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Assessing a fleet of robots for herbicide applications

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Abstract

Advanced technologies are critical for safe, site-specific and efficient control of pests (weeds, pathogens and insects) in agricultural crops. Although the scientific and technological bases of precision crop protection are mostly known and robust, the commercial application of these new technologies is still very limited. To overcome this situation, new farming methods and processes should be designed. Modern approaches rely on existing information and communication technologies (ICT) and design and construction of improved pest and crop sensors, along with enhanced pest control actuators. Mobile platforms are essential to move the needed sensors and actuators throughout the work field. Moreover, by using autonomous mobile platforms equipped with innovative perception techniques, data processing systems and tools for action, pest control procedures can be applied only if, when and where they are needed, reducing costs, environmental damages and risks for farmers. This article describes the RHEA fleet of robots highlighting the concepts and analyzing the results achieved on the application of herbicide on wheat with a spray boom.

Keywords: robot fleet, crop protection

1. Introduction

The EU-15 required more than 208,000 tons of pesticide in 2008 (http://www.ecpa.eu/information-page/industry-statistics-eu-15-total) to maintain food production. This represents a major economic burden for farmers and a substantial chemical load on the environment. Advanced technologies are critical for safe, site-specific and efficient control of pests (weeds, pathogens and insects) in agricultural crops. Although the scientific and technological bases of precision crop protection are mostly known and robust, the commercial application of these new technologies is still very limited. To overcome this situation, new farming methods and processes should be designed. Modern approaches rely on existing information and communication technologies (ICT) and design and construction of improved pest and crop sensors, along with enhanced pest control actuators. Mobile platforms are essential to move the needed sensors and actuators throughout the work field. Moreover, by using autonomous mobile platforms equipped with innovative perception techniques, data processing systems and tools for action, pest control procedures can be applied only if, when and where they are needed, reducing costs, environmental damages and risks for farmers.

