ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

FIELD ROBOTICS

Leading field-robot revolution

Il robot agricolo: la prossima frontiera già una realtà, gli obiettivi e le sfide

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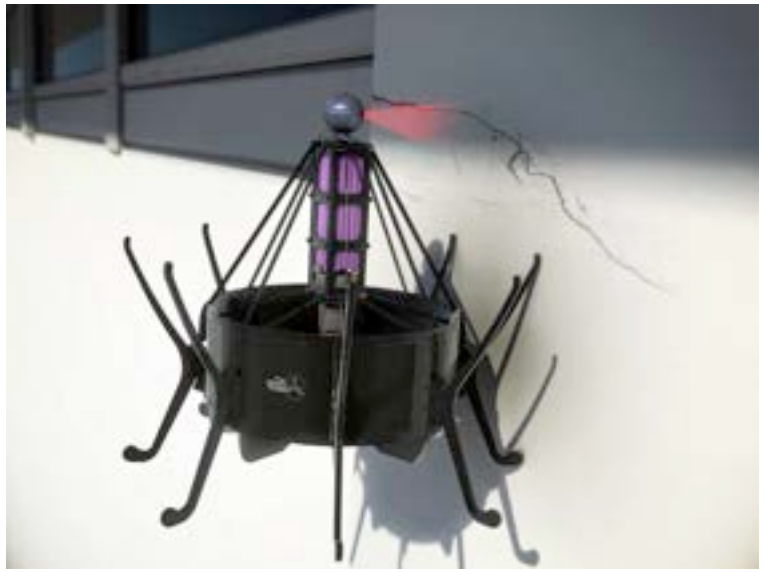
About me

- Full Professor at the School of Engineering – University of Bologna
- Specific Theoretical Skills: Nonlinear control Systems, Automation
- Specific Application-oriented Skills: Robotics, autonomous navigation, UAV, UGV
- PI of European Projects:
  - AIRobots
  - SHERPA
  - AirBorne
- Co-founder of the Spin-off FieldRobotics

AirRobots



SHERPA

Airborne

AirBorne

FieldRobotics

FIELD ROBOTICS

Leading field-robot revolution

Summary

- Conventional platforms (Transforming tractors in smart and autonomous systems)
- New concept agriculture platforms
- The Fieldrobotics experience and vision

A Timeline of Farming Tech

YEAR	AGRICULTURAL EVENT
1812	Richard Trevithick created the Barn Engine, the first portable steam engine for agricultural use.
1903	Charles W. Hart and Charles H. Parr created the first two-cylinder gasoline tractor in the United States.
1928	The General Purpose Tractor is introduced. This significantly increased output by allowing farmers to plant and cultivate in three rows.
1939	Model B John Deere tractors were the first to have electric starts, lighting, rubber tires, and increased horsepower; it was also the company's first diesel tractor.
1940	Frank W. Andrew built the driverless tractor by looping a cable from the tractor's front steering arm around a barrel or fixed wheel in the field.
1950s	Ford developed a driverless tractor known as "The Sniffer". But it was never sold due to the difficulty of running it without burying wire through the field.
1966	John Deere was the first tractor manufacturer to provide a roll bar for operator safety.
1970	To defend against heat, cold, and dust, agricultural tractors began to incorporate more comfortable operator seating and sound shielding.
1994	Silsoe Research Institute engineers developed a picture analysis system for managing a miniature driverless tractor designed for vegetable and root crops.
2008	The ITEC Pro guidance system from Deere and Company automates vehicle functions like end turns and is based on global positioning technology.

