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DEVELOPMENT OF A TRAINING PROGRAM FOR ENHANCING THE USE OF ICT TOOLS IN THE IMPLEMENTATION OF PRECISION AGRICULTURE

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Lecture 4: Robotics in Crop Farming

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Contents

1 Objectives

The objectives of this lesson are:

- Give an overview of the needs, target application domains and use of robots in field crops
- Understand the different levels of autonomy in the domain of weed control and hoeing and fruit harvesting.

Note that some insight of robotics in livestock farming are given in the introduction module.

2 Tutor instructions

This is a 2h lesson in presence. This presentation will lead the attendant to get an overview from mechanization to fully autonomous systems for crop farming.

3 Robots in Agriculture

Slide 3 from document Lecture_Robot_AS.pptx

The worldwide market of Ag Robotics is growing exponentially.

Slide 4 from document Lecture_Robot_AS.pptx

Ag robots can be classified according to a Technology Readiness Level (TRL) scale. It appears that robots used for animal production correspond to a mature market compared to most of applications in crop production. An intermediate situation is found for weeding bots.

Another classification is made by Bechar et al., based on 2 functionalities :
- The need for contacts with the environment (soil or vegetation)
- The need for prehension (ex fruit picking)

These two functionalities may require more or less complex control systems in addition to all functionalities already implemented to move the robot in an open field context, for example.

Slide 5 from document Lecture_Robot_AS.pptx

Three levels of Crop Bots functionalities can be distinguished and Slide 6 from document *Lecture_Robot_AS.pptx* introduces level II that corresponds to a situation where the robot has to deal with physical contact with the soil or the vegetation but no prehension is required.

4 Level II: Autonomous Weeding

4.1 Context and issues

Slide 7 from document *Lecture_Robot_AS.pptx*

Autonomous robotic weeding still requires some developments in order to become a mature technology.

Slide 8 from document Lecture_Robot_AS.pptx

Manual hoeing has been a traditional but laborious and fastidious necessity for the development of agriculture. Nowadays, the global trend to minimize the use of herbicides in modern agriculture has renewed the interest for this field operation while limiting manual operations.

4.2 Mechanical hoeing and other weeding solutions

Slide 9 from document Lecture_Robot_AS.pptx

Mechanical Hoeing is a logical answer. However alternative techniques were developed with thermal weeding but the cost of gas is a limiting factor to the development of this technique at large scale (Slide 10 from document *Lecture_Robot_AS.pptx)*

Slide 11 from document Lecture_Robot_AS.pptx

Other alternatives were studied with steam weeding technique but the cost as well as the productivity are limiting factors.

Slide 12 from document Lecture_Robot_AS.pptx

Electrical weeding has developped based on the use of an electrical arc between an electrode and the plant. A second electrode is connected to the soil. Since the electrical arc passes through the whole plant, it has a systemic action.

Slide 13 from document Lecture_Robot_AS.pptx

Examples of autonomous AgBots used for weeding:

University Illinois – USA https://csl.illinois.edu/news/illinois-team-looks-robots-not-chemicals-weed-free-crops-future

Ladybird (University Sydney - Australia) is an autonomous solution for scouting but also mechanical weeding
https://www.sydney.edu.au/news/84.html?newsstoryid=13686

RIPPA (University Sydney - Australia) applies micro doses of herbicide:
https://www.sydney.edu.au/news-opinion/news/2015/10/21/rippa-robot-takes-farms-forward-to-the-future-.html

AgBot II Queensland University of Technology Australia : https://research.qut.edu.au/future-farming/projects/robot-platform-design-agbot-ii-a-new-generation-tool-for-robotic-site-specific-crop-and-weed-management/

Slide 14 from document Lecture_Robot_AS.pptx

Agriointelli - Denmark : https://www.agrointelli.com/

BoniRob2 (video)

Lincoln Uni and Norvegian Uni of Life Science. Thorvald : https://www.robot-advance.com/EN/actualite-robotics-and-agriculture-thorvald-the-savior-111.htm

Slide 15 from document Lecture_Robot_AS.pptx

France : CENTEOL, OZ, Vitibot were the early technologies on the market

Slide 16 from document Lecture_Robot_AS.pptx

Productivity is a bottle neck for the development of mechanical hoeing in the past. It wasn't able to respond to fast weed emergence

Slide 17 from document Lecture_Robot_AS.pptx

New generations of AgBots in France, however the question of the productivity and economical interest is still raised.

