Agricultural robotics (in open fields)

From an **Auto-guided mobile platform** to a **Robotic platform !!**

(some scientific and technological challenges to address)

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Agricultural robotics :
A solution for mechanization in the future

- Demographic aspect: - continual decreasing of farm number
  [France : -3% per year in average since 93
  700 000 farmhouses (1993) -> 400 000 (2013)]

- Economic: - rarefaction of skilled labour

- Social: - reduction of hard working conditions/ repetitive tasks/ health operator
  - vehicle with walk-behind operator and musculoskeletal disorders
  - attractiveness of the sector thanks to new technologies

- Agronomic: - optimization of inputs
  - reduction of soil compaction
  - new approaches (ex: combined crops)

- Regulation: - suppression of chemical spraying by aircraft

Source CRAB et AXEMA

« Robotic systems » for open fields (low structured areas) : Still a challenge !!

Current Technological offers :
- prototype level

Exemples :

Ladybird

Australian Center for Field Robotics (ACFR)
Univ Sydney - Australie

Rowbot

Rowbot Systems LLC + Carnegie Robotics LLC
+ (Univ Carnegie Mellon)
USA Pennsylvanie - USA

BoniRob2

Applied Sciences Osnabruck Univ
+ AMAZONE + BOSH
(Allemagne)

