Automation and robotics for workers health and safety improvements in pot-plant nurseries

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Objectives

The pot-plants sector is very important in European agriculture, and employees a considerable number of workers. Most operations are still manually performed and many of them are critical for worker health and safety (Belforte et al, 2006). Pots handling is one of the most repetitive and heavy operations forcing workers to hazardous postures for musculoskeletal apparatus, whereas the high number of pesticide applications determines a strong exposition to toxic substances.
Robotic systems and automated machines able to perform repetitive and/or dangerous tasks could significantly facilitate and make safer the work in pot-plants nurseries where millions of pots are grown every year.
This paper discusses operations that can be conducted by automated, specific machines and presents the design of a multipurpose autonomous robot customized for pot-plants nurseries as well as other protected cultivations. Particular attention if focused on the control of the steering and path following systems.

Methods

Pot-plants are usually arranged in plots in greenhouses, walks in tunnels or outdoor. Crop unitary operations have been analysed observing workers in different periods of the crop cycle. The proposed robot has been conceived to operate on crops navigating over plots in autonomous way, by means of a ground reference consisting of a plastic strip laid on floor (for a detailed description of the system see Comba et al., 2012). The basic element is a four driving and independent steering wheels (4WIS) rover able to host different kind of implements. Propulsion and steering system will be implemented by electric motors installed into four wheel-modules and supplied by a generator or, in some specific cases, batteries. In order to change the wheels track, adapting it to the plots and corridors width, wheel modules are connected to the rover chassis by means of a pivot system. A number of 4WIS vehicles has been developed in the last decade (see e.g. Bakker, 2010; Cariou et al, 2009; Oksanen 2012; Simionescu & Talpasanu, 2007). All these vehicles use virtual links, implemented in the control software, to drive the four steering angles of the wheels. In particular most part of them refer to the Ackermann steering kinematic model to avoid the need for tyres to slip sideways when following the path around a curve (Simionescu & Talpasanu, 2007).
However, the narrow spaces in which the robot has to navigate in pot-nurseries make the Ackermann kinematic model (alone) unable to obtain the expected results. A 4WIS system,

with the steering angles of the four wheels really independent, can be able to follow a wider range of paths, allowing also sharp angles (not differentiable points in the path). This geometric driving system can allow to the rover to move in very crowded environment where only very narrow and sharp paths can be design.

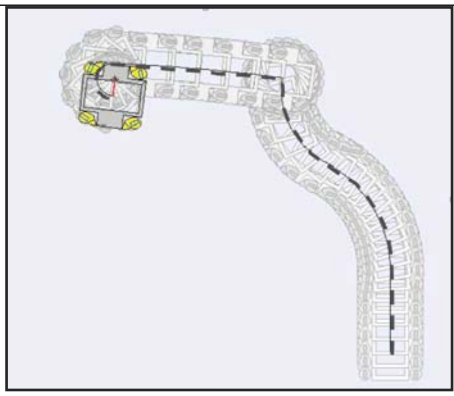

Figure 1: An example of feasible path which involves different kinematics models

Results

The introduction of a multipurpose autonomous robotic platform in the pot-plants farms will lead to significant improvements in terms of work safety as well as reduction of production costs. Pesticide applications will be carried out in automatic way avoiding the exposition of workers to dangerous compounds (Sammons, 2005). A precise distribution will also allow reducing the overall quantities of chemicals as well as the amount of pollutant scattered in the environment. At the same time, a number of highly repetitive tasks, such as pots handling, trimming and granular fertilization could be automatically performed by the robotic platform developing specific implements.

One of the most relevant open problems in the design of such kind of machines, which have been addressed in this work, is the control of the 4WIS module, once a viable path has been designed and assigned. There are some difficulties in solving this optimization problem. The main criticism relies in the definition of a criterion for determining whether a solution (set of steering and driving angles) is feasible or not. Some recent approaches (see e.g. Lun Lam et al., 2008) are based on the minimization of the wheel lateral force and/or of the slipping. The method proposed in this work is based on the adoption of a set of different kinematics (geometric) models that are implicitly feasible and described by a limited number of parameters. The optimization is then performed splitting the whole path in variable-length segments and associating to each of them the best kinematics model (with the respective parameters). An example of a not-smooth trajectory with a sharp edge is reported in Fig.1. As can be seen, the path of the robot is composed by different segments; in each of these segments a different kinematic models and/or parameterization has been choose by the optimization and control algorithm.

References

Bakker, T., Van Asselt, K., Bontsema, J., Muller, J., Van Straten. G. (2010). Systematic design of an autonomous platform for robotic weeding. Journal of Terramechanics, 47, pp. 63-73.

Belforte, G., Deboli, R., Gay, P., Piccarolo, P., Ricauda Aimonino. D. (2006). Robot Design and Testing for Greenhouse Applications, BioSystems Engineering, 95(3), pp. 309-321.

Comba, L., Gay, P., Piccarolo, P., Ricauda Aimonino, D. (2010). Robotics and automation for crop management: trends and perspective, International Conference on "Work Safety and Risk Prevention in Agro-food and Forest Systems", Ragusa, Italy.

Comba L., Finéz Martìnez S., Gay P., Ricauda Aimonino D. (2012). Reliable low cost sensors and systems for the navigation of autonomous robots in pot-crop nurseries. First RHEA International Conference on Robotics and associated High-technologies and Equipment for Agriculture, Pisa, Italy, 19-20-21 September.

Cariou C., Lenain R., Thuilot B., Berducat M. (2009). Automatic Guidance of a Four-Wheel-Steering Mobile Robot for Accurate Field Operations. Journal of Field Robotics, 26(6–7), 504–518

Lun Lam T., Qian H., Xu Y. (2008) Behavior-based steering control for four wheel independent steering vehicle. Robotics and Biomimetics, ROBIO 2008. Proc. of IEEE Int. Conf. on Robotics and Biomimetics, 536-541, Bangkok, Thailand, 22-25 February 2009

Oksanen T., Path following algorithm for four wheel independent steered tractor, CIGR-AgEng 2012 Conference, 8-12 July 2012, Valencia, Spain, con CD.

Sammons, P.J., Furukawa, T., Bulgin, A. (2005). Autonomous pesticide spraying robot for use in a greenhouse. Proceedings of the Australasian Conference on Robotics & Automation, Australia.

Simionescu P.A., Talpasanu I. (2007). Synthesis and analysis of the steering system of an adjustable tread-width four-wheel tractor. Mechanism and Machine Theory, 42, 526–540

Slaughter D, Giles D, Downey D. (2008). Autonomous robotic weed control systems: A review. Computers and electronics in agriculture, 61 (1), pp. 63-78.