United States Department of Agriculture
Project Initiation

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Project Title

Cooperative Human-Robot Networks for Agricultural Applications

Project Details

Sponsoring Institution National Institute of Food and Agriculture	**Project Status** COMPLETE
Funding Source NIFA Non Formula	**Grant Year** 2014
Grant No. 2014-67021-22109	**Cumulative Award Amt.** $532,607.00
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Project Director

Dankowicz, H.

Recipient Organization

UNIVERSITY OF ILLINOIS
506 S WRIGHT ST, 364 HENRY ADMIN BLDG
Urbana, ILLINOIS 618013620

Performing Department

Mechanical Sci. & Eng.

Non Technical Summary

Challenges to full deployment of autonomous robotic systems in agriculture include uncertainty associated with variable environmental conditions; unmodeled dynamics affecting the operation of mobile robotic platforms across highly uneven terrain; large variations in crop material properties; and the need for cooperative coordination in human-robotic interactions. Each of these challenges put significant demands on the versatility of hardware and software architectures, e.g., support for interchangeability of tools or platforms, as well as coordinated performance across a network of highly differentiated systems. This project targets the theoretical development and experimental validation of such control and planning architectures for cooperative networks of humans and robotic manipulators on mobile platforms in agricultural applications, using new insights from the field of adaptive control theory and scaled physical hardware realizations. Emphasis is placed on two key applications in precision agriculture: i) semi-automated seeding operations with dedicated, robotic refilling vehicles and ii) crop inspection and treatment operations in uncertain environments. Versatile control designs are sought that sustain guaranteed and coordinated performance even in the presence of significant delays in network communication and actuation channels, and that do not depend on detailed model knowledge of individual nodes in the network. The proposed architectures provide a technology innovation in support of robust human-robot interfaces, as well as interchangeability of tools, platforms, and crops with successful operation across highly variable terrain. Through collaboration with Deere & Co, the proposed research program is grounded in agricultural engineering practice, and lays the scientific foundation for downstream integration, application-specific design and development, and large-scale testing and deployment. Through integration with robotics and mechatronics education, it pools resources across multiple technological disciplines and provides an impetus to ongoing curricular engagement with industrial sponsors.

Animal Health Component

Animal Health Component: 0%

Research Effort Categories

Basic	100%
Applied	0%
Developmental	0%

Classification

Knowledge Area (KA)	Subject of Investigation (SOI)	Field of Science (FOS)	Percent
402	5310	2020	100%

Knowledge Area

[402] Engineering Systems and Equipment

Subject Of Investigation

[5310] Machinery and equipment

Field Of Science

[2020] Engineering

Keywords

Robotic manipulators, adaptive control, crop inspection, mobile platforms, networks, seeding

Goals / Objectives

The major goal of this project is to build a theoretical and experimental framework for cooperative networks of human operators and robotic manipulators on mobile platforms in agricultural applications that provides guaranteed performance in rapidly changing environments, associated with highly variable terrain topography and soil conditions, and that supports interchangeability of tools, platforms, and crops.Specific research objectives include:1. Design and analysis of cooperative, adaptive strategies for control of task-space performance of networks of robotic manipulators on mobile platforms; specifically, the verification of guaranteed bounds on time-delay margins, the tuning of the architecture to ensure a predictable response that is indifferent to high-frequency noise from the environment, and the incorporation of algorithms that establish a working domain of safe operation.2. Design and analysis of motion-planning algorithms for semi-automated seeding operations with robotic refilling vehicles; including conceptual design, as well as computer-based modeling and simulation, of the corresponding robotic manipulators and refilling system.3. Design and testing of scaled experimental models of human-robotic networks on mobile platforms across uneven and variable terrain; specifically the construction and deployment of customized manipulators for soil sampling and onboard soil characterization, as well as for multi-robot, cooperative handling of plant material and inspection.

Project Methods

This project will use i) theoretical tools of applied mathematics, multibody systems, and nonlinear dynamics (Years 1-2), ii) computational tools of modeling and simulation (Years 1-2), and iii) engineering design, realization, and experimentation techniques (Years 2-3), for the development, deployment, and validation of adaptive control architectures for individual robotic manipulators on mobile platforms, as well as manipulators in networks that may include human operators. The implementation of such adaptive control architectures will be analyzed numerically by means of simulation data measuring sensitivity to time delay in communication and actuation channels, to uncertainty in operation conditions, and to significant unmodeled dynamics of the mobile platforms. They will be evaluated experimentally by means of sensor data measuring tracking performance and quantifying the degree of response predictability across different experimental platforms. Successful designs will support interoperability of tools, platforms, and crops for operation across highly variable terrain. In the context of semi-automated seeding operations, the project will use tools from robotic path and motion planning (Year 2) to propose and analyze real-time algorithms for guidance of robotic refilling vehicles that ensure continuous operation of seeding units. The implementation of such planning algorithms, as well as of possible engineering designs of the corresponding robotic manipulators, will be evaluated using multibody vehicle simulations for a set of characteristics benchmark operating conditions. The results will be interpreted in the context of flexibility, safety, and cost-effectiveness. Collaboration with the Robotics Group at the John Deere Technology Innovation Center will be used to provide up-front design constraints in target agricultural applications and to integrate application-specific feedback on control performance. Experiential learning opportunities for engineering undergraduates interested in agricultural applications will be evaluated through the performance on required course elements of capstone design or independent-study courses. The impact of a workshop on applications of robotics to precision agriculture will be evaluated based on participant surveys.