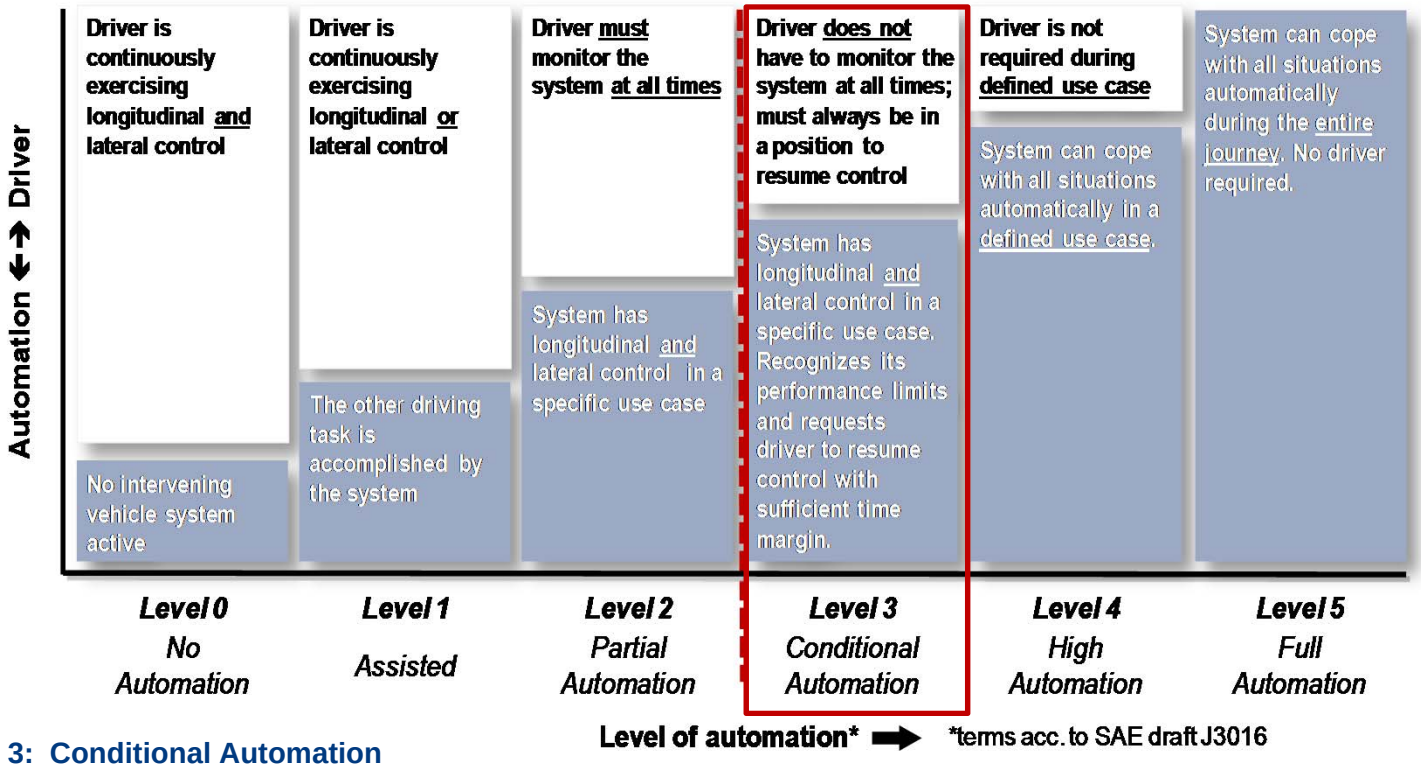
- few units on the market

Cäsar robot
RAUSSENDORF Gmbh
Univ Dresde – Fraunhofer MI
(Allemagne)

Current stage of Robotic Systems :
Auto-guided mobile platform without embedded driver

Path following by: GPS, Laser rangefinder, vision…
Obstacle detection : UltraSonic sensors belt, laser rangefinder,…

<=> Level 3 of SAE Classification / On-Road Motor Vehicle Automated Driving Systems



Level 3: Conditional Automation

Operator Activity : The driver doesn't have to continuously monitor the system

Limitations : The system identifies the limit of its own performances. Nevertheless, the system in not able to bring back alone to a minimum risk level in all the cases/situations.

Current stage of Robotic Systems : Auto-guided mobile platform without embedded driver => Remote operator !!

- Current monitoring solutions :

(**remote operator :**
- inside the field ?
- at the edge of the field ?
- outside the field ?)

A relevant question : How to well appreciate all remote issues in order **to reset and start again the machine** in automated mode in full security/safety ?

«From an Auto-guided mobile platform to a Robotic Platform»

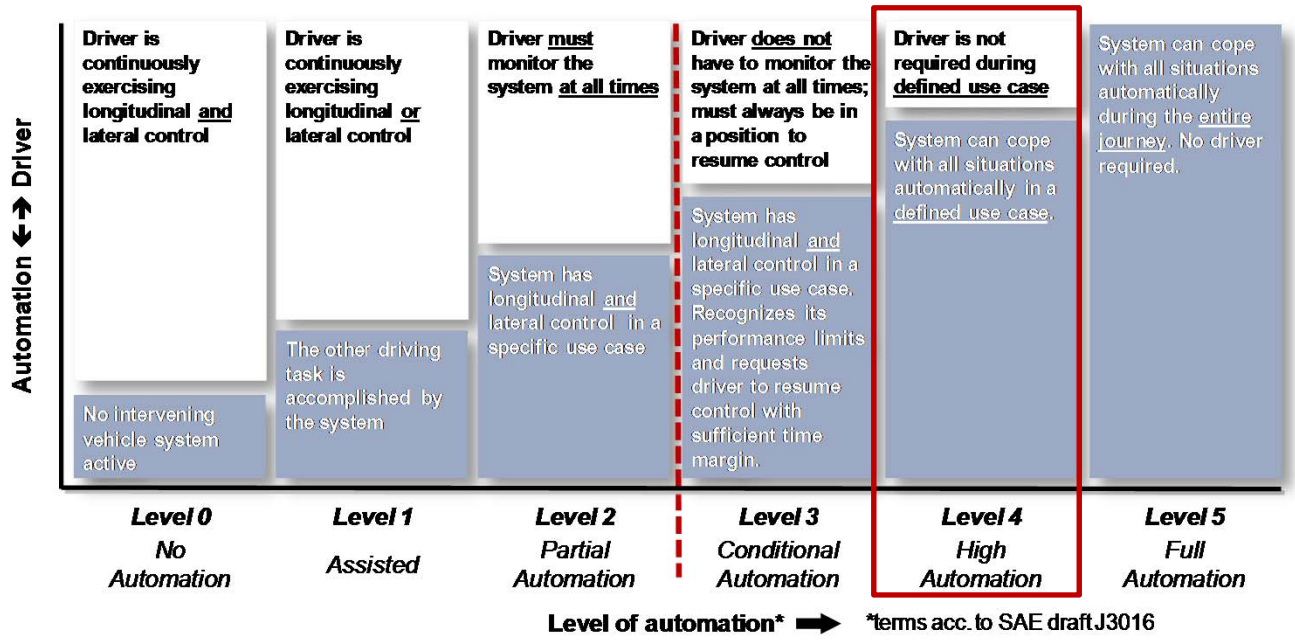
Challenge N°1 : ***To develop adapted devices for remote human operator in order to characterize all the complexity of the real situation and enable him to take right decisions for his action***

