IEEE Robotics and Automation Society Technical Committee on Agricultural Robotics and Automation

By Marcel Bergerman, Eldert van Henten, John Billingsley, John Reid, and Deng Mingcong

Agriculture is humankind's oldest and still its most important economic activity, providing the food, feed, fiber, and fuel necessary for our survival. With the global population expected to reach 9 billion by 2050, agricultural production must double to meet the increasing demands for food and bioenergy. Given limited land, water, and labor resources, it is estimated that agricultural productivity must increase by 25% to meet that goal, simultaneously limiting the growing pressure that agriculture puts on the environment.

Robotics and automation (R&A) can play a significant role in society to meet its future agricultural production needs. For six decades, robots have played a fundamental role in increasing the efficiency and reducing the cost of industrial production and products. In the last three decades, a similar trend has started to take place in agriculture, with GPS- and vision-based self-guided tractors and harvesters, which are already available commercially. More recently, farmers have started to experiment with systems that automate or augment operations such as pruning, thinning, and harvesting, as well as mowing, spraying, and weed removal. In the fruit tree industry, for example, workers riding robotic platforms have shown to be twice as efficient as workers using ladders (Figures 1–4). Advances in sensors and control systems allow for optimal resource and integrated pest and disease management. This is just the beginning of what will be a revolution in the way that food is grown, tended, and harvested. An unfiltered search on Google Scholar for the query "agricultural or agriculture" and "robot or robotics" reveals the increased interest from the R&A community to apply sensing, mobility, manipulation, and management technologies to meet agricultural needs (Figure 5).

Figure 1. Workers in a commercial orchard conducting green fruit thinning from onboard an autonomous orchard vehicle moving slowly down the row. (Photo courtesy of Carnegie Mellon University, United States.)

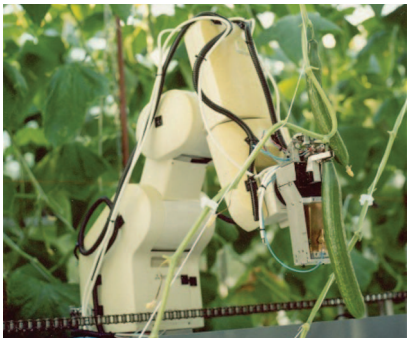

Figure 2. A cucumber harvesting robot. (Photo courtesy of Wageningen University & Research Centre, The Netherlands.)

Figure 3. The Intelligent Autonomous Weeder, a robot that performs autonomous weeding operations in arable farming. (Photo courtesy of Wageningen University & Research Centre, The Netherlands.)

Figure 4. Two autonomous tractors spraying a commercial orange grove. Their activities are coordinated by a high-level supervision architecture. (Photo courtesy of National Robotics Engineering Center and Deere & Company, United States.)

Current research in agricultural R&A focuses on embedding machines and vehicles with the intelligence needed to augment human workers and increase their efficiency, or to replace them altogether in unhealthy or laborious activities in fields, orchards, groves, vegetable farms, greenhouses, forests, and animal production. A noncomprehensive list of recent activities include

- automated thinning of flower blooms in fruit orchards
- automated pruning in grape vineyards
- automated plant growth monitoring in greenhouses

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- automated crop yield prediction in fruit orchards and vineyards
- automated tree counting and calipering in nurseries and orchards
- automated plant species classification and maturation determination
- automatic vehicle guidance
- autonomous orchard platforms to transport workers pruning, thinning, training trees, and harvesting
- autonomous seeding, phenotyping, and weed removal
- autonomous spraying in orange groves
- autonomous fruit harvesting in orchards and greenhouses
- advanced vehicle traction control
- vehicle formation control to enable multivehicle operation in fields and orchards
- multivehicle telesupervision
- livestock management.

The mission of the IEEE Robotics & Automation Society Agricultural Robotics and Automation (AgRA) technical committee is to promote research, development, innovation, and standardization in robotics and automation to enable safe, efficient, and economical agricultural production. AgRA is a forum where academic and industrial scientists and engineers meet to advance the state-of-the-art in sensing, mobility, manipulation, and management technologies applied to production of grains, fruits, vegetables, nuts, horticulture and nursery crops, and animal products.