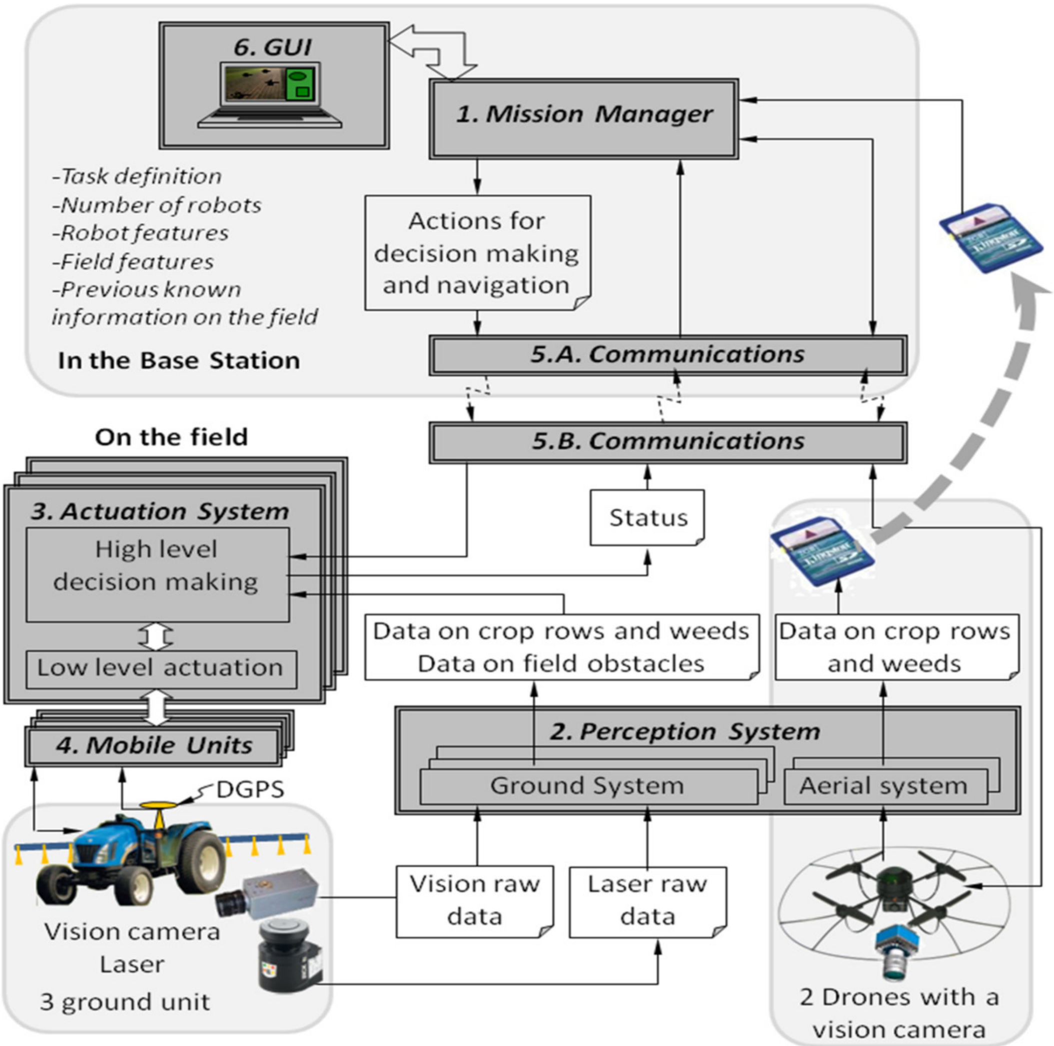


Fig. 1. *RHEA system breakdown*

Focusing on these ideas, the RHEA Consortium funded by the 7th EC Framework Programme has been involved in the configuration of a new generation of automated and robotic systems for both chemical and physical management of pests. A fleet of small, heterogeneous cooperative robots (Unmanned Ground Vehicles, UGV and Unmanned Aerial Vehicles, UAV) equipped with advanced perception systems, improved end-effectors and enhanced decision-making algorithms are being tested and evaluated in three scenarios: a) chemical weed control in winter wheat crops, b) physical weed control in maize crops, and c) application of insecticides and/or fungicides in olive trees.

The system is broken down into six main modules organized hierarchically:

1) mission manager (Ribeiro et al., 2011; Conesa et al., 2012),

2) graphic user interface,

3) perception system (aerial and ground) (Rabatel et al., 2012; Guerrero, 2012),

4) actuation system – implements (Peruzzi et al, 2012; Vieri et al., 2012, Carballido, 2012),

5) mobile units (UGVs and UAVs), and

6) localization and communication systems (Hinterhofer et al., 2011).

Figure 1 illustrates the interconnections of these modules and Figure 2 gives a general view of the fleet.

Fig. 2. *RHEA fleet*

2. Materials and methods

Two kinds of missions are tackled in RHEA: (1) a scouting or inspection mission, made by the aerial units that carry the remote perception system and (2) the treatment mission performed by the ground units, equipped with the appropriate implements.

The aerial unit is a hex-rotor with a structure of 2.20 m diameter and a weight of 4.5 kg. This drone has a big reach, 5,000 m, and a long flying time of about 40 minutes.

Regarding the remote perception system, it is based on 2 DP2 Merril cameras that, among other features, supply a high image quality (around 4,800×3,200×3 layers, i.e. 46x106 of pixels), great color, optically excellent lens and a full manual control. Furthermore, the NIR blocking filter has been removed in one of the two cameras turning it into a NIR camera. Finally, each camera is integrated in a mechanical device, which is fixed under each drone, and its shot can be controlled from the drone's software. Figure 3 displays an image of one aerial unit, carrying the camera as well as the sequence of operations that are performed over the aerial images acquired in order to get a weed map, which can then be used in treatment missions.

