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

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Lecture 2 : Structure of an Automated System

Authors: INRAE

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Contents

1 Objectives

The objectives of this lesson are:

- Give an overview of the basic functionalities of an Automated System
- Understand the Structure of an AS and the role of each component
- Understand more specifically the role and means for operative systems

2 Tutor instructions

This is a 2h lesson in presence. This presentation will lead the attendant to get an overview of the structure of Automated Systems (AS) with an insight on operative systems.

2.1. Functionalities of AS

(Slide 3 to slide 10 from document *Lecture_StructureAS.pptx*)

These slides aim at describing different levels of functionalities for the steering and guiding of a tractor with more or less autonomy.
Slide 4 introduces the basic hydraulic steering system allows a proportional action on the steering ram through the action of steering cylinders from the action on the steering wheel. It is to be noted that this full-hydraulic system is quite old and unique in agriculture and public works machines. It corresponds to a complete system including a control stage (with a hydraulic distributor connected to the steering wheel) and a power stage (hydraulic motor connected to steering cylinders). The system is also able to work as a pump in close circuit in case the power supply is not effective.
See animation for further details:
https://powersolutionslearningresources.azurewebsites.net/danfoss/resources/animations/index.html

Slides 5, 6 and 7 from document *Lecture_StructureAS.pptx*

Many commercial systems are existing, some examples:
Trimble : https://agriculture.trimble.com/solutions/guidance-steering/
John Deere : https://www.google.com/search?client=firefox-b-d&q=john+deere+steering+guiding+solutions

Slide 8-9 from document *Lecture_StructureAS.pptx*

U turns or K turns or swallow tail turns can be now automated.
An example of different phases is given on slide 9 that can be commented/deduced by the participants.

This link provides much documentation and videos https://agriculture.newholland.com/nar/en-us/precision-land-management/products/guidance-steering/integrated-steering-intelliturn

slide 10 from document *Lecture_StructureAS.pptx*
introduces a higher level of autonomy with the replication of trajectories and PTO settings for example with a sprayer or a seeder.
Additional information here : https://precisionmakers.com/en/x-pert

Slides 11 to 32 from document *Lecture_StructureAS.pptx* illustrate the different functionalities through interactions between the AS and the environment and the operator

Slide 12 from document *Lecture_StructureAS.pptx*
Focus on the action of the operator on the Machine including one or several automated system(s). The example of the tractor guidance is chosen. In this case, the operator set the information in terms of travel or guidelines.

Slide 13 from document *Lecture_StructureAS.pptx*
In accordance to the settings, the Machine acts is as to apply the prescription in terms of wheels orientation. This require the help of a Power chain and an Action Chain : the steering wheel of a tractor cannot directly act on the wheels.

Slide 14 from document *Lecture_StructureAS.pptx*
Feedback from the environment can be taken into account by the machine without specific action from the operator (example slopes, soil resistance, etc)

Slide 15 from document *Lecture_StructureAS.pptx*

Using the Man Machine Interface (MMI) the machine informs the operator about the current situation. This example shows a guiding system where the position of the tractor is manually adjusted following the initial prescription of the operator.

Slide 16 from document *Lecture_StructureAS.pptx*

However, since open field situation may be complex (and not fully controlled by sensors or the Machine itself), the operator may be directly informed about the environment

Slide 17 from document *Lecture_StructureAS.pptx*
Introduces concepts of information, power and action chains

2.1.1 The information chain

Slide 18 - 22 from document *Lecture_StructureAS.pptx*

Introduces the information chain with sensors (cf. AgrICT Training Package N°3. Different levels of information are combined, compared and processed using different types of logics.
Information is also given through communication between the operator and different interfaces using protocols and ports.
Higher levels of complexity are illustrated with slides 21 and 22 from document *Lecture_StructureAS.pptx* with supervised systems and remote controlled systems that find applications in the fleet management or IoT for example.