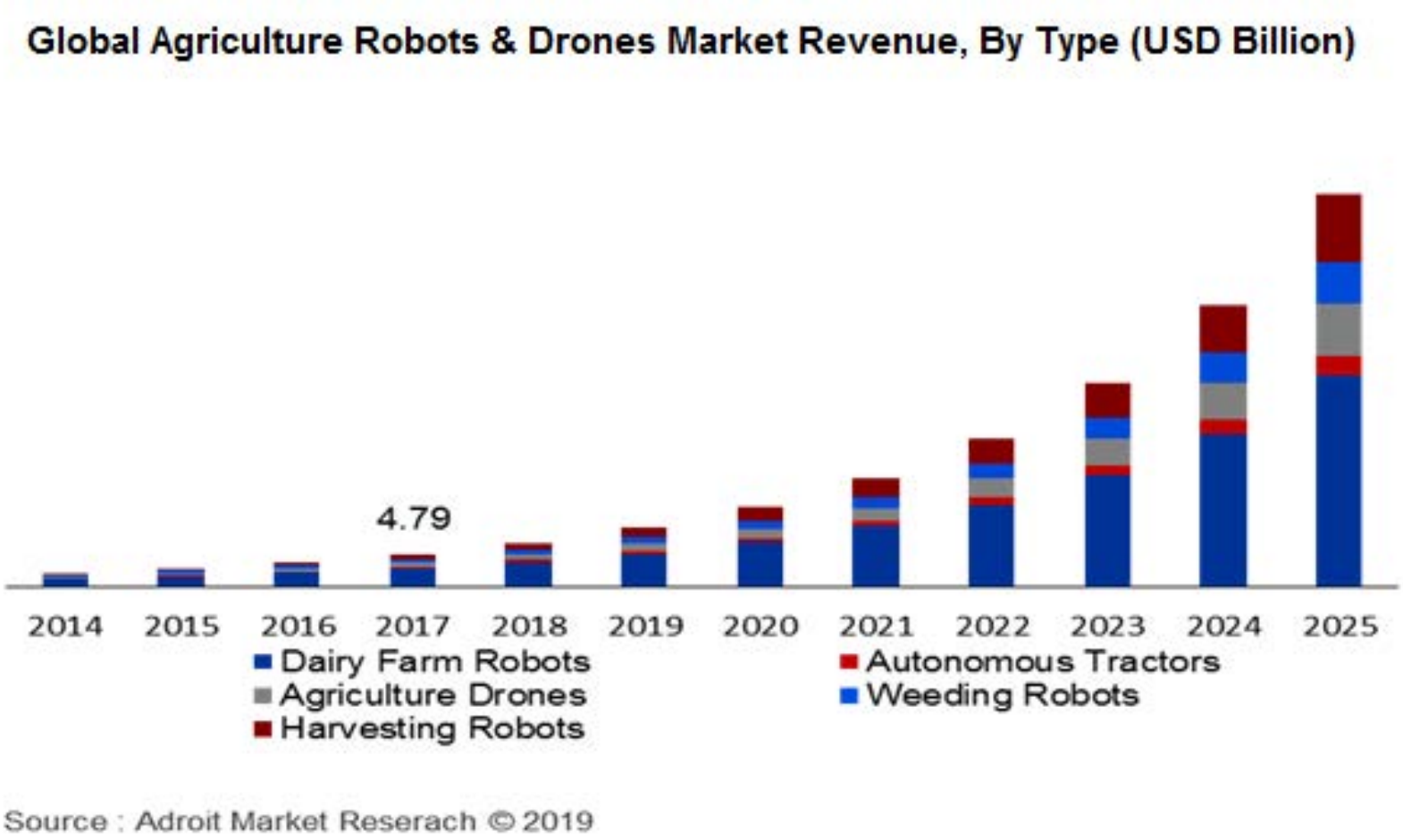
General purpose

"Autonomous"

safety

GPS

Statistics



The global market for the agriculture robots and drone develop a compound annual growth rate of 18% , to reach **USD 14 billion by 2028**

Lely

Lely reports its 2022 annual results: 15% growth with a total turnover of €702 million (2021: €611 million).

