

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



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

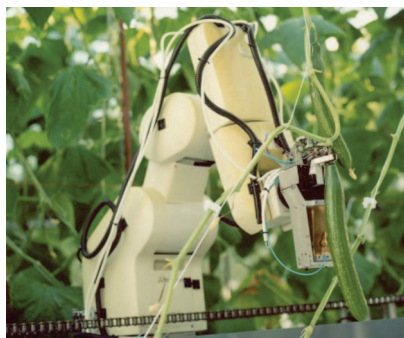


Figure 2. A cucumber harvesting robot. (Photo courtesy of Wageningen University & Research Centre, The Netherlands.)



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.)

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).

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

Digital Object Identifier 10.1109/MRA.2013.2255513

Date of publication: 6 June 2013

- automated crop yield prediction in fruit orchards and vineyards
- automated tree counting and caliper-ing 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,

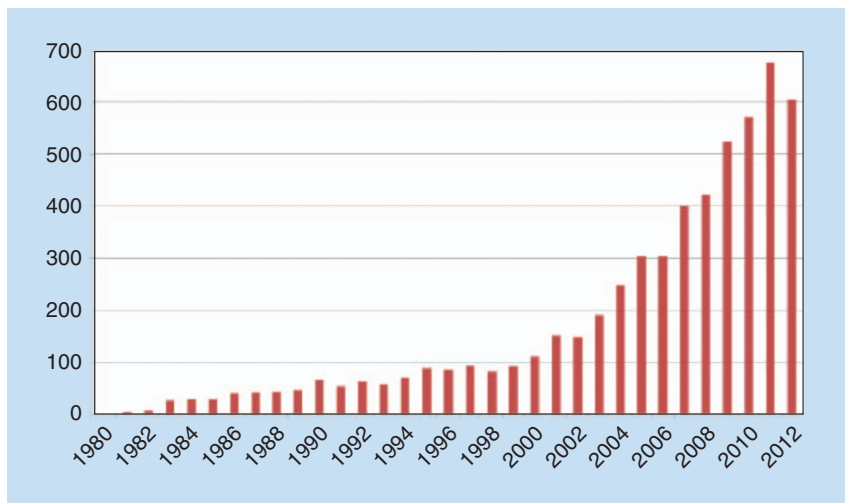


Figure 5. Number of articles on Google Scholar (1980–2012) that match the search query on “agricultural or agriculture” and “robot or robotics.” The graph reveals the increased interest from the robotics and automation community to apply sensing, mobility, manipulation, and management technologies to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

development, innovation, and standard-ization 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 manage-ment technologies applied to produc-tion of grains, fruits, vegetables, nuts, horticulture and nursery crops, and animal products.

7th Annual

ROBOBusiness

October 23-25, 2013
Santa Clara Convention Center
Santa Clara, CA

INVEST ▶ INNOVATE ▶ IMPLEMENT

RoboBusiness 2013 Sponsors

Platinum Sponsors: AETHON, BOSSA NOVA ROBOTICS, CSIRO

Silver Sponsors: ASI, CORUN, HUBER+SUHNER, MICROMO, rethink robotics, ROBOTIS, SICK, SRI International, Trimble

Sponsored by: Allied Motion, AUTONOMOUS STUFF, CoroWare, Elmo, freescale, INFRANOR, JETA, maxon, r², SCHUNK, Synapticon, US DIGITAL, VECTORNAV

Registration Sponsor: ADVANCED MOTION CONTROLS | Lanyard Sponsor: | Lunch Sponsor:

Connect with Thought Leaders and Peers Working to Accelerate the Commercial Advancement of Robotics

The Most Important Robotics Conference of the Year, Located in Silicon Valley, the Heart of Technology and Innovation

- Business Development & Investment
- New Markets & Applications
- Robotics Design & Development
- Enabling Technologies & Emerging Solutions

Media Sponsors: rbr, Robotics Trends, xconomy

REGISTER TODAY AND SAVE WITH EARLY BIRD DISCOUNTS
USE PRIORITY CODE **RASMAG** TO SAVE AN EXTRA 10%

▶ robobusiness.com

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

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 Katupityia	University of New South Wales, Australia

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

Butterfly Haptics

Magnetic Levitation Haptic Interfaces



Highest fidelity interaction for teleoperation and virtual environments

<http://butterflyhaptics.com>

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).

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.

(continued on page 125)

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.