On the other hand, ground mobile units are based on a CNH Boomer-3050. The tractor cabin has been removed and the space available has been used to host the onboard computer, the communication equipment, the GPS (RTK) receiver as well as the tractor controller. Other specific elements have been integrated outside the vehicle such as a camera system, a laser (Guerrero et al., 2012), emergency buttons, GPS antennas - connected to the GPS receiver (a Trimble® BX982 GNSS receiver), which accurately provides the heading and location of the vehicle, and the communication system antennas.

The herbicide sprayer is a device integrated by a 6 m spray bar with 12 nozzles, that can be independently activated, and 2 tanks. The main tank has a capacity of 200 L and the secondary one has a Direct Injection System (DIS) that allows injecting the chemicals directly at the end of the bar, avoiding mixing the herbicides with water in the main tank before the treatment application. With the DIS, it is possible to recuperate the surplus of herbicide, providing important environmental and economic advantages. Both tanks are supplied with optical sensors that check the liquid volume in the tank.

Finally, Figure 4 illustrates the architecture of the Base Station (BS). It shows the Mission Manager, which can be split into three types of modules according their functionality, those devoted to the mission planning, AMP for aerial units (inspection mission) and GMP for ground units (treatment mission), those in charge of the mission supervision, AMS for aerial mission (inspection mission) and GMS for ground units (treatment mission), and the MMD (Mission Manager Dispatcher) or the module that controls the workflow of the BS. Other important modules that run in the BS are: 1) the Aerial Unit High Level Controller (AUHLC); 2) the Weed Mapping System (WMS), related to the remote perception system, and composed by the orthorectification and Mosaicing System (MS) and the Weed patches detection system (WM); and 3) the Graphical User Interface (GUI) where the model of the real system is represented in 3D and the operator can interact in different ways to obtain more information about the fleet as well as real time information about whatever mission currently in execution. Operator can also send commands to all elements involved in a RHEA mission by using the GUI. The simulation model used by the GUI is based on the Webots simulation software and includes realistic physic simulation, sensors, and actuators simulation. At last, note that the high-level module that controls the aerial units (AUHLC), is executed in the BS while in the case of the ground mobiles units, such module (HLDMS) is run in the computer onboard the vehicle.

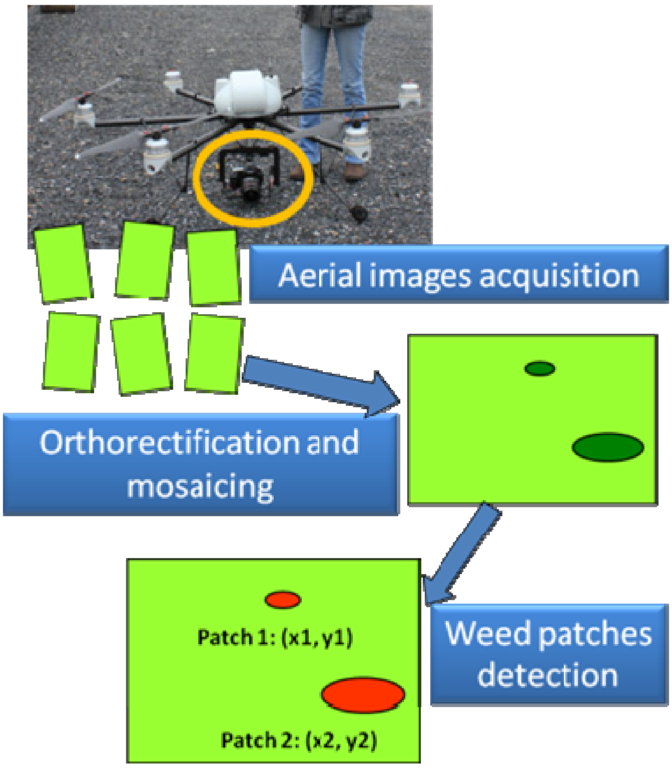


Figure 3 – Aerial unit carrying the remote perception system. Sequence of operations performed over the set of aerial images in order to get the weed map of a crop.

