Measuring Vine Canopy Density with Low Cost 3D Imaging

Tom Plocher, Moai Technologies LLC
9040 152nd Street N., Hugo, MN 55038 USA
01 651 323-7118; tom.plocher@gmail.com
Chuck Hisamoto, Aster Labs LLC
chuck.hisamoto@asterlabs.com
Kale Hedstrom, Aster Labs LLC
heds0002@umn.edu

Problem

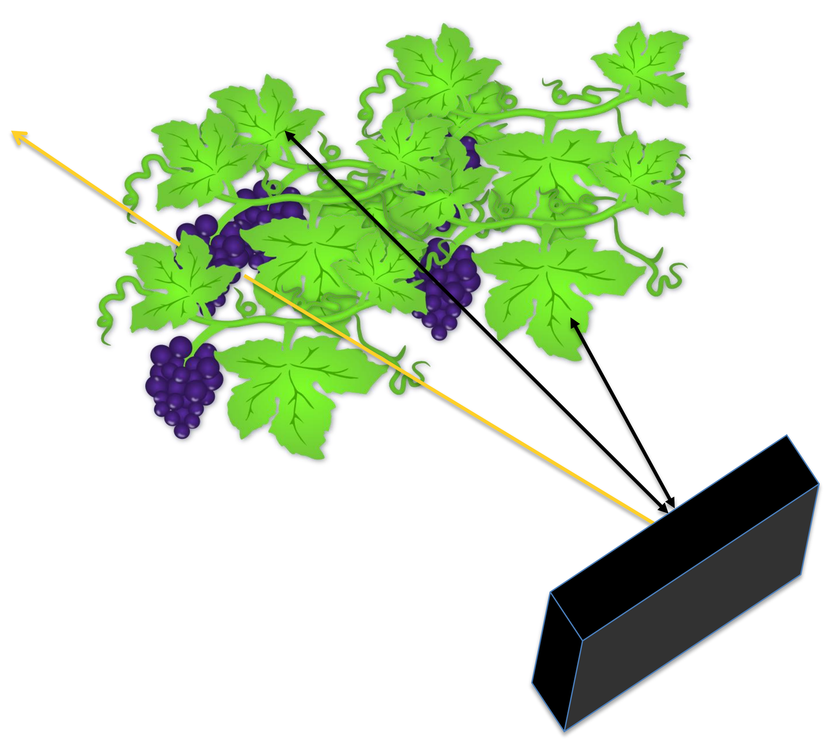
Grapevine canopy management is perhaps the most critical task in the production of uniformly high quality grapes and is directly related to wine quality. Good canopy management results in less disease, reducing the need for fungicide sprays. Thinning the canopy by means of hedging, topping, and leaf removal can be done by machinery. However, in current practice, the task of evaluating the vine canopy so that thinning can be done at exactly the right time and to the right extent, is manual, labor-intensive, and requires a good amount of expertise.

Measuring canopy density using point quadrat

Measuring canopy density using a Kinect2 3D/LIDAR camera

Automating Canopy Density Measurement

- Measures of vine canopy density all have the goal of evaluating light penetration into the leaves and fruiting zone.
- Laser beams are a perfect analogue to natural light…like natural light, laser beams pass freely through openings along their path but are blocked and reflected back by objects.
- Low-cost off-the-shelf 3D cameras are available that use LIDAR (Light Detection and Ranging). These emit ID-tagged laser beams at a high rate in a scanning pattern.
- The laser beam travels until it strikes an object, then reflects back to the camera. Camera senses its return and measures the amount of time and hence, the distance, that it has traveled.
- With tens of thousands of these time of flight measurements per second, we can produce a 3-dimensional picture of a complex object, like a grapevine leaf canopy.



How the Kinect2 time-of-flight or Light Detection and Ranging (LIDAR) camera works

Steps in processing a 3D camera image of the vine canopy

Map Kinect2 pixel data to gray scale values. Background objects (>1.7m from camera) are mapped to '255' (white); Objects close to camera (0.513 to 0.7m) are mapped to '0' (black). Objects (leaves and clusters) in between (0.7-1.7m) are gray scaled from '1' to '254'.

Reduce noise and blur by averaging and combining images froom 8 scans.

Assign each pixel to either vine or background (binary thresholding…white or gray or black)

Assign a gray scale value from 0-255 to each pixel in field-of-view (FOV), allowing 256 unique intensities of depth.

Locate leaves and gaps using "blob" detection, a comparison of multiple similar-gray-level pixels, compared to adjacent 'edge' pixels)

percent gaps = total area of gap "blobs"/total area of leaf "blobs"

leaf layer number = total leaf area/camera FOV

Research and Engineering Questions

- Will a cheap LIDAR 3D camera work on a bright sunny day?
- Is the imaging affected by wind moving the leaves or by moisture?
- How close must the camera be to the vine for sufficient resolution?
- How do measures of canopy density derived from 3D images compare to common manual measures?
- How much time does 3D imaging save over manual methods?

Field Trials

- In late summer, imaged 60 vines of Frontenac gris in two different MN vineyards. Vines had been topped and had one or two rounds of removing lateral shoots.
- Highly vigorous vines with large canopy, trained to Vertical Shoot Positioning.
- Vines were imaged from both sides.
- Collected measures of % gaps and number of leaf layers using two manual methods: the point quadrat and Smart's observational scorecard. Also measured total leaf area and derived leaf layer number using Schreiner's method.
- All data collection, imaging and manual, was completed over a period of 3 days in the first vineyard and in one day in the second vineyard.

Visual image-49% gaps

Visual image-9% gaps

3D camera image-49% gaps

3D camera image-9% gaps

3D camera gray scale: black=nearest the camera; grays=mid-ranges; white= farthest from camera, e.g. canopy gaps

Findings

- Robust to bright sunlight, wind, wetness, and background.
- Good resolution at 1 meter from vine (midway between rows)
- Highly accurate measures of canopy gaps and canopy width.
- Less accurate measures of leaf layer number.
- 10-20 times faster than manual measurements

Going forward

Experimenting with alternative ways to estimate leaf layer number more accurately:

- Inner layer leaves are cooler than outer layer leaves. Image processing on thermal images *probably* can detect these temperature differences and classify the leaf layers as inner or outer.
- By definition, inner leaves are occluded by outer leaves. Image processing of 3D images might be able to recognize leaves that are partially occluded and classify them as belonging to an inner leaf layer.
- If the average width of a single leaf layer is known for a variety, training system and site, then it can be used to classify along the gray scale into leaf layer categories.

Will propose Phase 2 engineering development project in Feb., 2016

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