The Innovation in robotics agriculture

Autonomy (make tractors autonomous and safe) is the driving capability, enabling many other innovations:

- Labor shortage/saving
- Repetitive works in structured environments
- Safety (fatalities at work)
- Precision (Automated pilots can be far more accurate than humans)
- Precisions means less chemicals, less fuel → more sustainability
- Massive data harvesting precisely localized → precision farming

Conditions Specific to Automated Agricultural Machinery

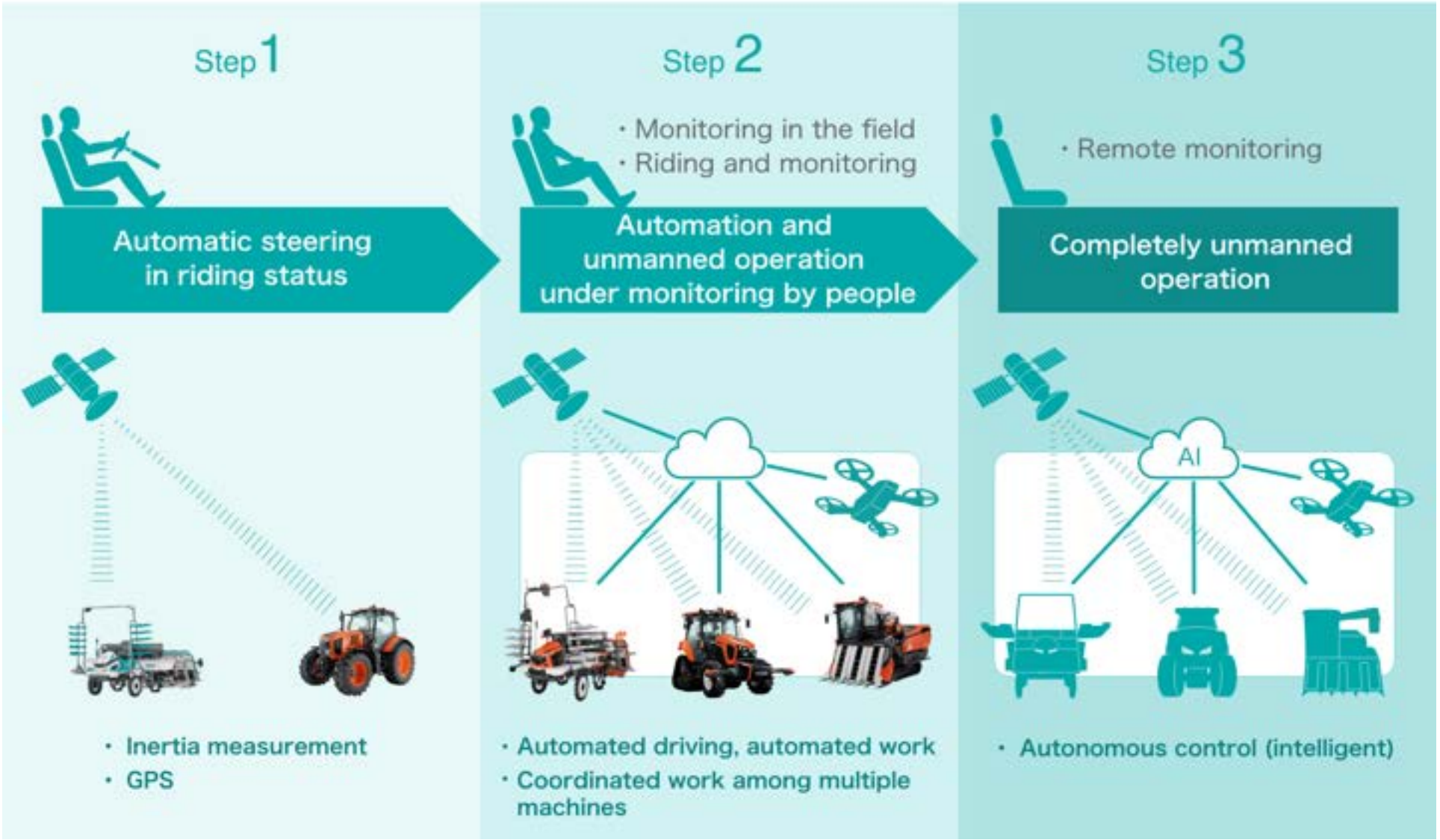
Autonomous drive for cars

- More structured environments (signs, traffic lights, road lines)
- Even Terrains
- Chaotic highly populated areas

Autonomous drive for tractors

- Unstructured environments
- Uneven Terrains (fields with rolls and slopes)
- Mainly free-of-obstacle areas