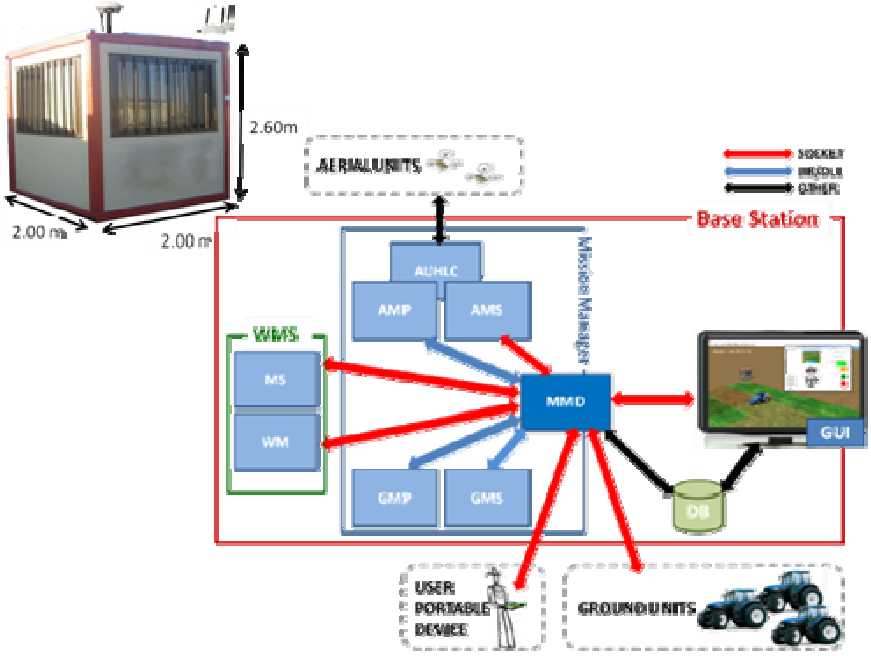


Fig. 4. *Physical place where the Base Station devices are housed. Base Station architecture*

A preliminary demonstration was conducted with the described system in a conventional winter wheat crop field, on January 30, 2014. The demonstration included the evaluations of the GMU-implement mission, the safety system and the fleet integration. For the first two evaluations, nine weed patches with size 3 m x 3 m were planted following a regular grid in a wheat field of 60 m x 40 m. Within the GMU-implement mission, the accuracy of herbicide spraying (i.e., on/off time lag, % targets sprayed, % target not sprayed and % non-target sprayed), and the GMU trajectory deviation from the route plan were evaluated (See Figure 5).