Examples of solutions : Virtual reality tools / Augmented tools

Robot = Ability to react itself to unforeseen events

Definition : « System with fitted intelligence and associated perception and control devices able to react itself to real time modifications (including unforeseen events) in the working space »

<=> Level 4 of SAE Classification / On-Road Motor Vehicle Automated Driving Systems



Level 4: High Automation

Operator activity: The driver doesn't have to continuously monitor the system

Limitations : The system identifies the limits of its performances and can automatically cope to all situations from usual cases. At the end of the usual case, the driver could take the vehicle control.

Robot = Ability to react itself to unforeseen events

«From an Auto-guided mobile platform to a Robotic Platform»

Challenge N°2 : ***To continuously identify and control the environment all around the machine under a large area in an anticipative manner***

Examples of solution :

- Dynamic mapping of the environment
- Construction / updating of Digital Terrain Models
  (DTM: obstacles, traversability, relief shape)

Ex : multi scanning laser rangefinder
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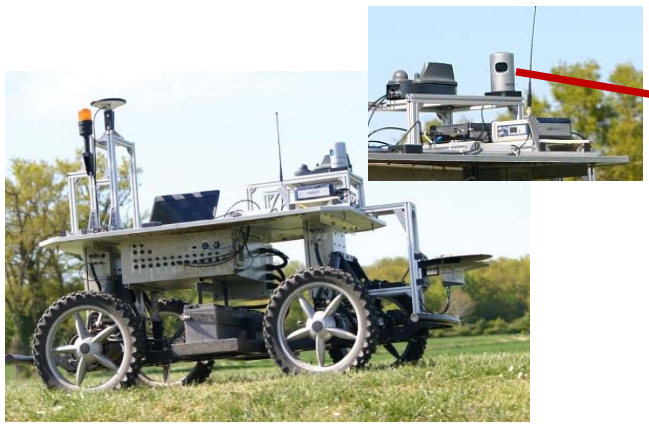

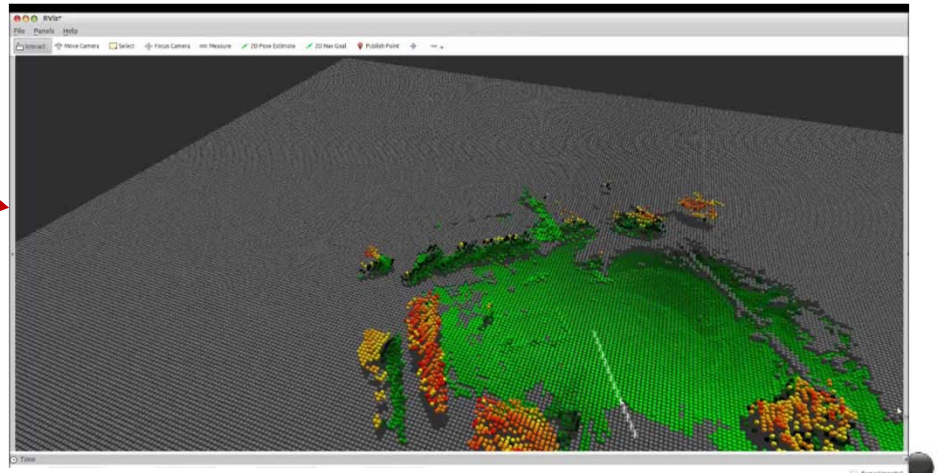

Robot = Ability to react itself to unforeseen events

«From an Auto-guided mobile platform to a Robotic Platform»

