Overview of two recent EU-projects in robotic agriculture

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Disclaimer

This is not an in depth analysis about impact of innovation on sustainability of EU agriculture

This is just a technical communication about two major EU projects on agriculture robotics:

RHEA: Robot Fleets for Highly Effective Agriculture and Forestry Management (credits to Pablo Gonzales, CSIC-Spain)

CROPS: Clever RObots for croPS Intelligent sensing and manipulation for sustainable production and harvesting of high value crops
RHEA: figures & partnership

4 years project 2010–2014 (6,6 Meuro)

15 partners from 8 Countries
- 3 Research Centers
- 4 Universities
- 7 SME
- 1 Multinational Industry

Highly interdisciplinary partnership
- Agronomists
- Robotics specialists
- Manufacturers of Ag Machinery
- Perception/Sensing
- ICT
- Electronics
- Renewable energy system
Main idea in RHEA was to configure and operate a **fleet** of reconfigurable, heterogeneous and **complementary robots** to cooperate in **weeding** and **pest management** in order:

- **to minimize**
  - chemical products
  - energy
  - operation time

- **to maximize**
  - the quality of products
  - safety

- **to guarantee**
  - application of the procedures to the entire operation field
Project scenarios:

Narrow-row crops:
- Wheat
- Barley

Row crops:
- Maize
- Sunflower
- Sugar beet
- Tomatoes

Tree crops:
- Olive trees
- Walnut trees
- Almond trees
Autonomous ground units
derived from CNH T3050 (37 kW / 1.2 tonne)

On board unit controller for autonomous functions:
• communication /cooperation with remote mission controller
• steering,
• throttle,
• clutching,
• braking
Aerial mobile units

Based on AirRobot Drone AR-200

- Diameter: 2.2 m
- Maximum payload: 3 kg
- Flight duration: 20-40 minutes
RHEA: sensing and perception

Aerial mobile units

MultiSpectral HiRes Camera *reflex cam for remote sensing*

Ground autonomous units

- Double GPS and inertial unit (IMU) to complement vehicle positioning;
- RT crop row detection on machine vision;
- Weed patches detection that relies on machine vision;
- Obstacles detection by LIDAR
- Remote communication to operator base station,
Physical weeding for row crops

Patch spraying for field crops

http://www.rhea-project.eu/Videos.php
Canopy volume optimised spraying

Canopy volume optimised spraying

α = 0° or α = 15° or α = 0°

http://www.rhea-project.eu/Videos.php
Mission 1: Weed patch spraying in wheat
Mission 2: Physical weeding in corn

- Plan for GMUs
- GMU Autonomous Execution (on board sensors)
- Selective Thermal treatment
Mission 3: Canopy spraying of olive trees
May 2014, field missions demonstration in Madrid (SP)

Presentations, videos and dissemination at www.rhea-project.eu
CROPS: figures and partnership

4 years project 2010–2014 (7,6 Meuro)
14 partners from 10 Countries

- 7 Universities
- 3 Research Centers
- 2 Large industries
- 2 SME

Highly interdisciplinary partnership

- Agricultural engineers
- Mechanical engineers
- Robotics specialists
- Computer scientists
- Software engineers
- Sensing
- Manufacturers of Ag Machinery

Onderzoek/Wageningen UR (Netherlands)
Katholieke Universiteit Leuven (Belgium)
Ben-Gurion University of the Negev (Israel)
Univerza v Ljubljani (Slovenia)
Umea Universitet (Sweden)
Università degli Studi di Milano (Italy)
Consejo Superior de Investigaciones Científicas (Spain)
Technische Universität München (Germany)
CNH Industrial Belgium NV (Belgium)
Instituto de Investigaciones Agropecuarias (Chile)
Force-A SA (France)
Festo AG & Co KG (Germany)
Sveriges Lantbruksuniversitet (Sweden)
Main target were specialty crops, i.e. fruits, vegetables, ornamentals, herbs etc.:

- High value crops
- Frequent management operations
- High intensity of crops needs (fertilization, water, protection etc.)
- High labour input (management+harvest)
- Suitable for selective harvest
- Market for diversity
- Typically grown in enclosed fields or protected environment
CROPS: overall objective

Overall idea in CROPS was to develop and operate a modular, highly reconfigurable, multifunction robot suitable for:

- different operations
  - Maturity/quality monitoring
  - Selective harvesting
  - Intelligent, selective spraying of diseases

- different specialty crops
  - Grapevine, apples, sweet-pepper
Modular architecture: a common manipulator...

Evolution of the developed manipulator for multifunction applications
Robust, dexterous and modular
Modular architecture: a common manipulator...