2.1.2 The power chain

Slide 23 from document *Lecture_StructureAS.pptx*
Illustrates on main function of the power chain is to feed the system with power. The example is a schematic representation of the feed of a 3 Phase electrical motor.

Another example is given on Slide 24 from *Lecture_StructureAS.pptx* with the feed line of a pneumatic ram. Additional functions are shown here in terms of logic level or signal inpt level

Slide 25 from document *Lecture_StructureAS.pptx*
Another functionality of the power chain is the conversion of energy. In this case the energy from the gasoil is successively converted into thermal, mechanical, hydraulic and mechanical energies.

Slide 26 from document *Lecture_StructureAS.pptx*
The Power is also dispatched simultaneously to several sub-units mechanical energy is provide to the PTO (Power Take Off) and Gear box and hydraulic energy is provided to the 3 point linkage and the steering.

Slide 27 from document *Lecture_StructureAS.pptx*

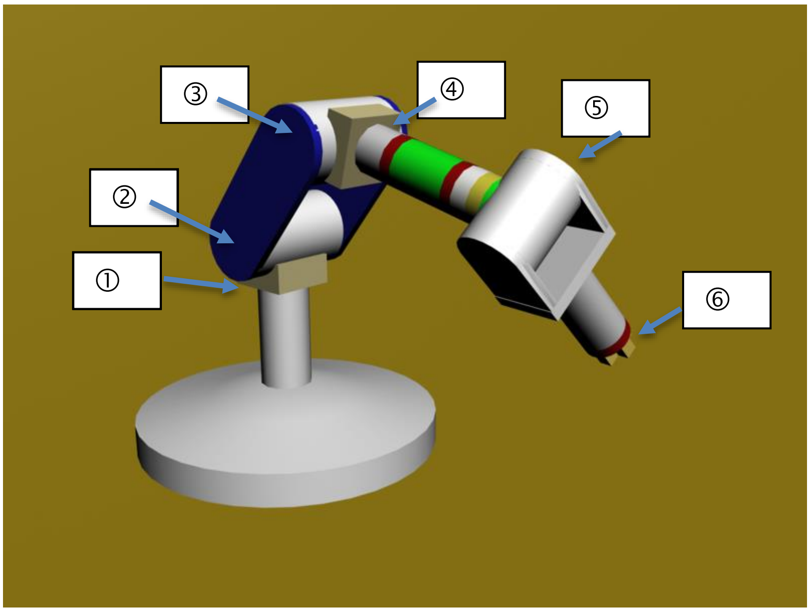
The dispatch of energy for different actions can also be illustrated by a kinematic chain. This basic concept of mechanical engineering is an assembly of rigid bodies/pieces by joints. It can be illustrated by a schematic representation of the links between the bodies. Basic movements represent rotations or translations that makes that any object has potentially 6 degrees of freedom (3 translations in X,Y and Z) and 3 rotations. An open loop kinematic chain means that there is at least one object linked only to one other object. A Close loop kinematic chain means that every object has two connections linked to a fixed frame. The global amplitude of movements in both cases (Slide 27 from Lecture_structure AS.pptx) is different.

Slide 28 from document *Lecture_StructureAS.pptx*

This slides illustrates the Transfer Action as part of The POWER CHAIN under the form, for example, of gear train found in a rotary harrow. In general, this transfer may include a reduction or an amplification of the revolution speed.

Slide 29 from document *Lecture_StructureAS.pptx*

Another example with a robotic arm including 6 pivots

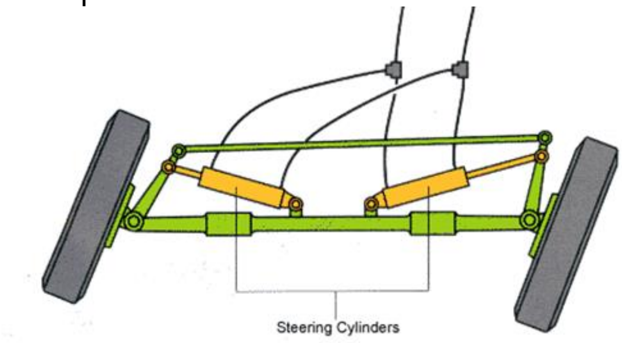


As only 1 axis (X,Y or Z) is allowed for each pivot only one degree of freedom is provided by each pivot.