Slide 18 from document Lecture_Robot_AS.pptx

An intermediate way is develop smart hoeing (using artificial vision) as travel issues are given to a tractor driver as a first step. Travel speed can be about 10km/h

Agronomic – France : 3D camera https://www.agronomic.eu/desherbage-mecanique/bineuses/

Carre – France : row detection using ultrasonic sensors or photoelectric cells https://www.carre.fr/entretien-des-cultures-et-prairies/guidage/?lang=en

Garford – UK https://garford.com/ ; https://garford.com/products/robocrop-guided-hoes/

Steketee – NL: https://www.steketee.com/camera-technology/

F. Poulsen DK : http://www.visionweeding.com/

4.3 Solutions adapted to large fields

Slide 19 from document Lecture_Robot_AS.pptx

Interest of smart hoeing in a context of large farms. Smart hoeing is combined with tractor autoguiding.

Slide 20 from document Lecture_Robot_AS.pptx

Developing autonomous smart hoeing for large fields : the example of RHEA European Project. See more details here : http://www.rhea-project.eu/

Slide 21 from document Lecture_Robot_AS.pptx

Following the idea of converting a traditional tractor to a robot, the example of Xpert from Precision Makers : https://precisionmakers.com/en
In this case the system learns from manual operations (steering, PTO management, etc. and copycat

4.4 The impact of machine size/weight

Slide 22 from document Lecture_Robot_AS.pptx

Ag Robotics development is also inspired by the idea of a smart and agile fleet of small machines rather than a single big machine. Benefits are found in the decrease in soil compaction that is highly sensitive. This slide explains the main factors affecting soil compaction.

Slide 23 from document Lecture_Robot_AS.pptx

Examples of alternatives to big Ag. machines is presented here. RHEA Project aimed at using fleets of drones to scout agricultural fields that will be cultivated by fleets of small robots.

The “3rd way” is a concept studied at IRSTEA (INRAE) based on a semi autonomy principle (master-slave concept). Only one tractor has a driver, two other machines are just following and work accordingly.

Slide 24 from document *Lecture_Robot_AS.pptx*
Developing robotics for high agricultural productivity is a challenge in an open field context. This slide introduces a awarded industrial project leading to manage 5 field operations in a flat 50 ha corn field.

4.5 Precision Hoeing in the intra-row

Slide 25 from document Lecture_Robot_AS.pptx

Another issue of mechanical hoeing is the restriction to inter-row weeding. In general, intra-row mechanical weeding is not really possible for row crops. Main applications are found in vineyards and orchards (intercep technology). In the case of row crops, a prototype was studied at UC Davis, California. In-the-row knives are automatically retracted in order to avoid the cultivated plants. The detection can be by image analyzis or after a RTK GPS aided seeding (Slide 26 from document *Lecture_Robot_AS.pptx*). vision techniques used for inter-row weeding are adapted to intra-row operations.

Slide 27 from document Lecture_Robot_AS.pptx

More complex algorithmes are used to detect weeds in the intra-row area. Weed detection can be operated using multispectral information, leaf morphology, image texture or plant height.

Slide 28 from document Lecture_Robot_AS.pptx

Deepfield robotics uses deep learning techniques https://www.farming-revolution.com/

Slide 29 from document Lecture_Robot_AS.pptx

Intelligent Localized Spray project
Ecorobotix solutions : https://www.ecorobotix.com/en/
Blueriver : https://bluerivertechnology.com/

Slide 30 from document Lecture_Robot_AS.pptx

F. Poulsen Thermal weeding. http://www.visionweeding.com/removing-weed-in-rows-of-sugar-beets-with-flames-of-propane-without-herbicides/

Low energy laser weeding : https://www.harper-adams.ac.uk/research/project/185/weed-management-using-low-energy-lasers-alone-and-in-combination-with-low-dose-photosynthetic-electron-transport-inhibitors

Weedelec : electrical weeding INRAE : http://challenge-rose.fr/en/projet/weedelec2017-2/

Slide 31 from document Lecture_Robot_AS.pptx

The integration of all functionalities (scouting, detection, analysis and weeding) on the same machine can problematic because the whole machine is dependent on the slowest process of the chain. That’s why alternative solutions based on specialized elements are studied. Example of RHEA Project where optimization criteria were studied: time, energy, level of infestation, etc.

Slide 32 from document Lecture_Robot_AS.pptx

Another way of integrating technologies is to improve spatial accuracy and to plant seeds with a parallel or diamant pattern using a GPS RTK. The robotization of hoeing (diagonal travels) but also other cultivation operations (harvesting bots) may be also eased.

