Precision Agriculture, Autonomous Machines and Robotic Integration

Massimiliano Ruggeri CNR

STEMS

Consiglio Nazionale delle Ricerche

APPLICABILE SAFETY STANDARDS FOR AGRICULTURAL ROBOTS

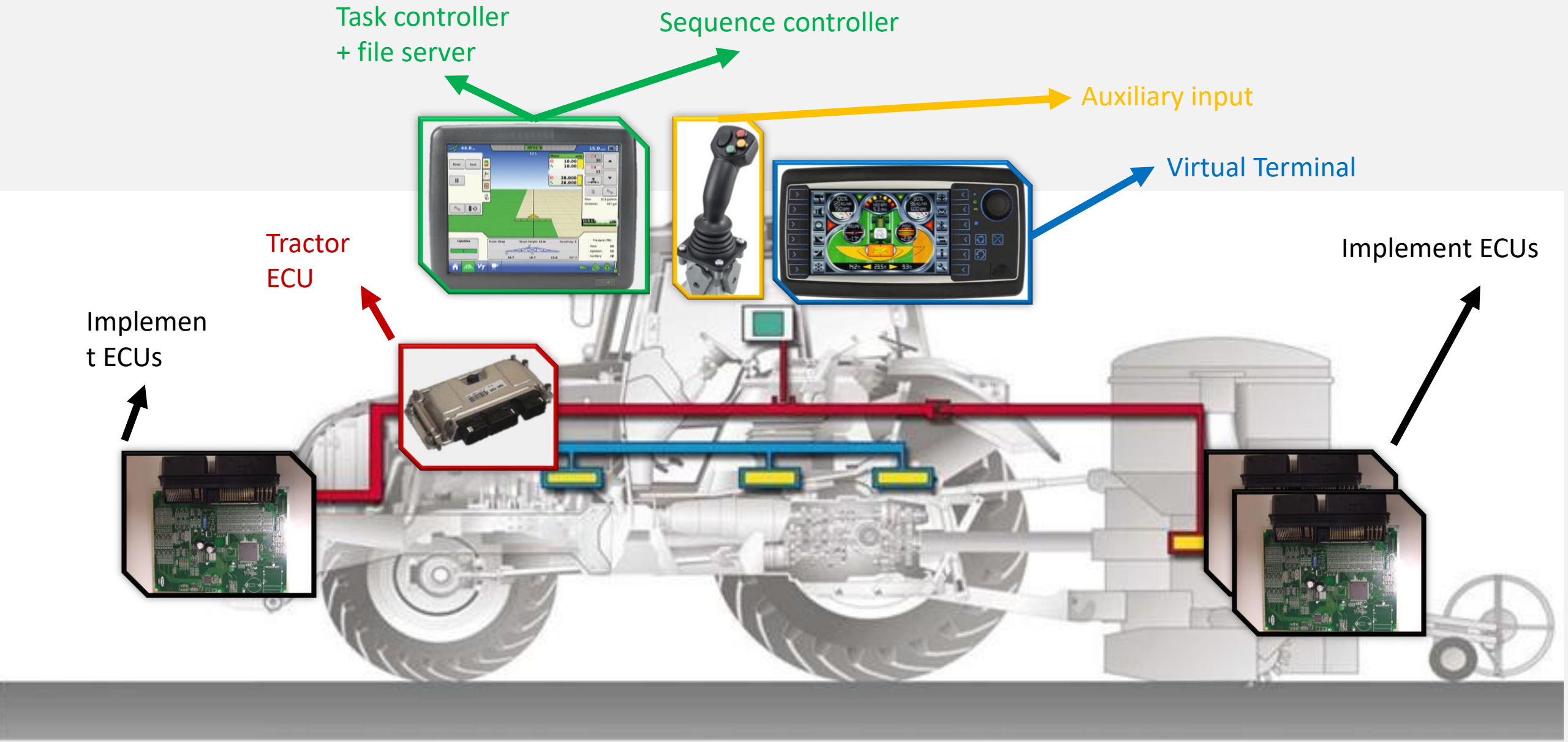
EU Directives

- Machine Directive is still applicable:
- Agricultural Tractor Directive for homologation:
  Regulation (EU) No 167/2013 of the European Parliament and of the Council of 5 February 2013 on the approval and market surveillance of agricultural and forestry vehicles Text with EEA relevance