Kubota's Roadmap of Automatic/Unmanned Agricutural Machinery



Three main envisioned technologies

- RTK-GNSS unit
- Surround View
- Human and Obstacle Detection System

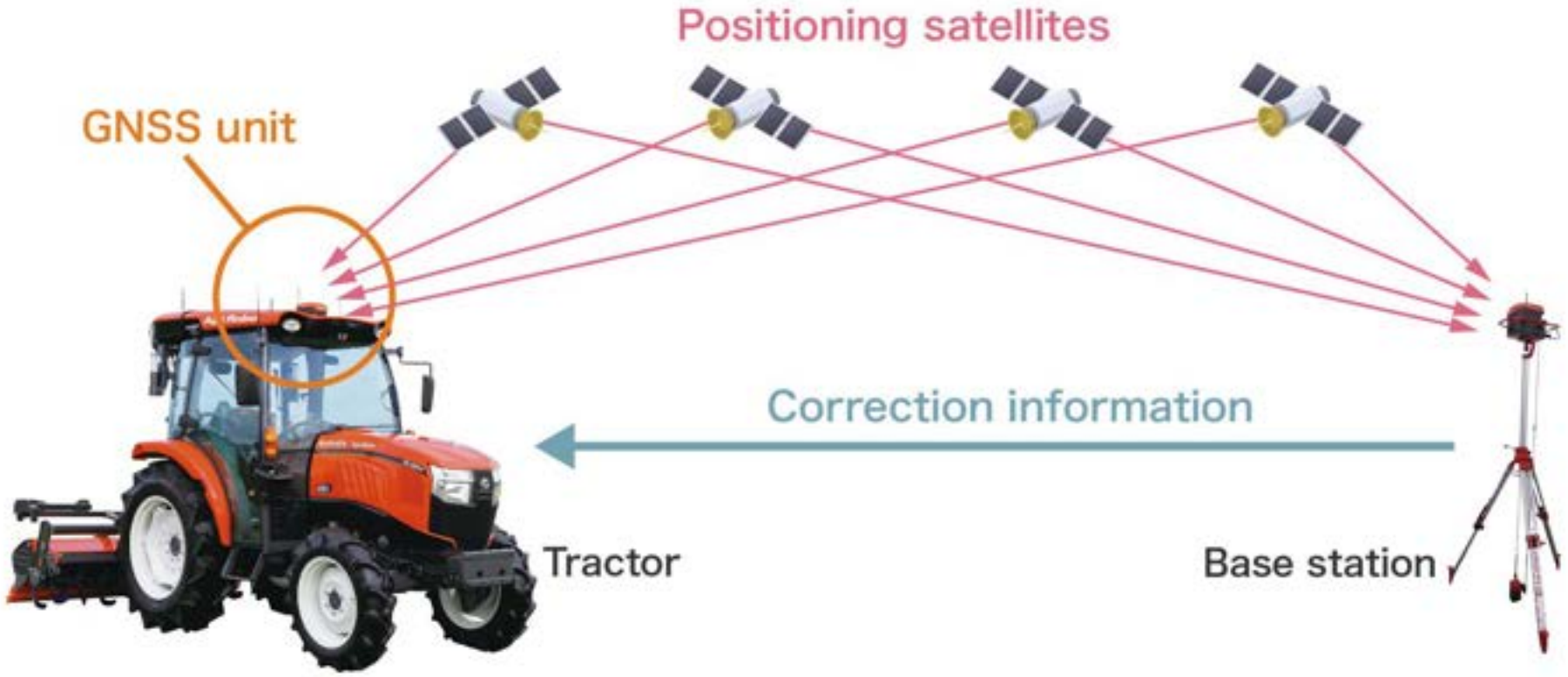
These technologies enable the system to support the following features:

- autonomous operation by a single vehicle under human monitoring
- cooperative operation by two vehicles with one operator using both unmanned and manned vehicles
- simultaneous operation of two machines (usually a tractor and an unmanned machine)