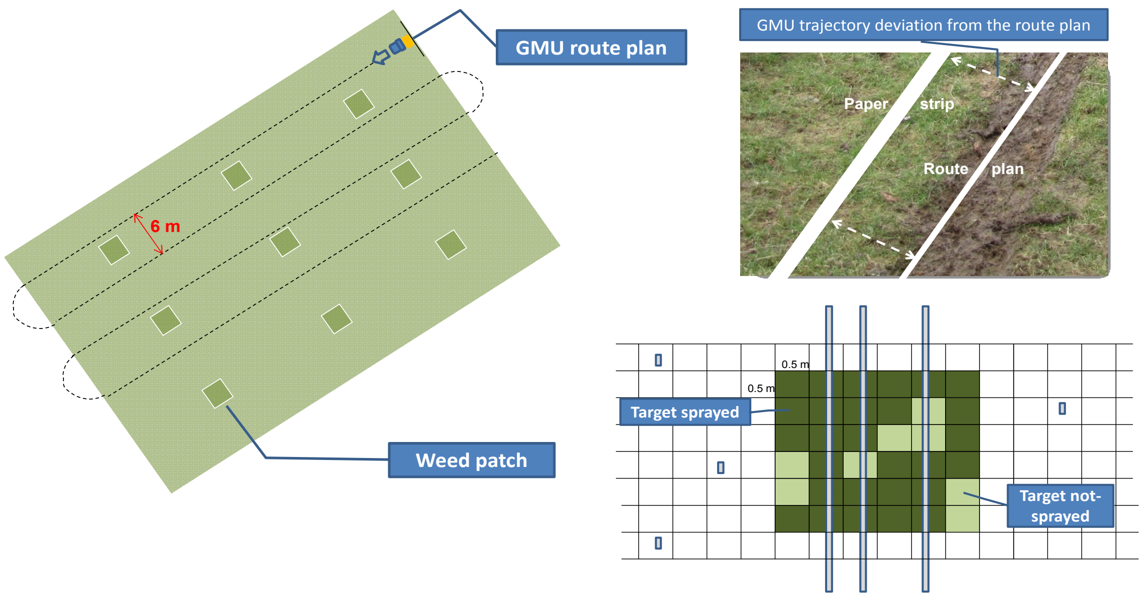


Fig. 5. *Left: Outline of the wheat field 60 m x 40 m showing the GMU route plan and the nine weed patches 3 m x 3 m. Top right: Method for measuring the GMU trajectory deviation from the route plan (paper strip). Bottom right: Method for checking the accuracy of herbicide spraying by paper strips located in the patch (on/off time lag, % targets sprayed and % target not sprayed) and paper labels outside the patch (% non-target sprayed).*

The assessment of fleet integration checked whether all three GMU working together followed the defined route plans (Figure 6). The evaluation of the safety system was carried out in an adjacent field uncultivated (fallow) of dimensions 40 m x 15 m, where the detection of ISO3411 standard obstacle and human person at normal working speed were checked in both the camera and laser systems.

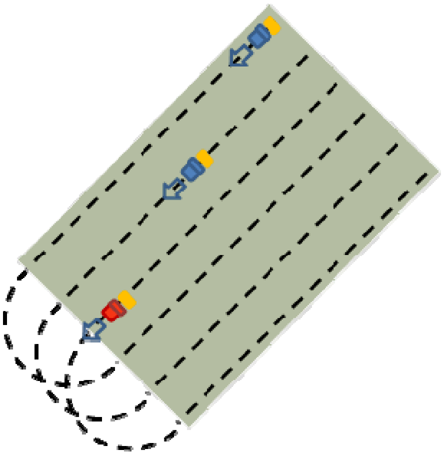


Fig. 6. Outline of the wheat field 60 m x 40 m showing all the three GMU working together following the defined route plan.

3. Results and Discussions

The evaluations conducted in the preliminary demonstration showed that the trajectory followed by the GMU barely deviated from the defined route plan pointing out high accuracy. Indeed, in the two tests performed mean deviation was less than 7 cm from the planned route (Figure 7).

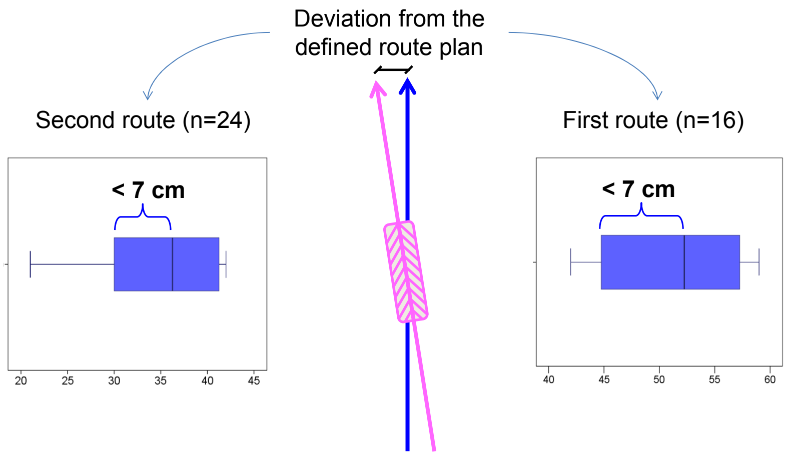
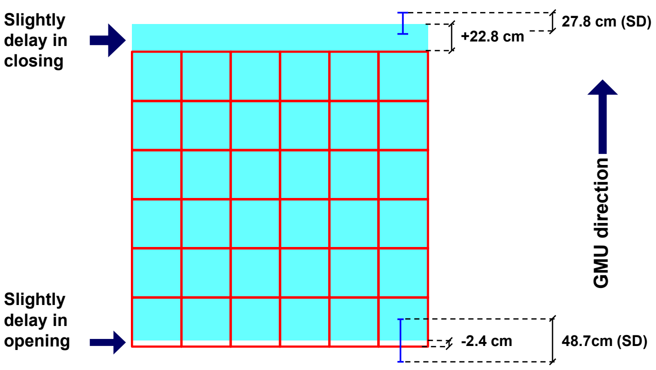