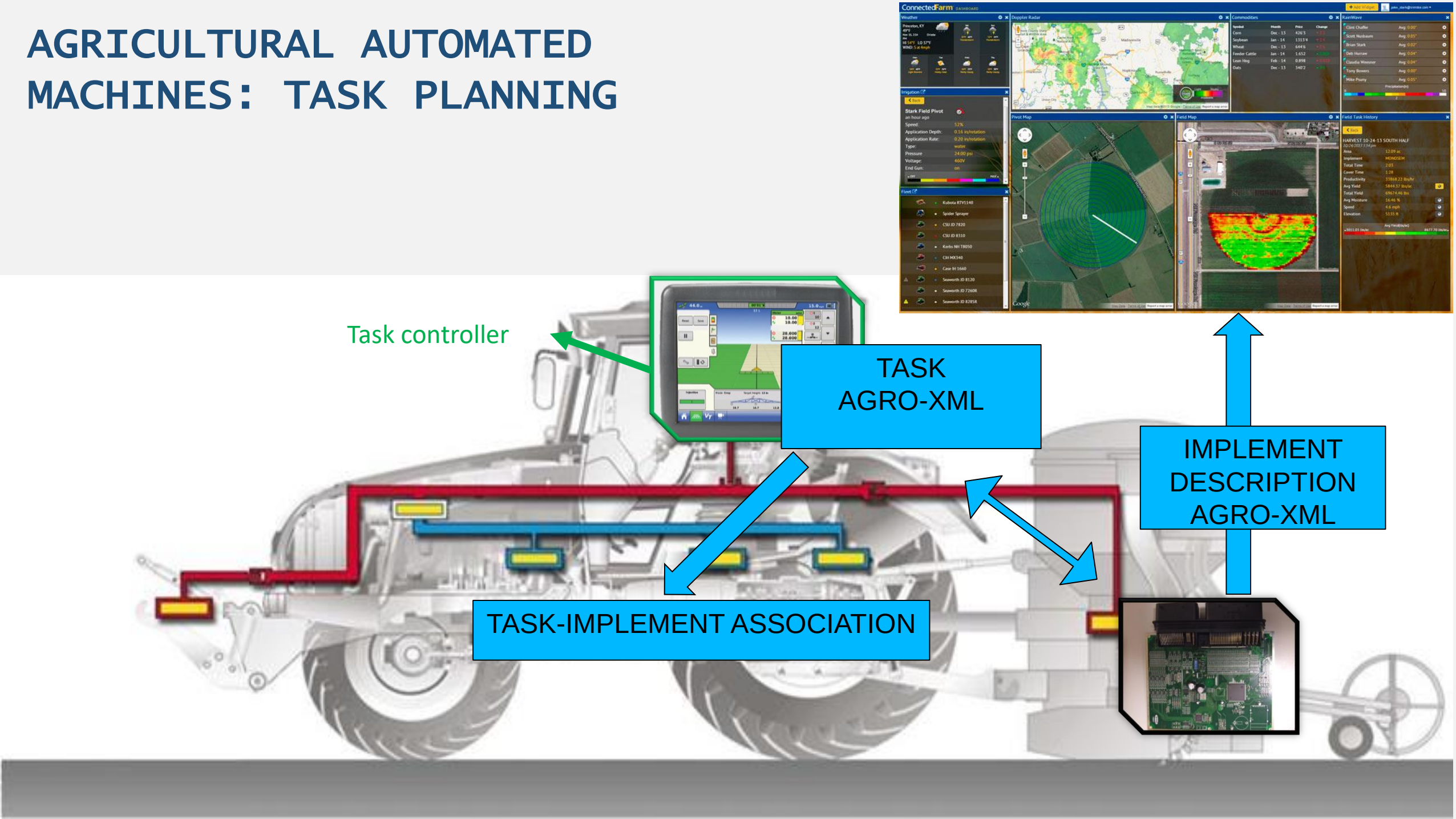
International Safety Standards

- ISO 25119 - Tractors and machinery for agriculture and forestry — Safety-related parts of control systems (parts 1 to 4)
- ISO 4254 - Agricultural machinery — Safety (parts 1 to 16)
- ISO 18497 Agricultural machinery and tractors — Safety of highly automated agricultural machines — Principles for design
- ISO 11783 Standard Communication Protocol for Agricultural Machines (ISOBUS)

AGRICULTURAL AUTOMATED MACHINES: ISOBUS



AGRICULTURAL AUTOMATED MACHINES: TASK PLANNING



TASK AUTOMATION AND ROBOTICS

On Line Field Analyzer: Real time optimized Variable Rate

Real “real-time” analysis

Online continuous monitor and learning for crop and soil model tuning inline and stress index for crops and water needs