Slide 33 from document Lecture_Robot_AS.pptx

Example of a mechanical tree planting to ease further hoeing and forestry applications

4.6 Autonomous mowing

Slide 34 from document Lecture_Robot_AS.pptx

Following commercial domestic applications, Autonomous Mowing is also an application domain of robotics in Agriculture.
Vitirover – France : https://www.vitirover.fr/en-home

Slide 35 from document Lecture_Robot_AS.pptx

Precision Makers : GreenBot https://precisionmakers.com/en

5 Level III : robots allowing physical contacts and prehension

5.1 Examples

Slide 36 from document Lecture_Robot_AS.pptx

This category corresponds to picking/harvesting robots that are mostly concepts and prototypes event though some commercial solutions arise on the market. Slide 37 from document *Lecture_Robot_AS.pptx*

Slide 38 from document *Lecture_Robot_AS.pptx*
Since fruit and vegetable harvesting is mostly a manual task, it is laborious and fastidious. There is a great interest to develop mechanical harvesting up to autonomous solutions. University of Florida did compare mechanical citrus harvesting with a robotic solution.
https://www.energid.com/industries/agricultural-robotics

In New Zeland a poly-function autonomous vehicule was designed for orchards *http://www.roboticsplus.co.nz/multipurpose-orchard-robotics*

Slide 39 from document Lecture_Robot_AS.pptx

Another application to fruit picking in California.
https://www.abundantrobotics.com/

Slide 40 from document Lecture_Robot_AS.pptx

Example of a EU – Chile project on robotics for crops: crops
http://crops.sweeper-robot.eu/

5.2 Necessity of a convergence of robotics and agrosystems

Slide 41 from document Lecture_Robot_AS.pptx

Locks are found when developing robots for agriculture :
- Select the environment for basic robots (ex orchard intra - row)

- Or adapt the crop to ease the passage and work of robots (pruning options, crop size, planting strategies, …)

Slide 42 from document Lecture_Robot_AS.pptx

The complexity of a tree in an open orchard makes things much complicated. Here is a comparison of fruit picking ion 3 different tree architecture : central Leader, Tall Spindle or Y trellis. The cost (ex computing time, movements, etc…) for harvesting can be more than two to three times greater depending on the number of Degrees Of Freedom (DOF).

Slide 43 from document Lecture_Robot_AS.pptx

An example of simplified systems using a single arm for fruit picking
https://www.ffrobotics.com/

Slide 44 from document Lecture_Robot_AS.pptx

Fruits are generally fragile and smart prehension systems are needed. Here are two examples:
A flexible microactuator
A tentacle gripper : https://www.festo.com/group/en/cms/12745.htm

6 Level I: Robots without physical contact nor prehension used for scouting, transport, spraying.

Slide 45 from document Lecture_Robot_AS.pptx

Slide 46 from document Lecture_Robot_AS.pptx

Assistance to the operator in carrying heavy loads and tools is much appreciated in agriculture. BAUDET ROB Project was aiming at developing this kind of solutions. Among different techniques, a 2D Lidar is used to scan the environment and to follow the operator.

Slide 47 from document Lecture_Robot_AS.pptx

Autonomous conveyors are also usefull in the field to carry loads.
https://www.windegger.eu/en

Slide 48 from document Lecture_Robot_AS.pptx

Two example of mature stage field robots :
Cäsar is devoted to field operations in vines and orchards : tillage, fertilization, plant protection and harvest (Uni Dresden – Germany)
https://www.raussendorf.de/en/fruit-robot.html

TED (NAIO France) is a straddle robot for mechanical weeding in viticulture
https://www.naio-technologies.com/en/agricultural-equipment/vineyard-weeding-robot/

Slide 49 from document Lecture_Robot_AS.pptx

Combining several simultaneous actions is a way to gain some productivity at low travel speed

Slide 50 from document Lecture_Robot_AS.pptx

Parallel functionalities can be mowing and spraying, (Cäsar)
Mechanical Weeding and mowing or spraying (NAIO TED)

Slide 51 from document Lecture_Robot_AS.pptx

A straddle robot as seen previously is a large equipment. An alternative solution can be found using autonomous equipments working each side of the vine row but following each other in parallel.

Slide 52 from document Lecture_Robot_AS.pptx

Crop survey (proxidetection) has numerous applications in Agriculture
VINBOT : https://robotnik.eu/projects/vinbot-en/

INESTEC: https://www.inesctec.pt/en/centres/cras

VINEROBOT https://cordis.europa.eu/project/id/610953/fr

7 Main challenges and opportunities

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Issues still to be challenged in agriculture robotics

Slide 54 from document Lecture_Robot_AS.pptx

Technological and scientific locks for the development of AgBots

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More constrains on the field of application

Slide 56 from document Lecture_Robot_AS.pptx

Full (integrated) automation of agriculture is an emerging concept

Slide 57 from document Lecture_Robot_AS.pptx

The number of functionalities to be integrated gets numerous : 3 point hitching or Syn-trac coupling system, automatic fuel refill, battery charging, etc.

Slide 58 from document Lecture_Robot_AS.pptx

One issue to be raised concerns the safety aspects considering autonomous vehicles : obstacle detection and tool retracting, dynamic instability of autonomous vehicle and definition of a safe working area for robots in open fields.

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Slide 60 from document Lecture_Robot_AS.pptx

Slide 61 from document Lecture_Robot_AS.pptx

8 Related links

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