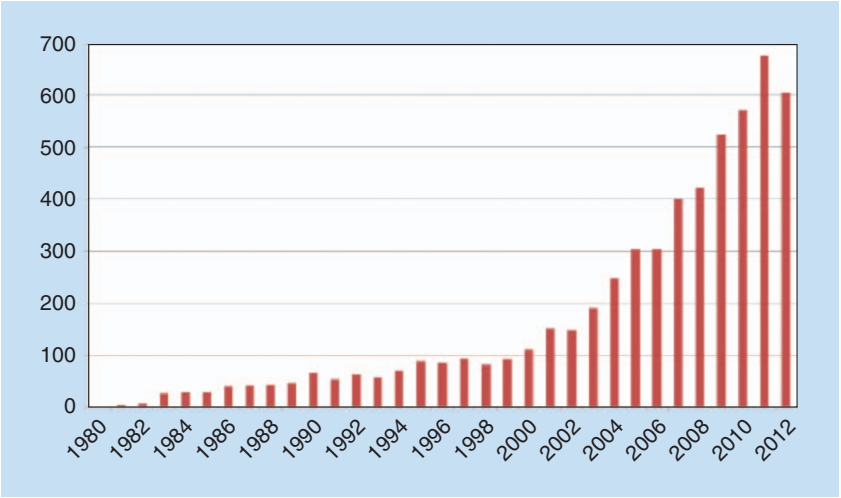

Figure 5. Number of articles on Google Scholar (1980–2012) that match the search query on "agricultural or agriculture" and "robot or robotics." The graph reveals the increased interest from the robotics and automation community to apply sensing, mobility, manipulation, and management technologies to meet agricultural needs.

Recent activities pursued by the technical committee (TC) members include the following.

Webinar Series: In 2012, we successfully launched the TC Webinar series with the goal of bringing together researchers and practitioners, academic and industrial, in an informal setting to increase knowledge dissemination in the field. We have hosted seven talks as of February 2013 (Figure 6). Attendance is via Web and phone, with the audience joining from all over the world. The talks are archived on the AgRA TC Web site (http://www.fieldrobot.com/ieeeras, click on Events). Our goal for 2013 is to hold at least eight Webinars and for 2014 to hold one every month.

Workshop on Agricultural Robotics: Held during IROS 2012 in Portugal, the half-day workshop was attended by 36 people who came to listen to and interact with the seven invited speakers (Figure 7). In addition to their instructive presentations, the speakers rounded up the afternoon with an insightful panel discussion. The papers are available at the workshop Web site, accessible from the TC Web site (http://www.fieldrobot.com/ieeeras, click on Events).

Title	Speaker	Institution
R Gator: An Unmanned Utility Vehicle for Off-Road Operations	Stewart Moorehead	John Deere, USA
Autonomous Orchard Vehicles for Specialty Crops Production	Marcel Bergerman	Carnegie Mellon University, USA
Robotic Control of Broad-Leaved Weeds in Dairy Pastures and Soccer Fields	Frits K. van Evert	Wageningen University and Research Centre, Netherlands
The Future of Precision Farming; Designing Systems for the Farm of Tomorrow	Simon Blackmore	Harper Adams University College, UK
An Autonomous Robot for Greenhouses and Vineyards: Localization and Navigation Methods	Giovanni Muscato	DIEEI Università degli Studi di Catania, Italy
Robotic Leaf Probing via Segmentation of Range Data into Surface Patches	Babette Dellen	Institut de Robòtica i Informàtica Industrial, Spain
Autonomous Systems for Broad Acre Farming	Jay Katupitiya	University of New South Wales, Australia

Figure 6. AgRA TC Webinars held in 2012–2013.

International Conference on Advanced Mechatronic Systems 2012: About 40 people from the United States, Canada, the United Kingdom, and Asian countries attended the plenary panel on "New Developments in Agricultural Robotics and Automation."