100% automated control

The integration of real time control of ISOBUS implements offering a totally Antomated task optimization for a precise fertilization

Computer vision

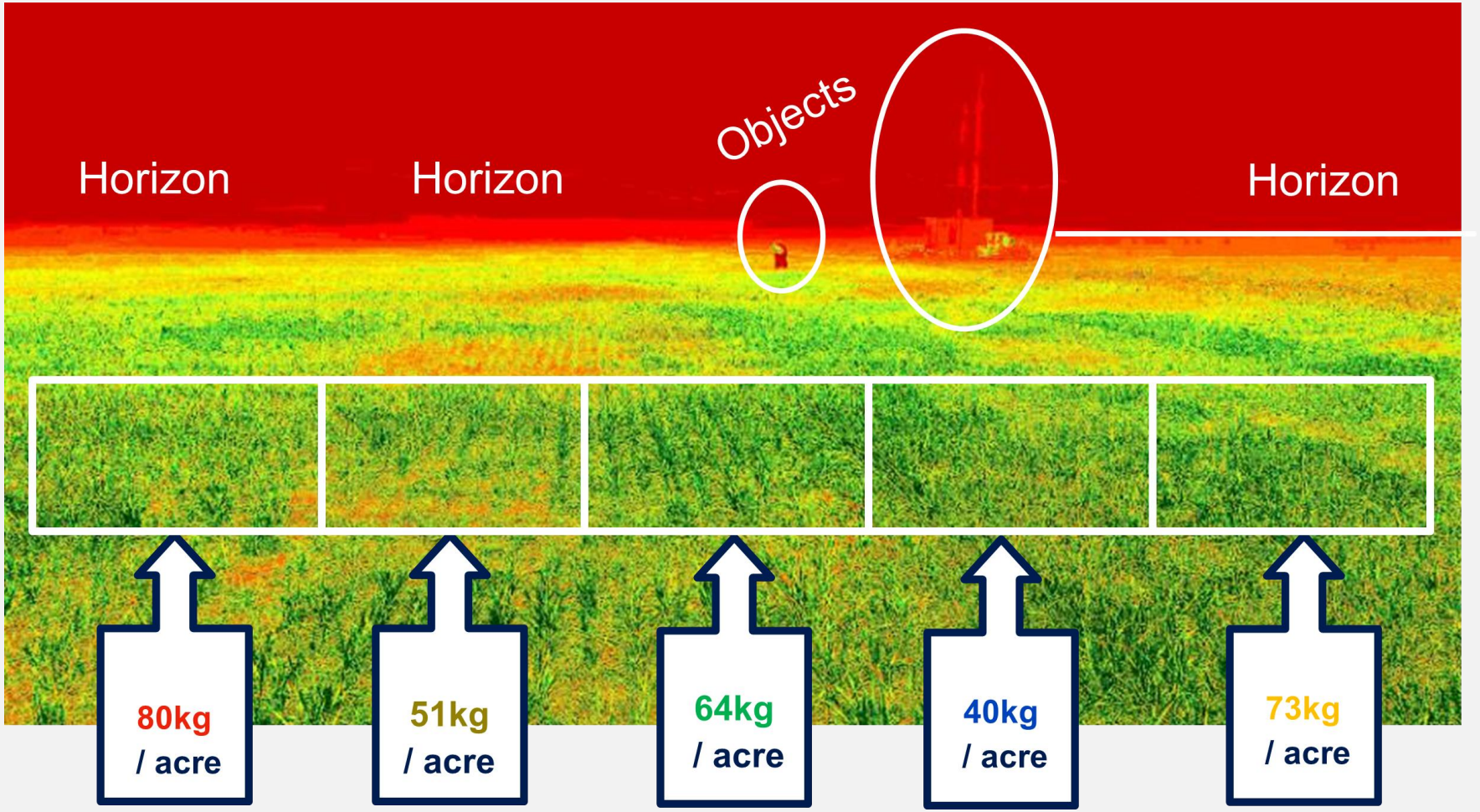
4K Multispectral Camera runs continuously

TASK AUTOMATION AND ROBOTICS

Sections

AUGMENTA
PRECISION AGRICULTURE · REDEFINED

Variable Rate Actuation



It defines sections where Vegetation Index is calculated and both stored and connected to implement actuators

TASK AUTOMATION AND ROBOTICS

Measure the needs of fertilization with high spatial precision

Application of online analyzer that scans crop health inch-by-inch calculating the required dosage of fertilizer dosage – all in real time.