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Ex: PELICAN
Hyperfrequency panoramic radar
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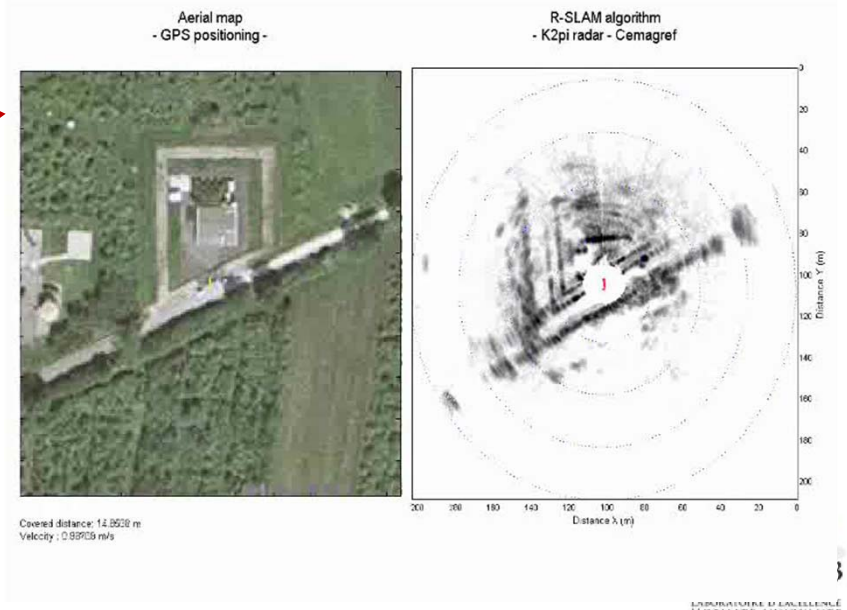

Robot = Ability to react itself to unforeseen events

«From an Auto-guided mobile platform to a Robotic Platform»

Challenge N°3 : ***To develop high algorithms decisional levels in embedded computer (supervision module)***

Example of solution: Updating and adaptation of the mission during its execution [navigation task, surveillance task,… of one (or several) robot(s)]

Ex:
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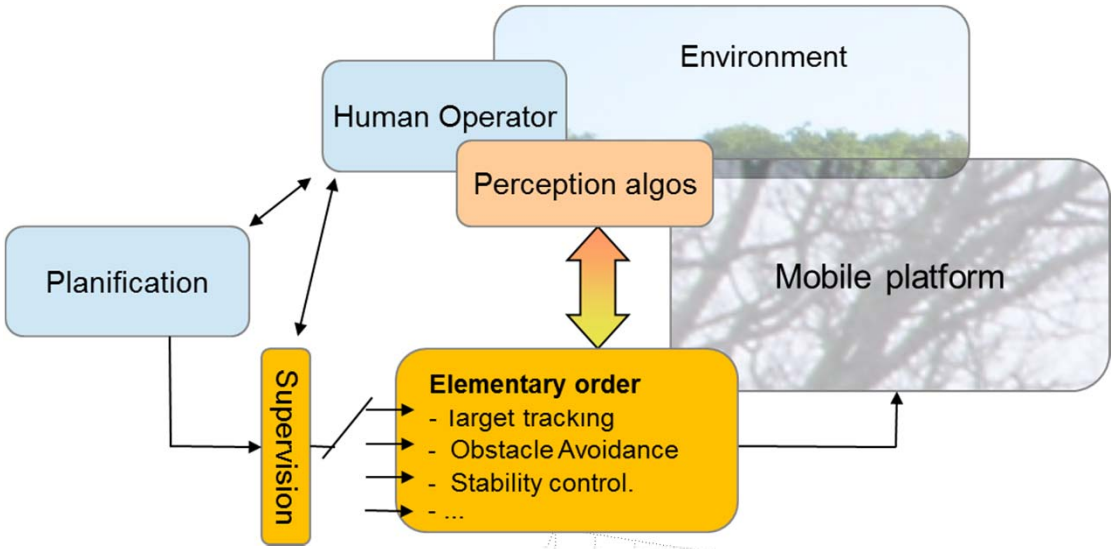
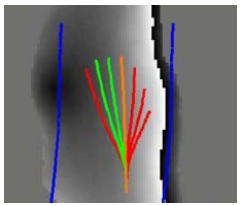
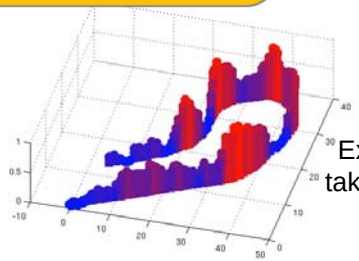


Ex: **Trajectory optimization** taking into account obstacle map (terrain traversability)





Ex: **Speed profile adjustment** taking into account terrain rugosity (terrain traversability)