***Fig. 7.** Deviation from the defined route plan measured in the two sampled routes.*

Regarding the accuracy of spraying herbicide, over 95% of the target area was sprayed while non-target area was 0% sprayed, showing no failure in the spraying operation. However, a slight delay in the opening and closing of the nozzles was observed (Figure 8).

***Fig. 8.** Precision in the opening and closing of the herbicide spray nozzles.*



Furthermore, because the cells to be treated were 0.5 m x 0.5 m, when the cells located at the border of the patch were partially treated in the first direction the GMU, then when return GMU these cells were marked as treated and the nozzle was not opened (Figure 9).

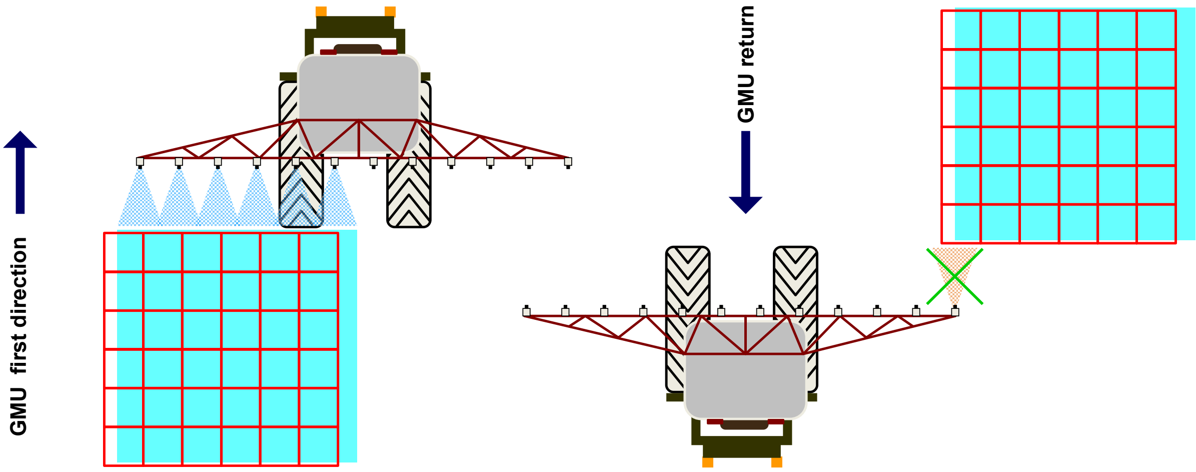


Fig. 9. *Failure in opening the nozzle edge since 0.5 m x 0.5 m cells were treated previously partially.*

Regarding the evaluation of the fleet integration, the preliminary demonstration results have shown that all three GMU working together followed the defined route plans. In addition, the safety verification showed that the camera and the laser systems detected accurately static and moving objects, ordering in both cases the detection of the GMU.

4. Acknowledgements (optional)

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