Detection of the Needs, with respect to location and density

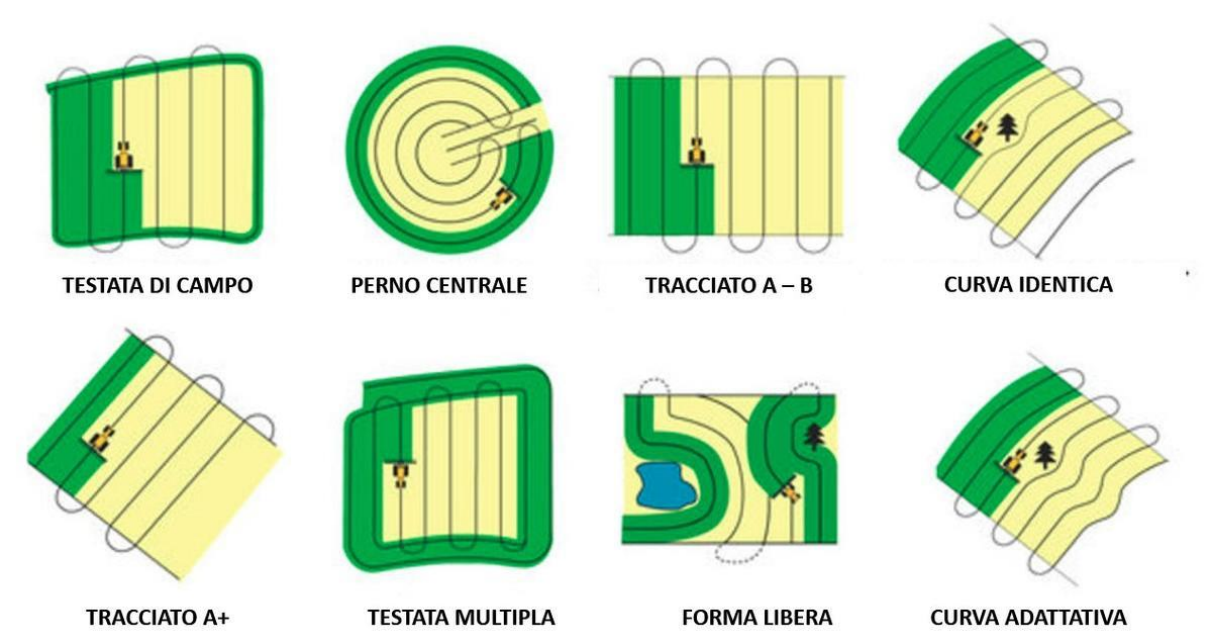
The Online Analyzer with its horizontal view it's able to catch the crop characteristics based on NDVi not affected by the soil characteristics, with very high precision. Using DGPS and a AHRS (Attitude and Heading Reference System).

AGRICULTURAL ROBOTS

- Agricultural Robots can be totally new machines
- Or also traditional big traditional machines with robotic functionalities
- At the moment these machines are NOT Cooperative but:
  - Master-slave functionality is a reality (one robotic machine and one with operator)
  - Cluster of machines are under development

AUTONOMOUS DRIVING

Agricultural Machines are today ”robots” because are equipped with autonomous driving systems and task management systems capable to autonomously actuate with georeferenced variable rate based applications. But by law machines MUST have operator on board and can’t be used in environment with humans presence.