Book Chapters: The TC members are rewriting the *Handbook of Robotics* chapter on Agricultural and Forestry Robotics and wrote an invited chapter on Agricultural Robotics on an SAE book on autonomous vehicles. Both works will be completed in 2013.

Beyond endowing machines and vehicles with higher levels of "intelligence," two long-term challenges must be addressed before R&A makes a full incursion into agriculture. The first is humanlike manipulation of crops, especially in orchards, vegetable fields, and greenhouses. The long-sought "harvesting robot" is still an object of fiction, especially when it comes to its economic feasibility. In the apple industry, for

Talk	Speaker	Institution
Navigation System of the Autonomous Agricultural Robot "BoniRob"	Slawomir Grzonka	Robert Bosch GmbH, Germany
Image-Based Particle Filtering for Robot Navigation in a Maize Field	Santosh Hiremath	Wageningen University and Research Centre, Netherlands
Development of Robotics Tool for Agricultural Task Achievement—The Example of Robot Formation Control	Roland Lenain	IRSTEA, France
Automating Orchards: A System of Autonomous Tractors for Orchard Maintenance	Stewart Moorehead	Deere and Company, USA
A Toolbox for Aerial Image Acquisition and Its Application to Precision Agriculture	Kalinka Castelo Branco	University of São Paulo, Brazil
Robotic Leaf Probing via Segmentation of Range Data into Surface Patches	Babette Dellen	Institut de Robòtica i Informàtica Industrial, Spain
Orchard Tree Modeling for Sprayer Control, Tree Inventory, and Autonomous Navigation	Carlos Vallespi Gonzalez	Carnegie Mellon University, USA

Figure 7. Program of the IROS 2012 Workshop on Agricultural Robotics.

Membership in the TC is open to all interested in contributing to the exciting field of agricultural robotics and automation. Our mailing list now counts with 114 members, 40 of whom joined in 2012—an increase of 54% over the previous year. More information about the TC can be found at the Web site: http://www.fieldrobot.com/ieeeras/ or by contacting the TC cochair closest to you:

- Marcel Bergerman, Carnegie Mellon University, marcel@cmu.edu (corresponding chair)
- Eldert van Henten, Wageningen University and Research Center, eldert.vanhenten@wur.nl
- John Billingsley, University of Southern Queensland, billings@usq.edu.au
- John Reid, Moline Technology Innovation Center, John Deere, ReidJohnF@JohnDeere.com
- Deng Mingcong, Tokyo University of Agriculture and Technology, deng@cc.tuat.ac.jp.

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example, the best human workers are capable of picking 40–60 pieces of fruit per minute, keeping bruising down to a few percent of the volume picked. Our community is relatively far from achieving that level of performance, but we don't need to get there in one shot. Many other easier, but equally valuable operations could benefit from an intelligent manipulation machine, including thinning and pruning; these can be the stepping stones toward a future harvesting robot.

The second is where robotic systems result in breakthrough worksite solutions enabling system-of-systems levels of increased productivity inserted into the farm production system. This will require a systems-level design of agricultural R&A technologies beyond the task-level solutions being sought today.

Systems meant to improve agricultural output and productivity must be designed with safety in mind, because of their operation near and among humans and valuable infrastructure and crops. This is an issue that needs attention from our community, perhaps at the standards and regulation level.

to Robotics Technology Development (1997) and the RAS Pioneer Award (2003). He received the French Légion d'Honneur for his contribution to international research cooperation in 1988. The impact of Georges Giralt on robotics in general and on the European robotics community in particular has led the European Robotics Network (EURON) to give his name to its Annual Best Thesis Award.

In addition to all his achievements and exceptional talents, those who were privileged to work with him will always remember him as someone who gave much of himself to our field and to the relationships and cooperation between people and nations. Giralt's kindness, openness, extraordinary enthusiasm, and humanity left a deep indelible impression on his many colleagues and friends throughout the world.

Tc Spotlight *(continued from page 23)*

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