RTK-GNSS

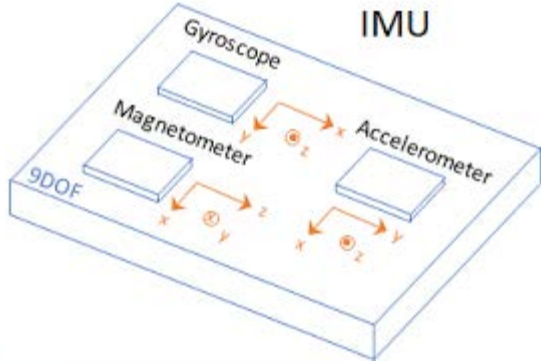
Global Navigation Satellite System (GNSS)

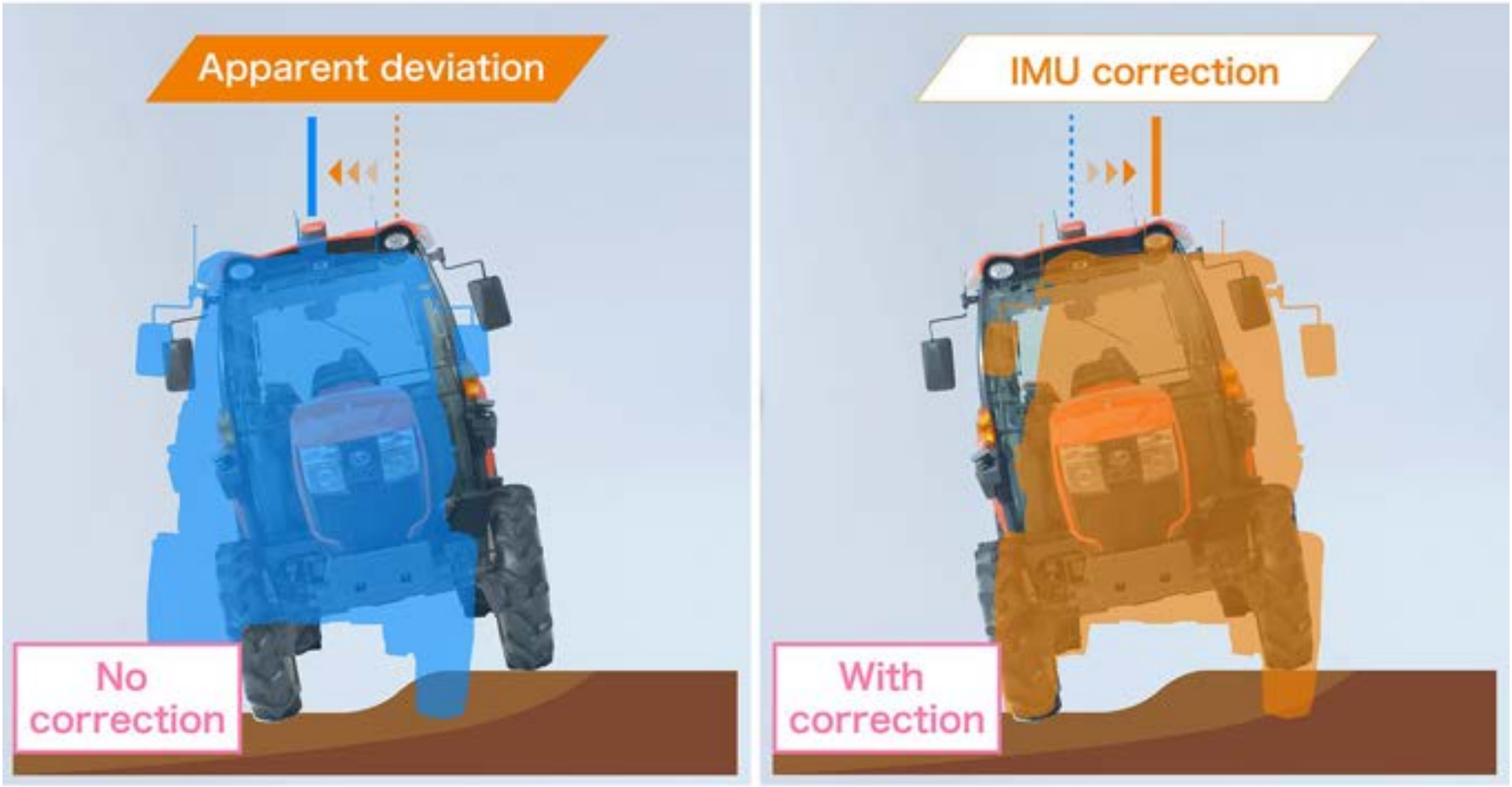
Real-Time Kinematic (RTK)