Robot = Ability to react itself to unforeseen events

Current robotic platforms
(Auto guided mobile platform without embedded driver
«Conditional Automation" level)
working on :
- flat terrains
- low speed
- structured environments

=>

Future robotic platforms
(robot : *"High Automation" level)*
with increased performances
able to address :
- slope terrains
- sliding disturbances
- complex environments
- high speed
- …

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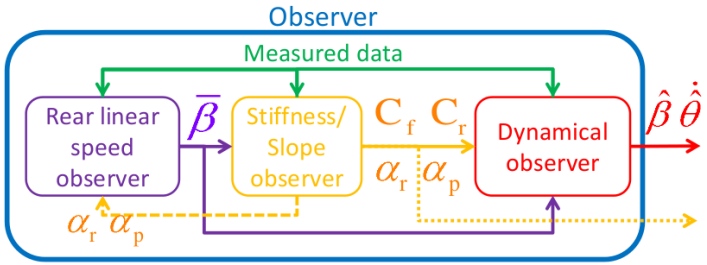
Robot = Ability to react itself to unforeseen events

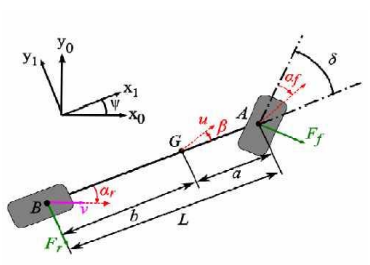
«From an Auto-guided mobile platform to a Robotic Platform»

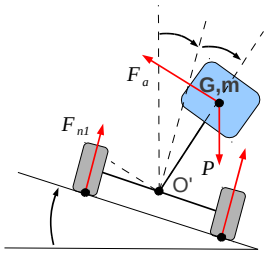
Challenge N°4 : ***Taking in consideration dynamic instability risk of the robot (vehicle integrity preservation)***

Example of solution: Active system to preserve from lateral and longitudinal overturning



Example: Irstea-TSCF developments

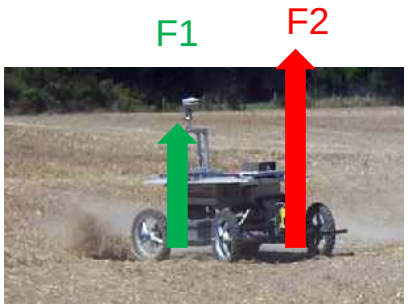




Estimation of dynamic loads (normal forces) on each side of the vehicle from inertial behaviour observations of the robotic platform

Lateral Load Transfert

$$LLT = \frac{F1 - F2}{F1 + F2}$$



Robot = High requirement level in term of safety guarantee

Safety of highly automated machinery: Start to establish a link with a potential existing frame of reference…

Annexe I

General Principles

« *The manufacturer of machinery or his authorised representative must ensure that a risk assessment is carried out in order to determine the health and safety requirements which apply to the machinery which he wishes to put on the market".*

1.1.2 Principle of safety integration:

"*a/ Machinery must be designed and constructed so that it fitted for its function, and can be operated, adjusted and maintained without putting persons at risk when these operations are carried out under the conditions foreseen but also taking into account any reasonably foreseeable misuse thereof.*

The aim of measure taken must be to eliminate any risk throughout the foreseeable lifetime of the machinery …

b/ In selecting the most appropriate methods, the manufacturer or his authorized representative must apply the following principles, in the order given:

- *eliminate or reduce risks as far as possible (inherently safe machinery design and construction)*
- *take the necessary protective measures in relation to risks that cannot be eliminated*

Ex: European «Machine» 2006/42/CE Directive

Robot = High requirement level in term of safety guarantee

Safety of highly automated machinery: Start to establish a link with a potential existing frame of reference…waiting in the future the availability of specific regulation framework

Ex: NF EN ISO 18497 Standard in construction (30/10/2014 Draft)

«The purpose of this future standard is to provide direction on the safety of highly automated agricultural machine operations »

(This standard will give means of complying with requirements of the 2006/42/CE machine Directive)

Examples of considered points:

- 3.11: Machine working areas – Four categories of controlled access area

- Category 1 : an area where access is controlled through fixed physical guards (walls, fence..)