Seeking Expressions of Interest

A consortium of international central banks is seeking expressions of interest to design, build and supply a device for the simulation of human-imparted wear on bank notes through the application of human-like forces and contacting surfaces.

Organizations that express interest in this opportunity may be invited to participate in a request for proposal process.

The Consortium is open to proposals from private sector, public sector, non-for-profit, and academic institutions. Proposals including purely mechanical, mechatronic and robotic solutions will be considered, provided they adequately mimic the human/bank note interactions.

To express interest in this opportunity, please provide a brief description of your organization and fields of expertise/experience in developing bespoke mechatronic or robotic applications to Krysta Charron at kcharron@bankofcanada.ca

Deadline to submit expressions of interest is June 30th, 2013

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)

References

[1] B. Hamner, M. Bergerman, and S. Singh, "Results with autonomous vehicles operating in specialty crops," in *Proc. Int. Conf. Robotics Automation*, St Paul, MN, May 2012, pp. 1829-1835.
 [2] E. J. Van Henten, B. A. J. Van Tuijl, J. Hemming, J. G. Kornet, J. Bontsema, and E.A.

van Os, "Field test of an autonomous cucumber picking robot," *Biosyst. Eng.*, vol. 86, no. 3, pp. 305-313, 2003.

[3] T. Bakker, K. van Asselt, J. Bontsema, J. Müller, and G. van Straten, "Autonomous navigation using a robot platform in a sugar beet field," *Biosyst. Eng.*, vol. 109, no. 4, pp. 357-368, 2011.

[4] S. J. Moorehead, C. K. Wellington, B. J. Gilmore, and C. Vallespi, "Automating orchards: A system of autonomous tractors for orchard maintenance," in *Proc. IEEE Int. Conf. Intelligent Robots and Systems, Workshop on Agricultural Robotics*, Portugal, Oct. 2012.



IEEE ICRA 2014

May 31 ~ June 5, 2014, Hong Kong, China

2014 IEEE International Conference on Robotics and Automation

<http://www.icra2014.com>



The 2014 IEEE International Conference on Robotics and Automation (ICRA) will be held at the Hong Kong Convention and Exhibition Center, Hong Kong, China, from May 31 to June 5, 2014. Hong Kong, situated on China's south coast and enclosed by the Pearl River Delta and South China Sea, is renowned for its expansive skyline and deep natural harbor. Hong Kong is one of the most densely populated areas in the world, and serves as the one of the busiest gateway between the east and west. The conference theme is "Robotics and Automation: Technologies Enabling New Economic Growth" reflecting the growing spectrum and recent developments in robotics and automation around the world.

Call for Papers

Papers are solicited in all related areas in robotics and automation. Prospective authors should submit PDF versions of their paper. Six pages in standard ICRA format are allowed for each paper, including figures. A maximum of two additional pages is permitted with extra cost. We also invited authors to submit a video clip to complement the submission. Detailed instructions for submission are available on the conference website. All accepted papers will be presented in oral sessions.

Call for Videos

Videos of 1.5 to 3 minutes illustrating new and exciting results are sought for dedicated video sessions. Videos should be accompanied by an extended abstract and should be submitted via the PaperPlaza submission site for the conference.

Call for Tutorials & Workshops

Proposals for half-day or full-day tutorials and workshops will be reviewed according to instructions on the conference website. Prospective organizers should emphasize new technologies in robotics, automation and intelligent systems, and address the conference theme and relevance to ICRA. Proposals must be submitted directly to one of the co-chairs of workshop/tutorials.

Call for Organized Sessions

Organized/special sessions are solicited on emerging areas and innovative applications of new technologies. Papers in organized/special sessions must be submitted through the regular submission process, while the proposals must be submitted to the co-chairs.

Important Dates:

AUG 15, 2013	Proposals for organized/ special sessions
SEPT 15, 2013	Submission of full length papers and videos
SEPT 15, 2013	Proposals for tutorials/ workshops
JAN 15, 2014	Notification of papers and videos acceptance
FEB 15, 2014	Final submission
General Chair	
Ning Xi	City University of Hong Kong
Program Chair	
William R. Hamel	The University of Tennessee, Knoxville
Program Co-Chair	
Jindong Tan	The University of Tennessee, Knoxville
Local Arrangements Chair	
King Lai	City University of Hong Kong
Exhibitions Chair	
Jizhong Xiao	The City University of New York
Conference Secretariat	
Tracy Tsoi	City University of Hong Kong
Email: icra2014@cityu.edu.hk	

