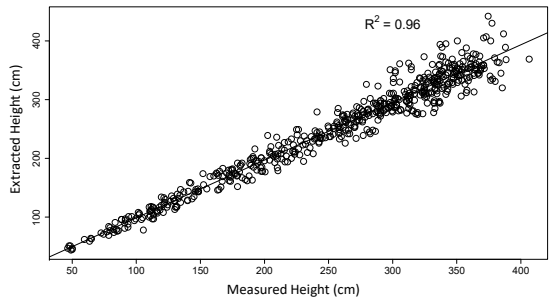




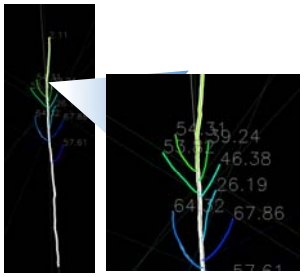
Results & next steps

The workflow successfully extracted height data for 554 trees in 134 images with a regression coefficient, $R^2 = 0.96$ compared to the previously collected empirical data.

Height: extracted vs measured



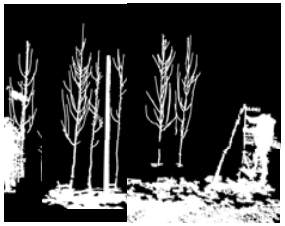
Next steps will include other vigor-related traits, such as branch angle, total scion growth, and total number of branches per tree.



Unable to recognize overlapping branches as individual objects

Current challenge: Inability to auto-mask the trees in each image. Currently, manual annotations are required.

Possible solution: Application of deep machine learning for auto-masking and trait extraction.



Acknowledgements

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