IMU

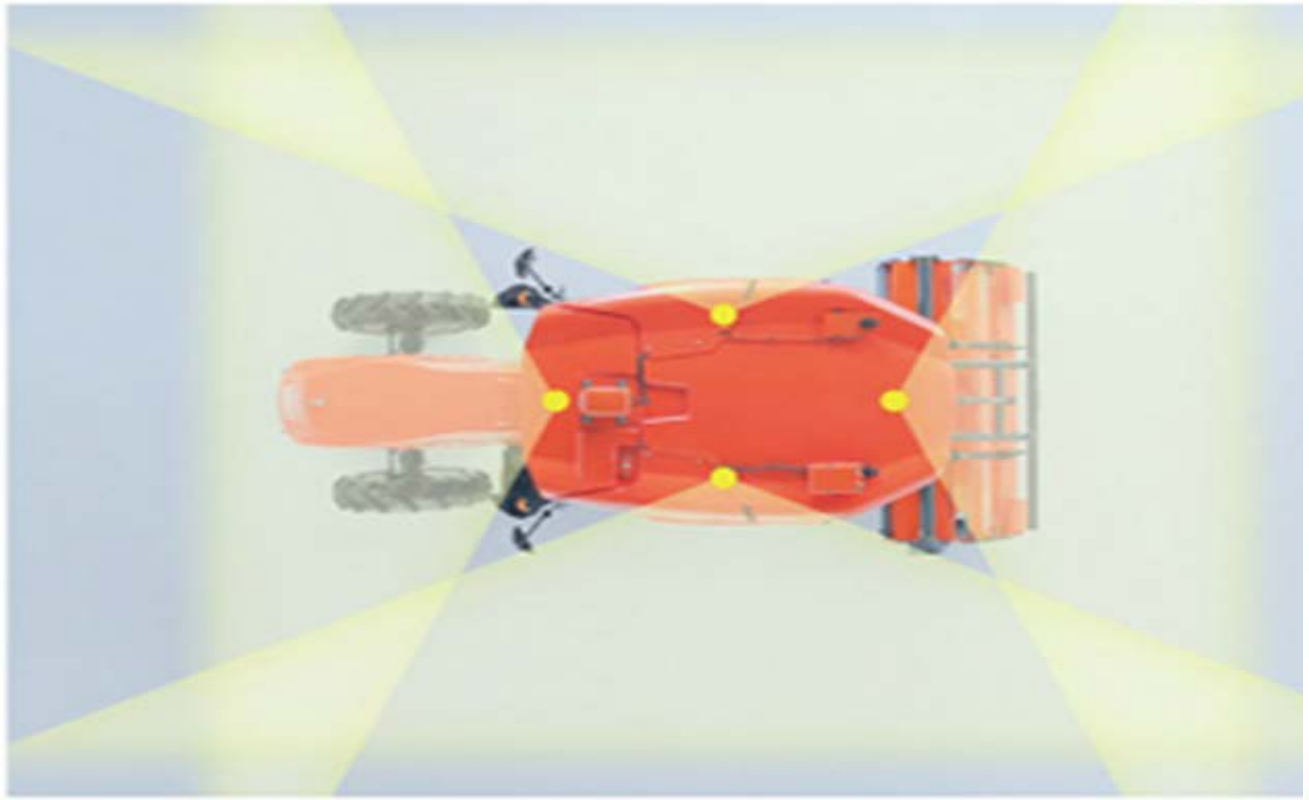
GNSS information always “fused” wth inertial data read with Inertial Measurement Units