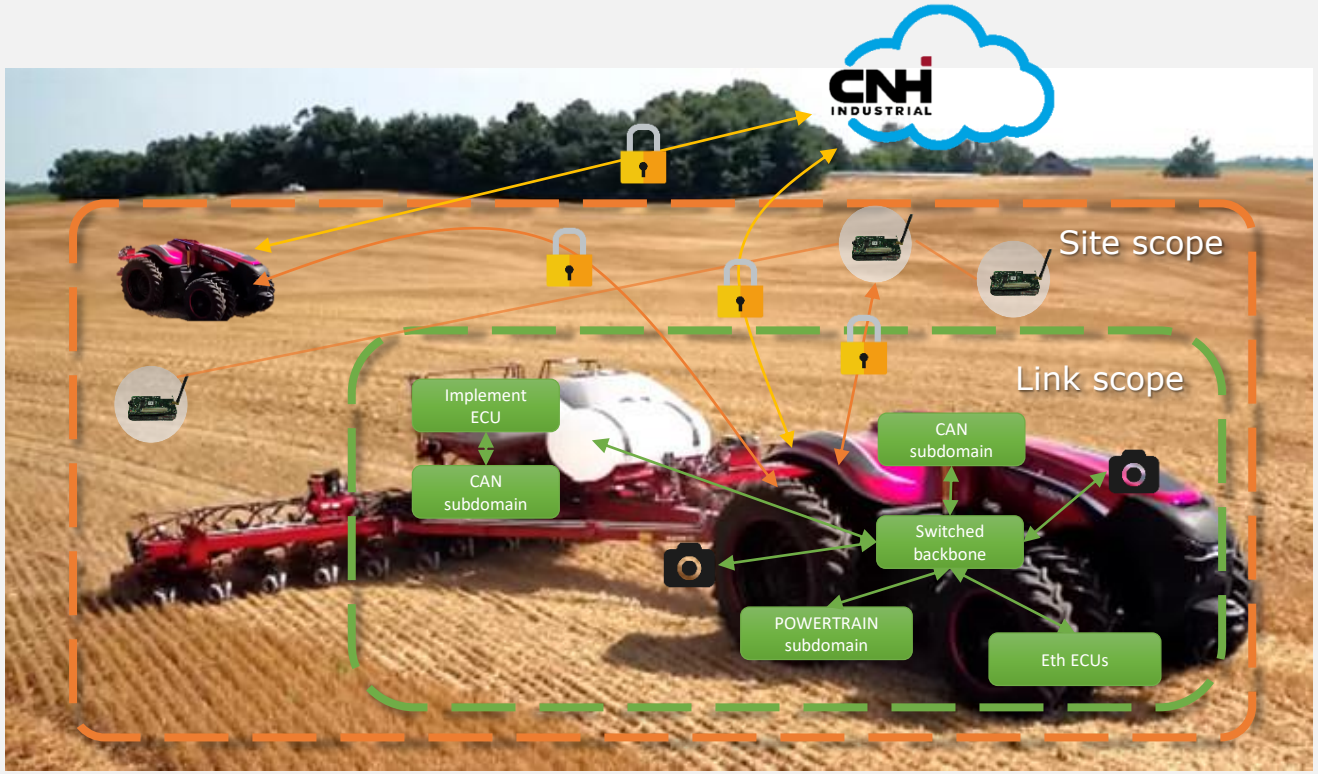


BIG AGRICULTURAL ROBOTS

BIG AGRICULTURAL ROBOT CONNECTIVITY

Global scope (cloud,fleetmgmt,log,service,…):

- Unicast/multicast/anycast comms;
- At least 4 billions of addresses directly addressable
- Hierarchies feasible via subnets
- End-to-End Security
- IPv6-over-IPv4 feasible



Site scope(SensorNetworks, Co-operativeTreatments)

- Traffic is not forwarded outside
- Easy to firewall w/out NAT-ing
- 6lowPAN (IPv6 for WSNs*)
- End-to-End Security
- Hierarchies feasible via subnets

Link scope (backbone Comms, tractor-to-implement, CAN-over-IP)

- Traffic is not forwarded outside
- Easy to firewall w/out NAT-ing
- VLANs to separate/prioritize traffic
- Hierarchies feasible via subnets/VLANS
- High Speed ISOBUS
- (End-to-End Security)
- Gateways/Domain controllers
- AVB/TSN (IP not needed)

BIG COOPERATIVE AGRICULTURAL ROBOTS (SWARM)

Clustering (Homo/Eterogenous)

- Auto-piloting,
- Master-slave structured (master manned slave(s) unmanned)
- Machine synchronization scenario
- Safety critical data exchange
- Not ready for cluster automation

AGRICULTURAL ROBOTS CHALLENGE

Precision Work Session

Security cameras for critical zone Assisted and Automatic Vision

Yard Management Information System

Robotic Manipulator

Connectivity 4G/5G Ubiquitous Connectivity

Automatic Guidance

Sensors for Obstacle Recognition

Virtual Fencing

OPERATION FOR ROBOTS/COBOTS IN AGRICULTURE

Task for Robots or Co-bots in Agricultural envirnoment can be classified as similar to operations in Industrial Environment:

- Moving objects
- Rovers to analyze areas
- Picking objects
- Specific operations (e.g. Cleaning versus fertilizing or seeding or chemical weeding ...) rover + implement

OPERATION FOR RO-/CO-BOTS IN AGRICULTURE

Most promising tasks are:

- the high human involvement or
- Heavy for humans

MANY OPPORTUNITIES FOR COOPERATION

- Planting machines
- Cutting grass machines (small)
- Cutting grass machines (big)