- Category 4 : an area where access is uncontrolled and unmonitored (e.g.: typical farm field)

- 4.12 : Perception system

For all machine working areas as defined in 3.11, the perception system shall be able to detect obstacles in the machine hazard zone.

- 5.1 : Module Performance Integrity Test

The manufacturer shall be responsible for designing and conducting a lab simulation test that employs real world applicable field data. The test shall deliver at least 99,9966% success rate when detecting the obstacle. Test shall consist of 30 trials

Robot = High requirement level in term of safety guarantee

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Challenge N°5 : ***Take the necessary protective measures in relation to risks that cannot be eliminated***

Example of solution : “Electronic” fence all a round the working area

Travaux
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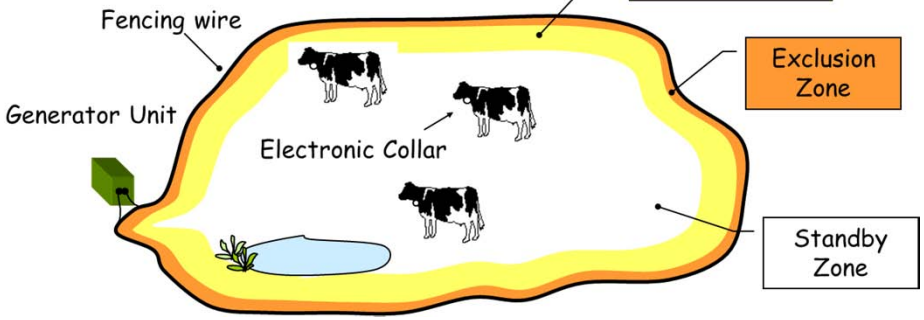

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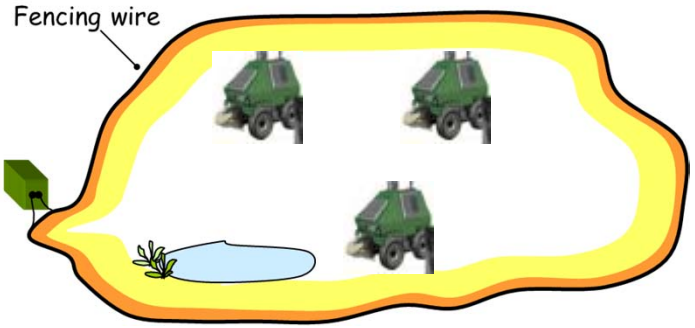
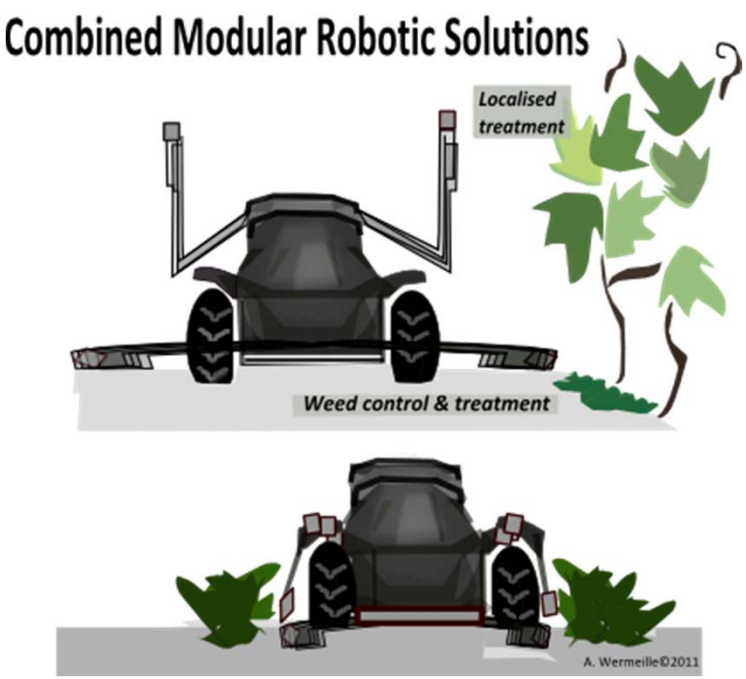


Ex: 2009 stakeless fencing for pastures for large area

Robot = Autonomy of the platform mobility
+ Control of the mobility of peripheral devices