Evolution of the developed manipulator for multifunction applications
Robust, dexterous and modular

http://www.crops-robots.eu/media
Modular architecture: ... specialised end-effectors

Development of specialised end-effectors and «plug & play» interfaces to the manipulator

- Apple gripper
- Sweet-pepper gripper
- Grapes gripper
- Spot spraying end-effector
Modular architecture: ... software

«plug & play» interfaces also needs for modular software (ROS)
CROPS sensing

Development of sensors modules and associated processing algorithms:

- Detect, identify position of fruits and detouching point (imaging + TOF)
- Maturity of apples and grapevine (NIR spectrofotometry and fluorescence sensing)
- Detection of disease symptoms (multispectral imaging)
# CROPS: multifunction robotic platform for specialty crops

<table>
<thead>
<tr>
<th>Modular, highly configurable Robot System</th>
<th>Pepper</th>
<th>Apples</th>
<th>Grapes</th>
<th>Spraying</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manipulator</td>
<td><img src="image1.png" alt="End-Effector" /></td>
<td><img src="image2.png" alt="Apples Manipulator" /></td>
<td><img src="image3.png" alt="Grapes Manipulator" /></td>
<td><img src="image4.png" alt="Spraying Manipulator" /></td>
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<tr>
<td>Platform</td>
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<td><img src="image8.png" alt="Platform" /></td>
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<tr>
<td>Sensors</td>
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<td><img src="image11.png" alt="Sensors" /></td>
<td><img src="image12.png" alt="Sensors" /></td>
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</tbody>
</table>

+Ripeness
Integration of demonstration prototypes (1)

CROPS platform ready for **robotic harvest of sweet-pepper** in a commercial greenhouse Wageningen (Netherlands), July 2014

- Fully autonomous detection of ripe peppers
- Limits in harvest: less than 40% successfully detached and realised
- Cycle time slow

http://www.crops-robots.eu/media
Integration of demonstration prototypes (2/3)

CROPS platform integrated for **robotic harvest of apples** in an experimental orchard Leuven (Belgium), Oct 2013

and for **robotic harvest of grapes** in vineyard, Sept 2014

- Autonomous detection of 100% of ripe apples
- 90% success grasps, 72% released (mostly touching fruits)
- Satisfactory time cycle (<15s)
Integration of demonstration prototypes (4)

CROPS platform integrated for selective spraying of disease foci

University of Milano (Italy), Feb 2013
Disease detection: optical techniques/algorithms development

Different approaches applied in lab/greenhouse and in field conditions

- Point-wise spectrophotometry at leaf and sub-leaf scale
  - Characterizing optical features for disease detection
  - Preliminary tests and algorithms reinforcing

- Fluorescence radiometry at multi-leaf/bunch scale, fluorescence imaging
  - Pre-visual sensing

- Transportable multi-camera imaging system at canopy scale
  - Multispectral, hyperspectral, RGB, monochromatic imaging
  - Multispectral imaging = sensing approach transferred to final application
Accuracy of CROPS precision spraying

Homogeneity of spray deposit on foliage improved by three sub-sprayings from different angles (3x 0.5 s, total spraying time 1.5 s)

Mean spot diameter $\approx 15$ cm

1.5 s spraying time equivalent to $AR = 380 \text{ L/ha}_{\text{canopy\_area}}$

Overall precision spraying inaccuracies lower 3 cm (or less if considered the fuzziness of spot size)

http://www.crops-robots.eu/media
CROPS validation experiments: one example of results

Objective: automatic detection and autonomous selective spraying of grapevine canopy areas exhibiting symptoms of Powdery Mildew

Results for the whole plot
One example of results: **robot vs reference**

Disease foci automatically detected and **robot operated** sprayings

- # Robot spray spots: 25
- 100% Disease sprayed [targets actually sprayed]
- 92% Avoid spray excess [area not to be sprayed actually left unsprayed]
- 84% Pesticide reduction [compared to homogeneous spraying at same application rate]

CROPS platform was able:

- to treat 85-100% of the targets (depending on the disease stage)
- to **remarkably reduce pesticide** use compared to conventional homogeneous treatments (always reached about 90% of the maximal reduction, i.e. sprayed area strictly necessary to treat all the foci)
CROPS dissemination material

Presentations, papers, videos and dissemination at www.crops-robots.eu
There is a long list of lessons learned and some relevant success in autonomous crop management demonstrated in the field, such as:

- cooperation of multiple systems is a key issue for complex task in agricultural environment
- modular, reconfigurable, multifunction platforms is feasible and strategic for cost/benefit sustainability
- optimizing crop environment /workspace is a key issue to boost performance and cost/benefit ratio (e.g. CROPS apple harvest was successful also because addressing crops architecture)
- robotics advances can contribute in reducing production costs of high-value crops, by extending working time and production timeliness and avoiding repetitive, intensive manual operations
- but also can contribute in disclosing new high-precision operations in crop management and in favoring high-educated jobs in agriculture and services
- robotics modules (hw, sw,) and concepts ready for transfer/vision to advanced Ag Machinery to which manufactures could pay attention