IFAS Citrus Initiative
Annual Research and Extension Progress Report 2006-07
Mechanical Harvesting and Abscission

Investigator: Dr. Tom Burks
Other Contributors: Dr. Fritz Roka

Priority Area: Mechanical Harvesting Enhancements

Purpose Statement:

The eventual adoptions of MH systems for processed citrus will likely demand extending the normal work day from the traditional 8 hr/d to a 24 hr/d, in order to obtain full economic potential for the grower as well as the harvesting crew. This concept opens up a whole new realm of challenges, which range from equipment logistics, load allocations, safety, operator effectiveness, and equipment interactions. This project will explore the feasibility of 24 hr/day harvesting from these varied perspectives. In addition, we are pursuing autonomous navigation technologies which can be applied to a wide range of equipment and applications in citrus production and harvesting. This was the second year of a five year project, which will seek to enhance machine performance, develop equipment utilization and logistics tools.

Work Plan Objectives:

a) Development of autonomous vehicle guidance and navigation as an enhancement to harvesting performance and operator effectiveness.
   - Completion of in row navigation and control
   - Retrofit John Deere e-gator controls for autonomous navigation
   - Implement obstacle avoidance and end-row turning
   - Conduct field study of TS&C system navigation

b) Development of a stochastic equipment utilization model to optimize producer/harvesting/hauling/processing aspects of the harvesting chain operation. This year's work will focus on the development of a fundamental harvesting model for a trunk-shake-catch harvesting system, which can later be expanded to other harvesting systems. Research in conjunction with Dr. Fritz Roka.

c) Development of sensing, data archival and virtual reality technologies capable of enhancing equipment utilization, operational safety, and tracking during 24 day harvesting.

First Objective: Advancement of autonomous guidance technologies

Detailed Accomplishments in 2006-07

- Conducted extensive testing in grove to improve fusion based guidance (Sum ’06 – Fall ’06)
- Wrote paper for the same and submitted for publication in journal (Fall ’06-Sum ’07)
- Transferring guidance system from JD 6410 to JD e-gator (Fall ’06-Sum ’07)

Areas where progress exceeded expectations

- The results from the sensor fusion-based guidance system have been excellent. When comparing our advanced approaches to that of John Deere, we clearly have made some significant improvements over what they reported at a recent International Robotics conference.

Areas where progress didn't meet expectations

- Transfer of guidance system to e-gator has been a very difficult and time consuming job, since John Deere was not willing to provide any documentation to the system. All circuits and controls that were previously on the E-gator had to be reverse engineered before we could start applying our technology. We have recently completed this task and have resumed field test with the new vehicle.

Impact of accomplishments towards overall goals

- The new vision/ladar sensor fusion guidance approach will have significant advantages for autonomous navigation in the grove. It gives the opportunity to not only guide the vehicle, but watch out for obstacles like drainage ditches, livestock, and so on. This technology should be applicable to a broad range of uses in citrus navigation for harvesting, spraying , mowing and so on.
- Transferring the guidance system to e-gator gives more flexibility in navigating the entire grove when compared with using the tractor and will allow us to move to fully autonomous navigation..

Presentations associated with 2006-07 efforts

Vijay Subramanian and Thomas Burks, Autonomous vehicle navigation through the headlands of citrus groves. ASABE AIM, 2007

Publications from 2006-07 efforts

Vijay Subramanian & Thomas Burks, 2007. "Sensor fusion using fuzzy logic enhanced Kalman filter for autonomous vehicle guidance in citrus groves". Under review with Computers and Electronics in Agriculture.

Next steps

- Navigate headlands of grove
- Path planning
- Obstacle avoidance
- Complete the in row guidance work and then move into fully autonomous travel in the grove. There is a lot of work left to do, but this is a good first step.

Second Objective: Investigation into potential for multiple shift harvesting

Detailed Accomplishments in 2006-07

- Primary tasks are associated with the development of stochastic modeling tools which will predict the machinery utilization performance of various harvesting scenarios. Continued planning and interactions with Dr. Roka continue to suggest the value in the development of such modeling tools.

- Development of preliminary harvesting model for a trunk shake and catch, and trunk shake and pickup harvesting scenario.

Areas where progress exceeded expectations

- This task as not progressed as planned and is significantly short of where we hoped to be.

Areas where progress didn't meet expectations

- Due to the delay in funding availability we were not able to hire a graduate student until the Spring 07. Consequently a critical class necessary for our modeling work was not available (offered in Fall). It was necessary for the student to attempt self teaching of the modeling environment, which has been slow. We are starting to see progress at this point.

Impact of accomplishments towards overall goals

- This work has clearly identified resource modeling as a major interest for growers/harvesters/processors who are struggling with resource allocation and economic questions. It suggests that resource modeling will demonstrate whether it is economically viable to pursue multiple shift harvesting.

Presentations associated with 2006-07 efforts

- Not applicable

Publications from 2006-07 efforts

- Not applicable

Next steps

- To begin framing a resource allocation model which can model a fundamental harvesting scenario. As experience and data become available the model can grow to accommodate more complex harvesting scenarios.

Additional Research or Extension Efforts needed in these areas:

- It is recommended that a multi-year research effort begin which will consist of three major efforts
  - Collect appropriate time and motion data along with event frequency data to describe the harvesting scenario
  - Create a stochastic model describing the citrus harvesting that is capable of accommodate various equipment, crew, hauling, load allocation scenarios.
  - Integrate these with a economics model that can provide cost-benefit feedback to industry about various scenarios of harvesting.

Other Information to Report:

Third Objective: 3D geometric mapping of canopy and image registration

Detailed Accomplishments in 2006-07

- Panorama : It is believed that the use of panoramic viewing capability will be integral to a number of applications in citrus including robotic harvesting, disease scouting and nighttime surveillance in 24 hour harvesting. We have focused in this year on the development of an image mosaicking technique which will be robust with grove canopy scenes. We now have a working model capable of generating a continuous image mosaic from a mobile camera moving down an alleyway.
- Sensing capabilities: We developed a scanning system that linked DGPS with laser radar which can be used to map canopy depth into the camera scene for 3D image reconstruction. There are still some sensor fusion issues to work out, but this is a nice first step.

Areas where progress exceeded expectations

- Although it has taken more time then expected to get to this point. The feature detection, and tracking algorithms and long with the ladar scanning technology give us a solid foundation to move into the next phase of development

Areas where progress didn't meet expectations

- Good progress, but has take more time then anticipated.

Impact of accomplishments towards overall goals

- We have made a good start on the creation of a visual scene mapping and reconstruction program that will be helpful for a number of applications in citrus harvesting and other important technologies in citrus.

Presentations associated with 2006-07 efforts

- Han, S. and T. F. Burks. Video Image Mosaicing for Non-planar Grove Scene, 2007 ASAE Annual International Meeting, Minneapolis, MN.

Publications from 2006-07 efforts

- Han, S. and T. F. Burks. Video Image Mosaicing for Non-planar Grove Scene. ASAE Paper No. 071145. St. Joseph, MI.

Next steps

- Combine mosaicing algorithm with depth estimation approaches to achieve 3D image reconstruction.