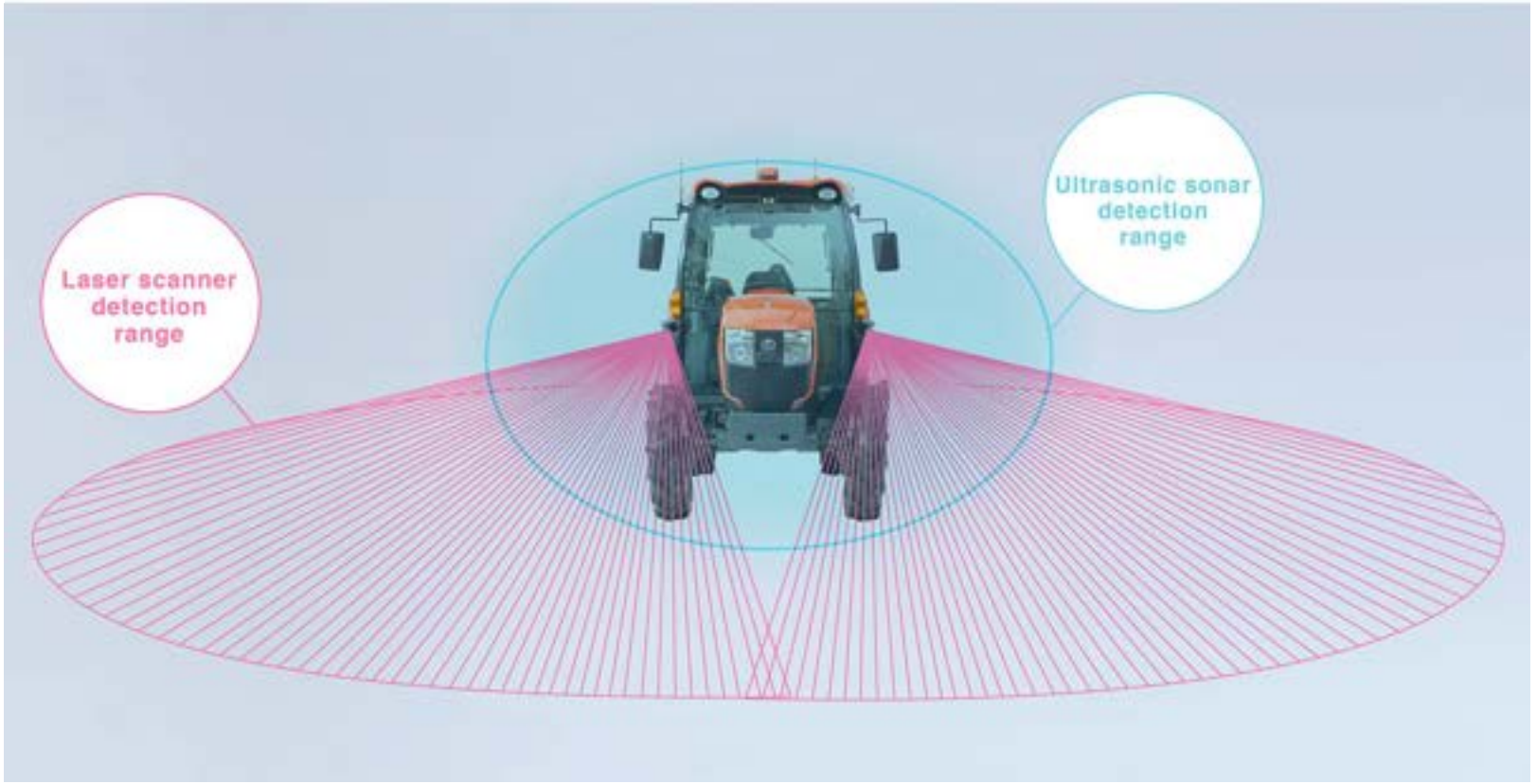
Surround view

technology that combines images from cameras mounted on all sides of the tractor to generate a bird’s-eye view and display a clear 360-degree image of the area around the tractor.



Human and Obstacle Detection System

Other sensors are then fused for reliable detection of surroiunding environment: laser scanners and ultrasonic sensors



Innovation in conventional tractors

Deere's 8R tractor

The autonomous tractor has six pairs of stereo cameras, which enables 360-degree obstacle detection and the calculation of distance

Control room

Operators control the tractor – or multiple tractors – from afar. A live video from the tractor-mounted cameras is fed to a central viewing, allowing the operator to observe the tractor(s) in operation.