2.1.3 The Action Line

Slide 30 from document *Lecture_StructureAS.pptx*
The Action Line corresponds to interface between the Power line and the environment. This interface encomprises both actuators where the energy can be converted (ex a steering ram linked to the steering rod) and end effectors.

The example is given with the steering mechanism where the actuator correspond to rams and end effectors to the rods.



Slide 32 from document *Lecture_StructureAS.pptx*
Represents a synthetic overview of information/power and Action Lines including sub functionalities. The Automated System uses external information from MMI or other systems, gives order to the power line and uses feedback information from the power line.

2.2 Structure of an AS

Slide 33 from document *Lecture_StructureAS.pptx*
Gives an overview of the global structure of an automated system. This diagram applies for every type of machine/system. 3 main elements are part of the automated system:

- The Man Machine Interface
- The control part will be developed in the following presentation (See document *Lecture_ControlAS.pptx*)

The operative part including sensors and (pre) actuators will be developed further on this presentation from the document *Lecture_StructureAS.pptx*

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This automated systems applies guidelines form the operator and provides feed back as well.

2.3 Examples of Operative systems

Slide 34 from document *Lecture_StructureAS.pptx shows a historical automation on tractors. The principle is to adjust the plow depth through the resistance of the soil (draft control). The weight of the plow is supported by the 3 point linkage system resulting a mass transfer from the plow to the rear wheels but also from the front wheels to the rear wheels. The benefit of such system is found in terms of traction capability that is directly linked to the supported weight on the wheels.*
More details of the automated system are given in slide 35 from document *Lecture_StructureAS.pptx. The information of soil resistance is provided by the draft sensor directly located in the lower part of the linkage. The operator*

panel allows the operator to set a certain working depth according to average soil resistance. The system will act in order to maintain the current draft force as constant as possible. In case the soil resistance increases, the sensor informs the control unit that gives order to the hydraulic distributor in order to lift the plow. In case the soil resistance is lower, the plow will work deeper.

Draft control can be associated with a position control in order to limit lower positions of implements.

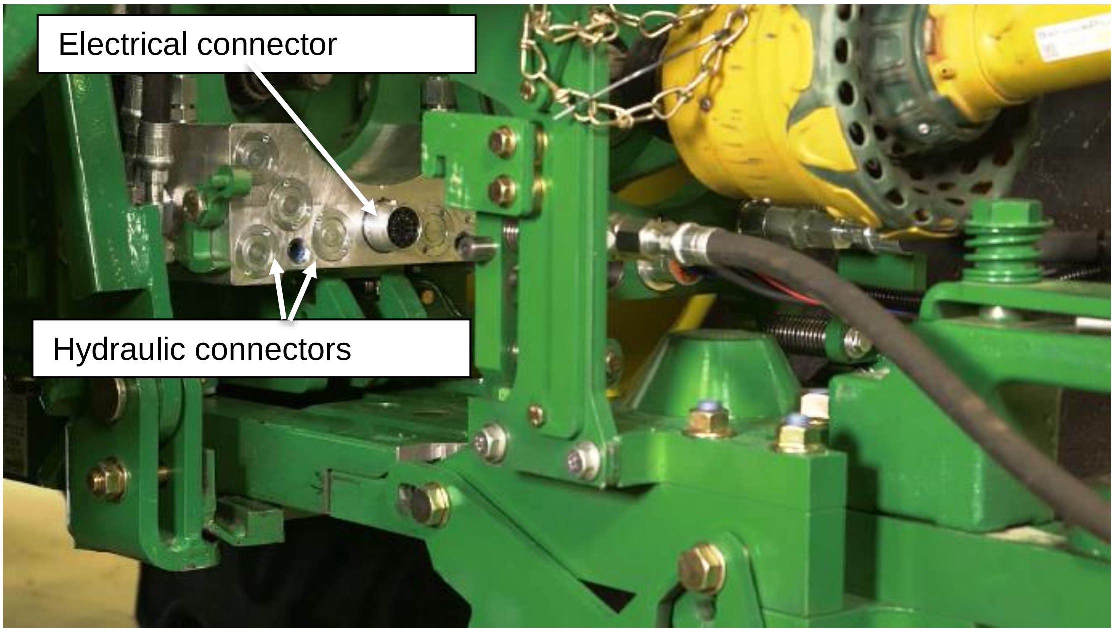
Slide 36 from document *Lecture_StructureAS.pptx*
Further developments associated with the draft control are the slip control were the depth of the implement can be adapted so as to limit the slippery of the wheels by using a Radar.
The slippery of wheels under traction conditions has a strong impact on soil compaction especially when the soil moisture content is important. It can lead to irreversible modifications of the structure of the soil.

