walnuts.org

HIGH-THROUGHPUT PHENOTYPING OF WALNUT YIELD

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Objectives

1. Collect RGB and multispectral imagery on walnuts in the field at the pre-harvest stage of development.
2. Develop and assess various potential methods for the detection and quantification of nuts within images.
3. Investigate, assess, and address the issues of occlusion, clustering, and other factors on nut recognition and localization.
4. Validate the developed methods against field walnut count data.

Background

Increasing walnut quality and yield relative to associated system inputs is an important challenge facing the California walnut industry. While specific traits of interest, such as those associated with yield and quality, can be effectively targeted with the use of genomic technologies, the revolutionary potential of such genomic tools is not always fully realized due to the existing "phenotyping bottleneck." Current phenotyping methods are often labor-intensive and slow, which creates a lag between our capability of producing genomic data and capability to rapidly collect accurate large-scale phenotypic data.

High-throughput phenotyping (HTP) methods, which often use non-destructive imagery, analysis, and modeling techniques, offer the potential to alleviate this phenotyping bottleneck. These methods are capable of providing a large amount of phenotypic data over a relatively short time period.

The overarching goal of this project is to introduce a new high-throughput phenotyping approach for walnut yield. The purposes of this project are multifold: a) identification of walnut trees with high yield potential in order to inform selection for further breeding; b) statistical assessment of the interconnections between total number of walnuts, their number in a single cluster, and position on a branch for analysis of cluster dynamics; and c) a means of early yield estimation for walnut growers.

Results & Discussion

To date, work has focused on collection of field imagery using multiple sensing platforms in order to begin developing, assessing, and testing candidate methods for autonomous detection of walnuts in the images, and ultimately to estimate total yield.

In fall of 2020, we collected about 500 12-band multispectral images from various positions and heights in two walnut orchards, in addition to roughly 150 RGB images. We found that RGB images and near-infrared reflectance images at 970 nm produced the best contrast between nuts and leaves. The RGB images provided more contrast between nuts and leaves than was initially expected. Using the naked eye, it is relatively easy to pick out the nuts in view of the camera. However, this method has a number of significant limitations. First, it requires that the camera be relatively close to the nuts. Aerial images of the canopy made it difficult to identify nuts unless they were on branches at the very top of the canopy. Second, only nuts on the outermost portion of the canopy can be readily seen. This means that RGB-based methods will rely more heavily on algorithms to adjust for occlusion effects (to be explored in Year 2).

The single-band near-infrared images provided the best contrast between nuts and leaves, which was unexpected. We had originally conceived of the use of the multispectral camera for measurement of reflected light (as is traditional in remote sensing). In the case of reflected light, there is relatively little difference in the reflectance of leaves and nuts in any given waveband. However, the difference in transmission of light between leaves and branches is high, particularly in the near-infrared bands. Leaves are relatively translucent to sunlight in the near-infrared bands (transmissivity of about 50%), whereas nuts and branches are opaque (transmissivity of 0). Thus, the multispectral camera acts as a sort of “x-ray” when the tree is placed between the light source (the sun) and the detector (the camera). Much as x-rays pass through organs but not bones, near-infrared light passes through leaves but not nuts and branches. The fact that both nuts and branches appear dark in the near-infrared images means that a simple intensity thresholding cannot be readily used. Currently, the best path forward appears to be to combine RGB images with near-infrared images into a four-band image for nut detection that will enable more robust detection and to better separate branches and nuts within images.

Work began to test different feature detection algorithms to autonomously identify nuts within the images. This included using traditional convolutional neural networks (CNNs) with rectangular label bounding boxes and using Mask RCNN that can utilize labeled data based on polygons that better isolate the shapes of nuts.

We have built a framework for generating large amounts of “synthetic” training data that is automatically labeled. We are working on adapting this pipeline for walnuts.

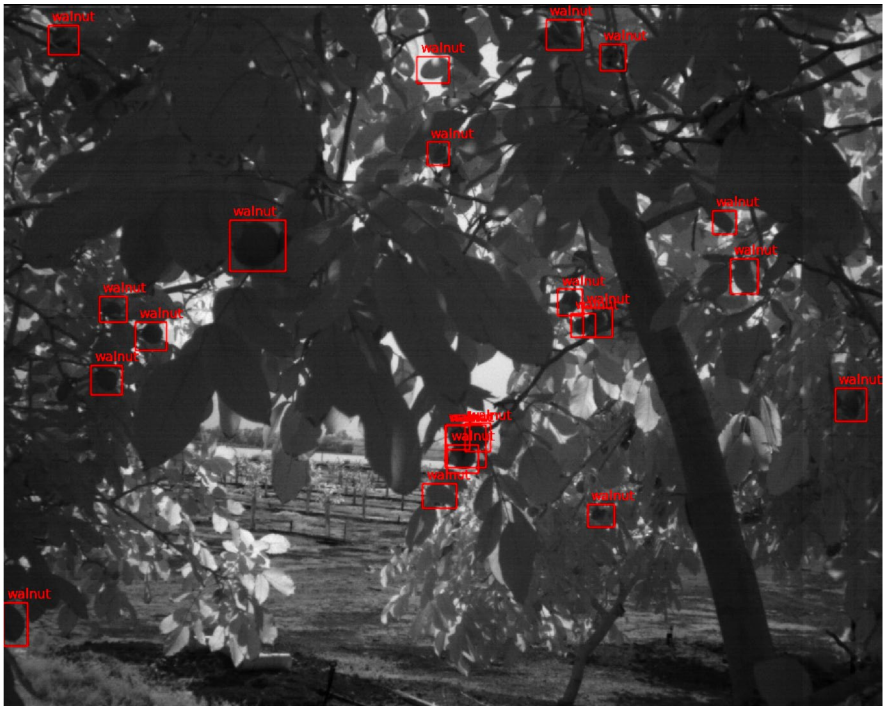

FIGURE 1. Example illustration of autonomous walnut detection using the Python Detecto package and near-infrared imagery.