IFAS Citrus Initiative
Annual Research and Extension Progress Report 2007-08
Mechanical Harvesting & Abscission

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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 8 to 24 hr/day, 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 seek to develop the capabilities of fully autonomous vehicle navigation and path planning, which has applications for mechanical mass harvesting systems (CCSC and TSC), robotic harvesting, goats, and various other applications such as scouting, spraying, mowing and so on. Progress to date has demonstrated the capability to navigate through a grove alley way using machine vision and laser radar with advanced sensor fusion techniques. We are currently developing the capabilities to navigate a vehicle through headland turns. Once these capabilities are perfected we will begin fully autonomous navigation techniques.

In addition, this project will explore the feasibility of 24 hr/day harvesting through the development of harvesting systems modeling tools, which will seek to optimize the selection and utilization of harvesting equipment and the resources needed for the complete harvesting systems. Numerous questions exists about the optimal selection of harvesting equipment. Issues such as block size, load allocation, terrain, equipment relocation, number of goats needed, mean-time to breakdown, and so on, will influence management decisions about the optimal harvesting equipment selection and duration of workdays. The use of stochastic modeling tools has been used effectively in industrial as well as agricultural applications to answer these complex questions. Once linked with economic models, these tools will help the growers and harvesting companies make more informed management decisions. This is the second year of a five year project, which will seek to enhance machine performance through autonomous navigation, develop equipment utilization and logistics tools. Refer to 2006/07 year end report for progress to date.

Work Plan:

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

c) Development of autonomous vehicle guidance and navigation as an enhancement to harvesting performance and operator effectiveness.
    - Implement obstacle avoidance and end-row turning
    - Implement fully autonomous grove navigation and path planning.
    - Conduct field simulation of TS&C system navigation

First Objective: Advancement of autonomous guidance technologies using John Deere E-gator equipped with machine vision and laser radar

Detailed Accomplishments in 2007-08

- Finalized in row fusion based guidance (Sum '07)
- Submitted for publication in journal (Fall '07)
- Developed end of row turning approach (Su 07 – Winter 08)
- Developed basic DGPS based guidance with obstacle detection (Sp 08)
- Defended dissertation on topic

Areas where progress exceeded expectations (why?)

- The results from the in row navigation development and end of row turning were very encouraging although not perfect. It was especially positive to see the implementation of fully autonomous row to row turns operating in u-turn and switch-back mode. However, this success came at the cost of time available to work on the obstacle avoidance and open field navigation as we would have liked. We also found during testing that there were certain scenarios at which the controller didn't perform as expected. However, overall the results were very promising and give us a good success to build upon.

Areas where progress didn't meet expectations (give rationale)

- Although we were able to develop open field navigation using DGPS and obstacle detection using ladar, and tested the procedures in a non-citrus application, we were not able to finish the groves trials as we would have liked. In addition, the intention of developing a trial scenario for trunk shaker auto-steer was not realized. The cause for the delays were several; 1) extra effort required to finish end of row turning, 2) delays in funding availability, 3) graduate student took industry position in early spring, 4) possibly an overly ambitious set of objectives

Impact of accomplishments towards overall goals

- We have now demonstrated an ability to navigate down the alleyway of a grove, the ability to turn at the headland, the ability to navigate in open field with DGPS, and a limited ability to identify obstacles in the vehicles path and stop. Pieces the accomplishments together we can now demonstrate to the industry that we are closing in on fully autonomous navigation. There are several enhancements that we are working on to improve performance which we get us closer to having a robust fully autonomous navigation system for citrus groves.

Presentations associated with 2007-08 efforts

Vijay Subramanian and Thomas Burks, Obstacle detection and avoidance for autonomous vehicle navigation in citrus groves. ASABE AIM, 2008

Publications from 2007-08 efforts

Vijay Subramanian & Thomas Burks, 2008. "Sensor fusion using fuzzy logic enhanced Kalman filter for autonomous vehicle guidance in citrus groves". Under review with Transactions of ASABE.

Vijay Subramanian, 2008, Autonomous Vehicle Guidance Using Machine Vision and Laser Radar for Agricultural Applications, University of Florida, PhD Defense.

Next steps (may not be any)

- Modify headland navigation to be more robust under varying light and row end conditions
- Obstacle avoidance and path planning for inter-block transfers

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 scenario.

Areas where progress exceeded expectations (why?)

- This task has not progressed as planned. However, we have developed a fundamental model architecture and have developed a nice graphical users interface which allows users to customize their grove scenario in order to most closely reflect their particular scenario

Areas where progress didn't meet expectations (give rationale)

- We were delayed in the development of the model due to two primary reasons. First, the initial software development tools (ARENA by Rockwell Automation) turned out to be inadequate for the task at hand. It was very limited in the flexibility given for defining event commands ans schedules. Consequently, we were required to switch to a more flexible development using Microsoft Excel as the host development environment. This also meant that we now had to develop our own GUI interface using visual Basic. The student has done a nice job of catch up, but due to the delay in hiring him we did not really get started until Spring 08 semester.

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 suggest 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 (may not be any)

- Validate model accuracy using current event data
- Collect appropriate data for harvesting events currently estimated
- Add other harvesting scenarios and gleaning

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

Detailed Accomplishments in 2006-07

- Developed image enhancement filtering combination specified for grove scene such as citrus canopy.
- Developed a modified Lucas-Kanade method to track feature points for video image (implemented but marginal performance).
- Developed a dynamic feature manager which reorganizes features when they repeat appearance and disappearance or get bad information.
- Developed 3D Reconstruction system with a single camera to initialize fruit location of a canopy before harvesting.
- Developing dynamic texture image mapping on the reconstructed canopy model.

Areas where progress exceeded expectations (why?)

- Although it has taken more time then expected to get to this point. The feature detection, and 3d reconstruction algorithms have progressed However, we are still stalled at developing a successful feature tracker, which can keep successive image frames registered when the camera and tree are moving.

Areas where progress didn't meet expectations (give rationale)

- Due to motion in the leaves, camera, and the non-planer nature of the tree canopy, developing a robust feature tracking algorithm has been a major hurdle. From the literature, no one has solved this problem, so we are breaking new ground.

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. Transactions of ASAE (In preparation)

Next steps (may not be any)

- Stabilize tracking and reconstruction algorithm against error sources such as wind-waving, moving things, and make it work in real time.