

Robotic Mechanical Harvester for Fresh Market Citrus

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Vision Robotics (VRC) has demonstrated that it is possible to see all the oranges (>99%) on trees in production groves from somewhere outside the tree canopy. In practice, this requires a thorough scan of the tree canopy, and the closer to the canopy and wider the viewing angle the better.

During 2008, VRC built a Scout prototype capable of thoroughly scanning small orange trees. The prototype consists of a nine foot long, agriculture arm, canopy scouting camera mast, a generator and electronics mounted on platform. The platform is a trailer that may move itself down rows via an integral winch.

In operation, as the Scout moves along a row it looks ahead to determine the shape of the canopy of each tree. As the platform passes a tree, the arm moves the camera head along a grid located approximately six inches outside the canopy. This requires a detailed map of the canopy contour and a wide angle camera. In this way, the system is able to Scout the full half tree adjacent to the row. VRC will process the data with software created in 2007 to fuse the data from all the pictures to count and provide accurate location and size information for the oranges in the area scanned. In this phase, the plan is to scout in a step by step fashion where the platform and arm stop at each grid location. Future versions will evolve for continuous motion.

Hardware:

VRC has designed and fabricated the full prototype Scout as shown in Figure 1. The platform is a stock, four-wheeled wag-on. Existing manufacturing arms are not applicable for the production robots for reach, cost and weight considerations. Therefore, VRC designed an 8' arm consisting of shoulder and elbow joints, which move two 4' links in a plane perpendicular to the Scout's direction of travel, and two wrist joints, which enable the cameras to look up-and-down and side-to-side.

The camera head, Figure 2, uses scouting hand with 4 sets of cameras each looking at a different direction. This "cross-eyed" configuration has an almost 180° field of view. In addition to designing the housing and the mechanics, VRC built these cameras specifically for the citrus Scout. The Scout will take all 8 pictures simultaneously, ultimately enabling a continuous scan. The canopy scanning mast uses 6 or 7 pairs of stereo cameras to look ahead of the platform to map the up-coming tree canopies.

Software:

The prototype uses a fusion of data extracted from the pictures that is run through several algorithms to identify the pieces of fruit and their centers. In addition, the system tracks the same piece of fruit in nearby images. Using the stereo data, the system determines the location of each piece of fruit and estimates its size. The data for all the fruit is combined to generate a 3D model of the fruit on the tree.

There are two new software modules required for this phase of the project: 1). Code to determine the canopy shape and dynamically plan the scanning arm motions. A preliminary version of the canopy contour software was implemented in simulation two years ago. During this year, the algorithms will be refined for operation with real orange trees and the contour-following path planning implemented. 2). Code to determine the locations of the scouting hands as images are captured. The goal was to create a lightweight, inexpensive arm. One tradeoff is that the arm is not perfectly precise; the end could be a couple inches away from what is reported by the internal sensor. In addition, the pitch and roll of the platform can significantly affect the position of the end of an 8' arm. The new localization system involves the combination of odometry data from the platform and all the joints on the robot arm with information determined by tracking the movement of individual pieces of fruit between images.

Results:

All hardware is complete for the prototype. The motion of the arm has been quantified and control implemented. Preliminary canopy contour mapping is complete. Preliminary arm path planning is complete. And, integration of hardware and software is complete. In January, VRC plans to demonstrate the full system scouting in production orange groves.



Figure 1. Scout prototype.



Figure 2. Camera head.

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