But strong need for standards and regulation

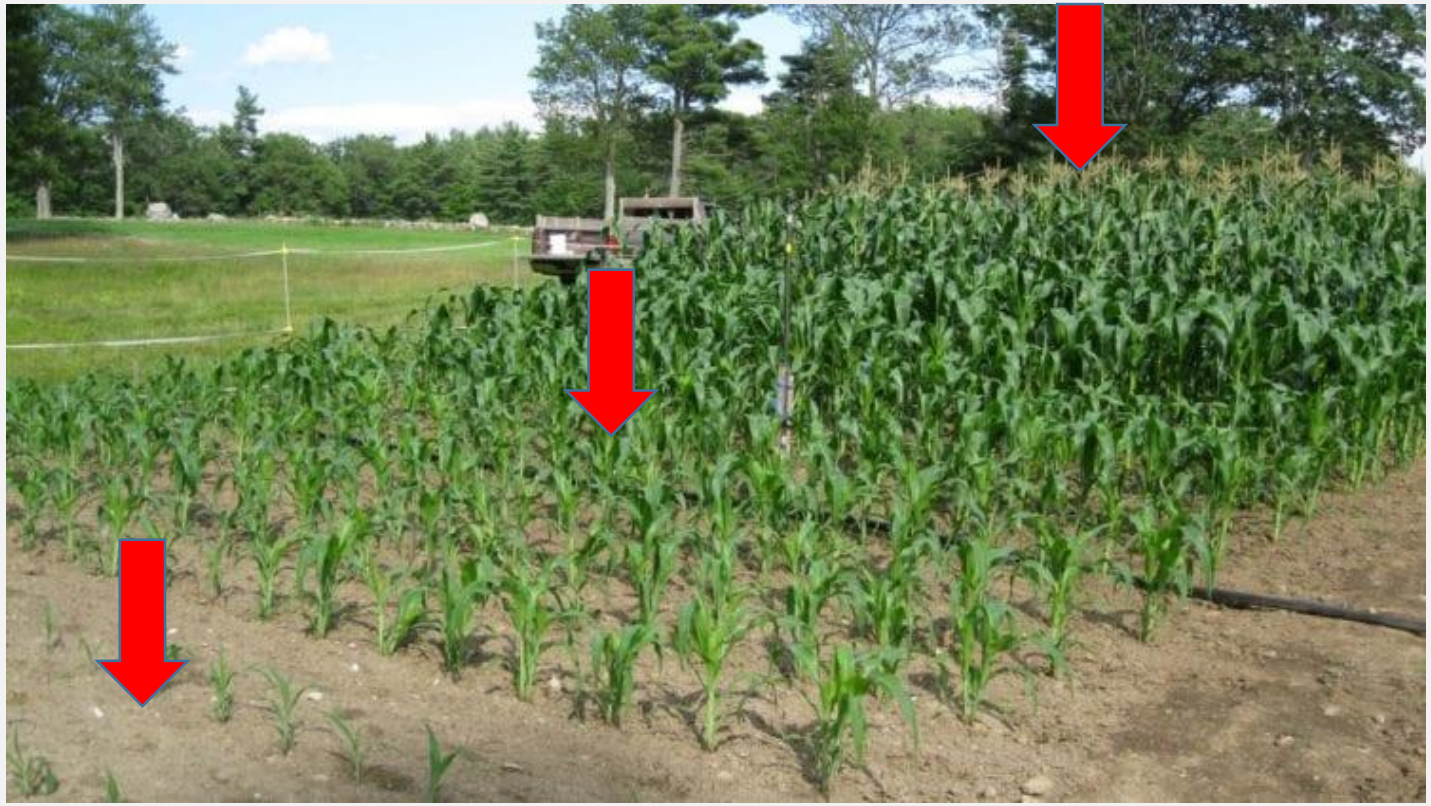
ANIMAL COOPERATION

PLANT COLORS/SHAPE/VOLUME: ENVIRONMENT RECOGNITION

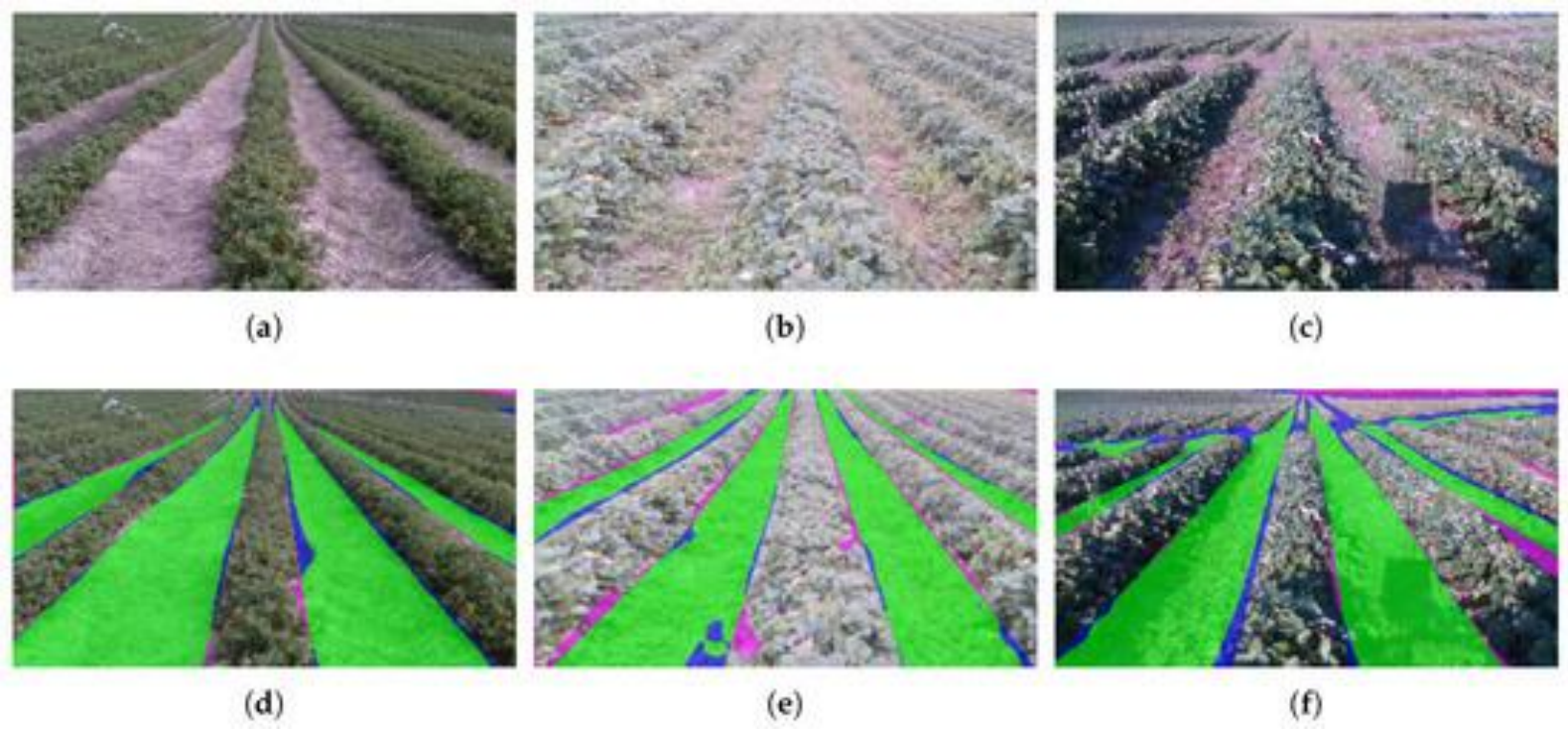
Environment acquisition and mapping
Must be repeated for each working session,
due to very fast leafts growth in spring
Colors and light are challenging variables
For objects classification

DIFFERENT CROP GROWTH CONDITION

Plant height MUST be a parameter, in respect to define if the robot have Probablity to recognize humans or obstacles



MOVING IN ROWS (SENSORS)