In case the control unit compares the apparent travel speed of the tractor from the wheel revolution speed and the current travel speed provided by the Radar.
Additional functionalities to draft control are listed here

- Active oscillation damping : limits dynamic transfer from the implement to the tractor especially on the road
- Pressure control for weight transfer : can limit the hydraulic pressure in the hydraulic system
- Direct Weighting system using the draft sensor
- Lateral levelling system in order to compensate the length of the left and right linkage arms
- Diagnostic system : allows the auto diagnostic of malfunctioning
- Electronic bus connection (ex. CANbus)

Slide 37 from document *Lecture_StructureAS.pptx* shows an example of automatic linkage of a tractor and implement. Accidents occurring during the connexion of implements to 3 pont linkage are still numerous.

This system uses a camera for precise localization and a telescopic arm to connect the implement. (See videos included for operation). The PTO and hydraulic circuits are also automatically connected.



Slide 38 from document *Lecture_StructureAS.pptx* shows the principle of a DPA (in French: Débit Proportionnel à l'Avancement - Flow proportional to travel speed) function on a sprayer.

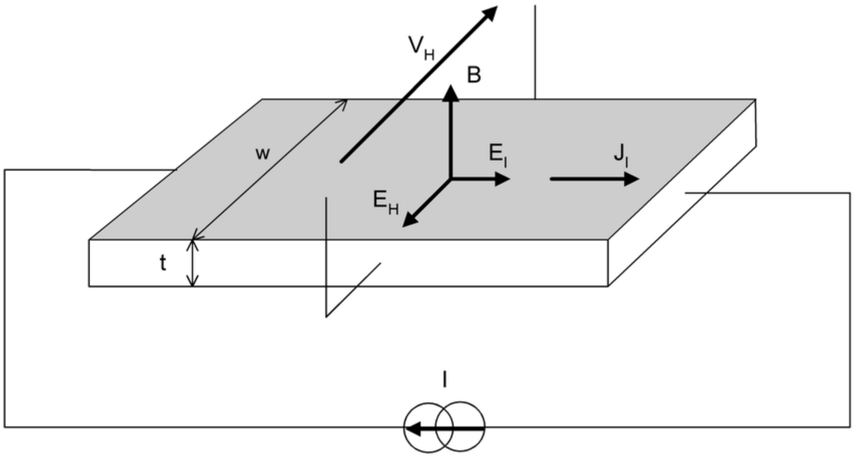
The main variables of a sprayer are linked together according to the following formula :

$$F = \frac{d\,W\,S}{600}$$

F : total flowrate l/min
d: dose rate (l/ha)
W : working width (m)
S: Forward speed (km/h)