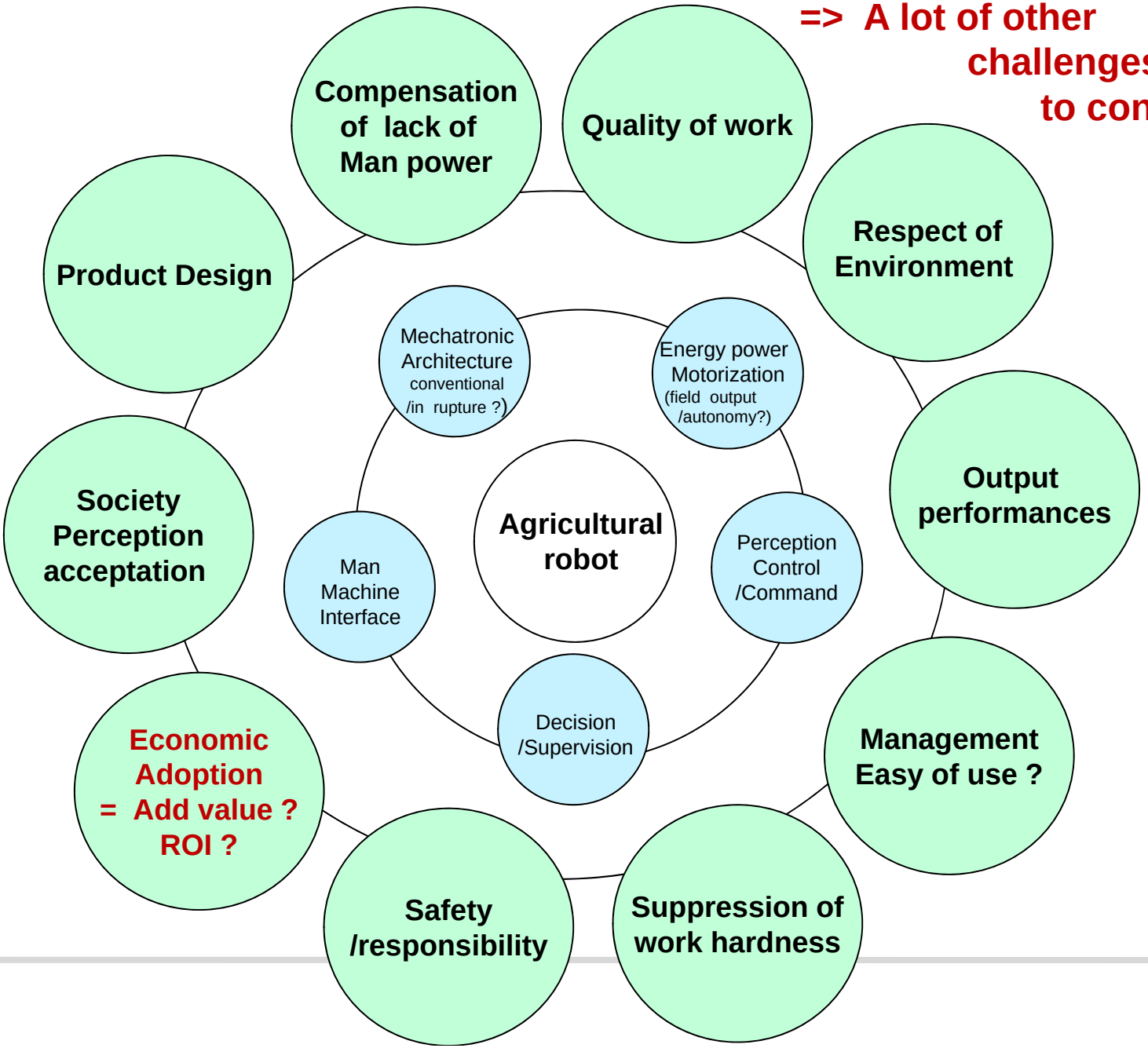
«From an Auto-guided mobile platform to a Robotic Platform»

Challenge N°6 : ***Control in a close interaction the mobile robotic platform with its associated tools*** *(more or less complex)*



Robotics for Agriculture : Not only a technological dimension

=> A lot of other challenges to consider



Thanks

You are welcome
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BAUDET-ROB : Robot for logistic assistance to Human operator

Thanks to all IMobS3 colleagues (Institut-Pascal, Irstea) involved in Mobility Research about Off-road Vehicles