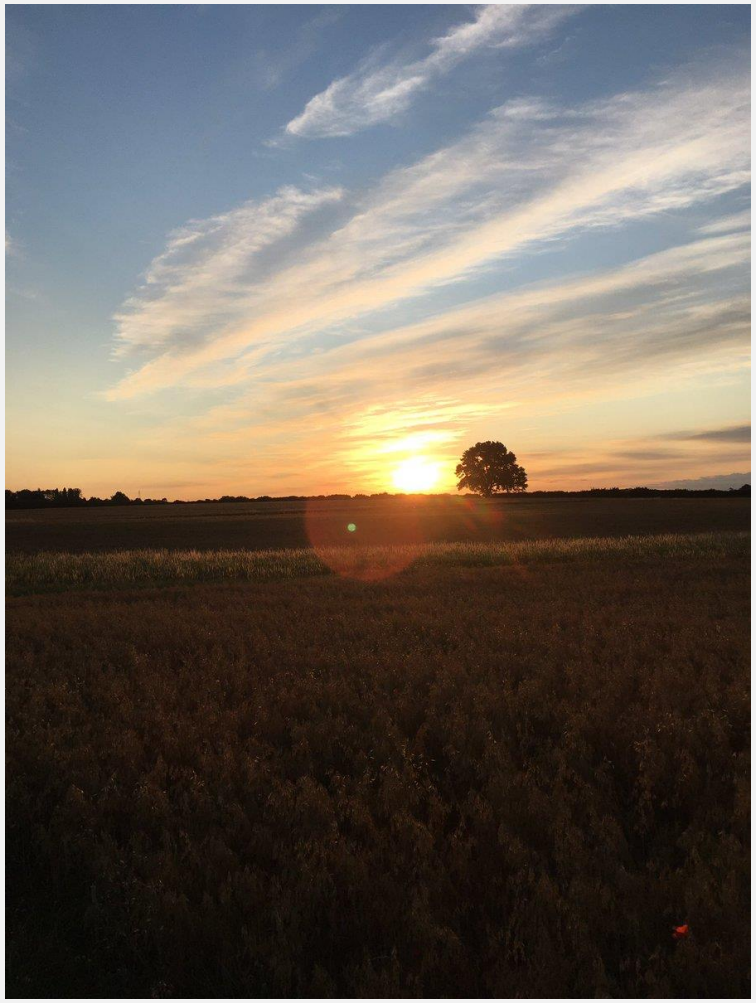


DIFFERENT CROP GROWTH CONDITION

Plant height MUST be a parameter, in respect to define if the robot have a good probablity to recognize humans or obstacles

DIFFERENT LIGHT

- Light changes dramatically from the morning to the evening and both light intensity and direction affect vision
- Most of Agricultural machines work also during the nght i critical periods (like product harvesting).
- Night vision is different from daily vision
- Need for etherogeneous sensors for plants, objects and human recognition



HARSH CLIMATIC CONDITIONS

Visibility can be really low and affected by climatic events or working condition

Often in greenhouses there is a sort of fog due to irrigation
While in the morning and evening a real fog appears due to humidity

HARSH CLIMATIC CONDITIONS

Visibility can temporarly or permamently affect vision systems
As well as heavy rain can affect other type of sensors:

- radar scattering or
- lidar object recognition
- Camera dirt due to dust: impossibility to use

ABILITY/FUNCTION

Abilities should be related to travel and maneuver of the robot in different terrain conditions:

- Dynamic stability: Maintain trajectory
- Maintain proper alignment: Respect area fencing during change of direction
- Very difficult in rough (plowed) terrein
- Vision/Sensing affected by stability

SPECIFIC NEEDS/COMMON CHARACTERISTICS

- Common Characteristics:
  - AGV + TOOLS (manipulators) or traditional agricultural tools (implements, mounted not usually towed)

→ similar skills, similar tests

- Special needs:
  - Environment unknown and also when acquired it changes quickly
    - Task changes (plowing,, tilling, sowing, planting, fertilizing, harvesting, spraying, spreading…)
    - Light changes
    - Terrain changes (type: snow, dust, mold)
    - Tractionability changes
    - Colors change
    - Plants/leafs change
    - Boundaries/Environment change (plants and leafs change in rows).

→ More variability, more tests needed, special focus on object recognition/classification, → more safety strategies (ask for vision improvement)

SPECIFIC NEEDS/COMMON CHARACTERISTICS

- interactions:
  - With objects
  - With humans
  - With animals

→ New Classifications: Agricultural robots and Livestock robots

- Interaction with animals
  - Animals are «obstacles»
  - Animals are target (e.g. milking robots)

→ Very important skill limit force and movement when in proximity to animals (non-logic behavior)

OPEN POINT

Impossible to certify this kind of machines withing Functional Safety Standards.
Impossible to protect bystanders from the tool with an electro-mechanical safety barrier.
DANGEROUS MACHINE -> NO COBOT POSSIBLE

OPEN POINTS

- Need tests on more robots to validate the concepts but Plants/Vegetation and vision are a big issue in cobots for Agriculture
- Need for a “last barrier” as a physical safe mechanical barrier/sensor for safety that must be a physical system (safety bar or similar)
- New tests needed for Agricultural Robots to maintain safe distance:
  - free land and
  - Rough terrein
  - cultivated land, parameterized on the height of vegetation
  - Harsh climatic conditions
- Standard functionality should be to stop the robot, not to change path for cultivated land, while change of path should be possible in livestock.
- Protocol with change of path needed for animal interaction just in case animal does not move or is not the target.

QUESTIONS?