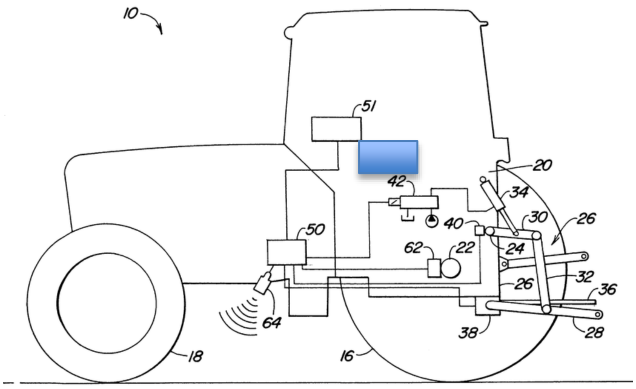
In case a variation of the travel speed occurs (due to a shift in engine RPM for example) this must involve a compensation in the total flowrate in order to maintain the dose rate as constant as possible.

DPA function requires a travel speed sensor. Common systems are based on Hall Effet with a sensor close to the sprayer wheel nuts. Each nut passing in front of the sensor generates a deviation of the magnetic field as is counted as one pulse.



Principle: a conductor plate is fed with an electrical current. When this plate is located close to magnetic field (B) that is perpendicular to the plate (B is vertical here), the Hall effect generates a voltage V_H that is proportional to the intensity of the magnetic field.
This type osf sensor is non contact, relatively robust and is widely used as position sensors, revolution speed sensors. In this last case there is generally one magnet on a bolt of a wheel.

Another type of speed sensor is a Radar '(RAdio Detecting And Ranging) generally mounted on the tractor equipped with slip control.



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The Radar generates a signal at a frequency of 2.4 GHz that corresponds to microwave wavebands. The signal is reflected by the ground and part of it is travelling back to the sensor. When the tractor is immobile, it acts like a telemeter. When the tractor moves, the delay between the emission and the reception is proportional to the travel speed.

The GPS system is already developed in TP2 of this training course.

Slide 40 from document *Lecture_StructureAS.pptx* illustrates other automated systems that can be present on modern sprayers and concerns the boom stability and terrain following.
The quality of the spray is highly dependant on the nozzle distance to the target for boom sprayers. Two cases are to be considered : i) the terrain following options for the entire boom or individual boom sections ii) the dynamic compensation of vertical boom movements.

Proximal sensors are typically used such as Ultrasonic sensors that corresponds to telemeters using a soundwave above 20 kHz. (case of Horsch boom control)
Alternative telemetry sensors are found with infrared laser systems.

Slide 41 from document *Lecture_StructureAS.pptx* shows another operative system that automatically shut the boom section off to avoid overdosing (right hand side of the picture) or to spray on a no spray zone.

This systems uses the GPS position that is affected to each boom section (or to each individual nozzle). Each part of the field already sprayed is not sprayed twice. This systems is often combined with a guiding system in order to optimize trajectories.

Slide 42 from document *Lecture_StructureAS.pptx*
The canopy detection is of great interest for bush and tree crop sprayers. It uses the information from either ultrasonic sensors or a 2D Lidar (that is a RADAR generally using infrared light). The no control situation (top left) is illustrated by sprays totally independent from the canopy size.
A first level of operative system is the canopy actuated system. Small blue triangles still correspond to sprays while bigger grey zones correspond to the sampling zone of ultrasonic sensors. As a consequence, boom sections are controlled according to the presence of vegetation or not.
A second level is based on the use of a Lidar (the sampling area is a portion of a disc. (Example Lidar SICK LMS 100, IR band 905 nm ; 50 rev/s, 0.5 degrees resolution, 270° angle). In this case, nozzles are activated individually according to the presence of the canopy and/or canopy density.

Both systems may lead to a significant reduction of plant protection product losses.

Slide 43 from document *Lecture_StructureAS.pptx*
Green houses typically see a large number of AS. The example here is a dosing system where the quantity of fertilizer or PPP can be adjusted proportionally to the quantity of water. It is a direct injection system with several advantages : no tank mix required, the product can be directly sucked from its container, limited wastes after rinsing. Sophisticated systems combine several systems and may adjust the dosing according to the agronomical needs.

A portable version of direct injection is shown on Slide 44 from document *Lecture_StructureAS.pptx.* This commercial system is able to manage the dosing of several liquids or powder simultaneously. However in most cases the range of dosing capability is sometimes limited and does not always accept the whole travel speed variability in the field during acceleration or deceleration phases.

Slide 45 from document *Lecture_StructureAS.pptx.*
This is an example of operative system in livestock farming used for the adaptation of cattle feed distribtors for concentrate or milk for the veals. The distribution is done according to the identification of the cow (RFID) and technical parameters linked to the milk production of this cow. .

In 2020 only 15% of milk farms were using a RFID marking on cows in France and mainly corresponded to 100 or more cows (25% equipped). http://idele.fr/domaines-techniques/sequiper-et-sorganiser/identification-rfid/publication/idelesolr/recommends/la-rfid-bovine-utilisee-essentiellement-par-les-eleveurs-laitiers/print.html (in French)

ISO Standards are existing for RFID badges : ISO 11784 (for HDX Half Duplex) and ISO 11785 for FDX (Full Duplex). In France 75% of RFID badges are HDX type that correspond to the standard system for concentrate or milk distribution.

Slide 46 from document *Lecture_StructureAS.pptx.*

This slide introduces a schematic representation of a greenhouse with all external parameters (meteorological) to be considered, internal parameters to be controlled and means of control for the following parameters:

Daytime and nighttime temperature inside and outside of greenhouses
Humidity, moisture, and CO2 levels
Light efficiency and sun radiation effect
Soil, watering, and draining measurements
Plant health and maturity
…
The list of parameters and means of control can be discussed with the participants

Slide 47 from document *Lecture_StructureAS.pptx*
This slide represent actuators and sensors used to control the climatic conditions in the greenhouse. The list of sensors and actuators can be discussed with the participants

Slide 48 from document *Lecture_StructureAS.pptx*
Operative systems in greenhouses can also have a high level of autonomy while robot arms can be used for manipulative actions in the greenhouse (right) or the picking of strawberries (left)

3 Related links

Ivan Margolius,'The Robot of Prague', Newsletter, The Friends of Czech Heritage no. 17, Autumn 2017, pp. 3 - 6. https://czechfriends.net/images/RobotsMargoliusJul2017.pdf Archived 2017-09-11 at the Wayback Machine

Karel Capek – Who did actually invent the word "robot" and what does it mean? at capek.misto.cz[*dead link*] – archive

Kurfess, Thomas R. (1 January 2005). Robotics and Automation Handbook. Taylor & Francis. ISBN 9780849318047. Archived from the original on 4 December 2016. Retrieved 5 July 2016 – via Google Books.

King, A. Technology: The Future of Agriculture. *Nature* **544,** S21–S23 (2017). https://doi.org/10.1038/544S21a

Zhao, Y., Gong, L., Huang, Y., Liu, C., 2016 A review of key techniques of vision-based control for harvesting robot. Computers and Electronics in Agriculture, 127, 311-323. DOI 10.1016/j.compag.2016.06.022

Driessen, C., Heutinck, L., 2015. Cows desiring to be milked? Milking robots and the co-evolution of ethics and technology on Dutch dairy farms. Agric Hum Values (2015) 32:3–20. DOI 10.1007/s10460-014-9515-5

John, A.J., Clark, C.E.F., Freeman, M.J., Kerrisk, K.L., Garcia, S.C., Halachmi, I., 2016, Review: Milking robot utilization, a successful precision livestock farming evolution, Animal (2016), 10:9, pp 1484–1492 © The Animal Consortium 2016 doi:10.1017/S1751731116000495