Retro-fitting

Commercial solutions for making autonomous standard tractors are available.

https://autonomy.trimble.com/en/agriculture

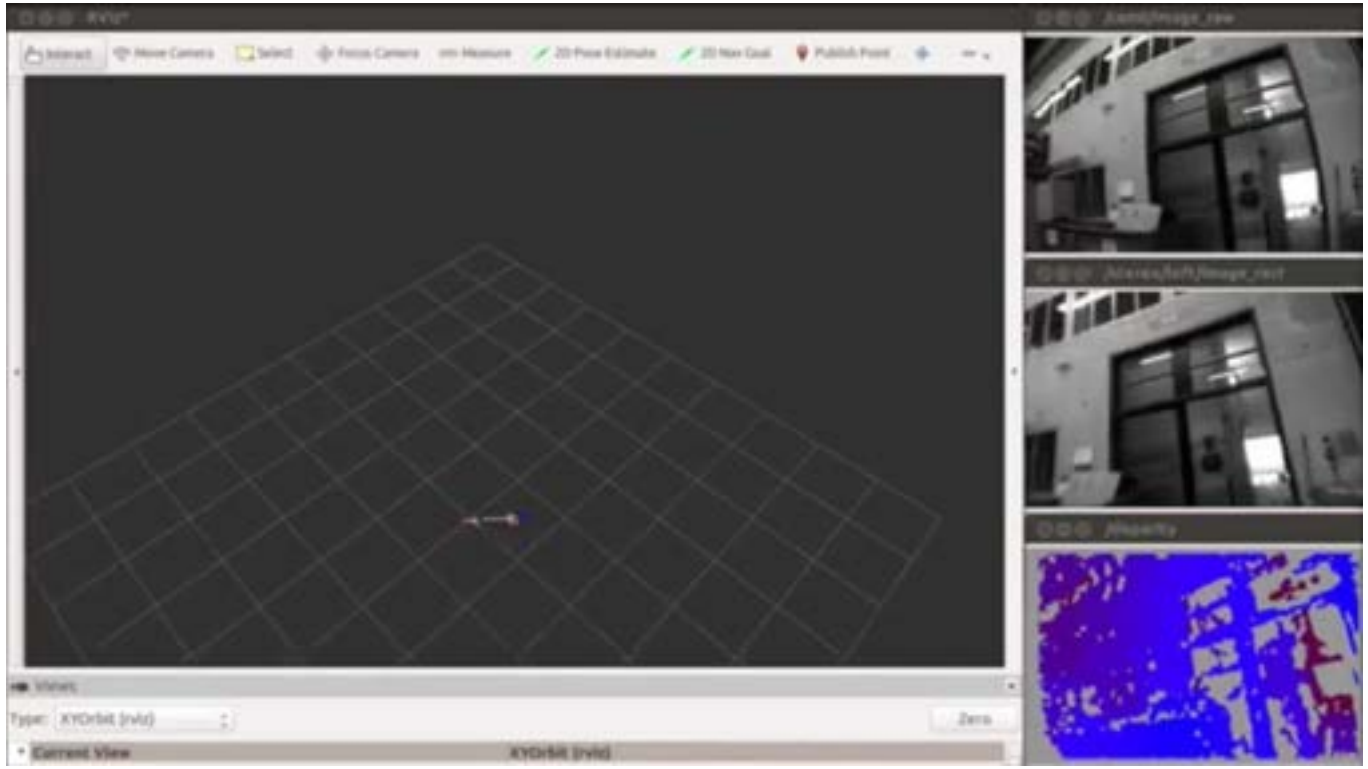
SLAM: Simultaneous localization and mapping

GPS-based localization techniques are not always applicable.
SLAM: Used by autonomous vehicles to build up a map within an unknown environment while at the same time keeping track of their current location.

Unbiased map
needed for localization

chicken
or
egg
dilemma

Accurate pose estimate
needed to build that map



ETHZ - Skybotix

“Intelligent” implements: The JD Planter

- Equipped with 300 sensors and 140 controllers
- Planting 100 seeds per second
- "With a configuration like this, it’s not unheard of to plant 400 to 500 acres in a day”

New Concept Platforms

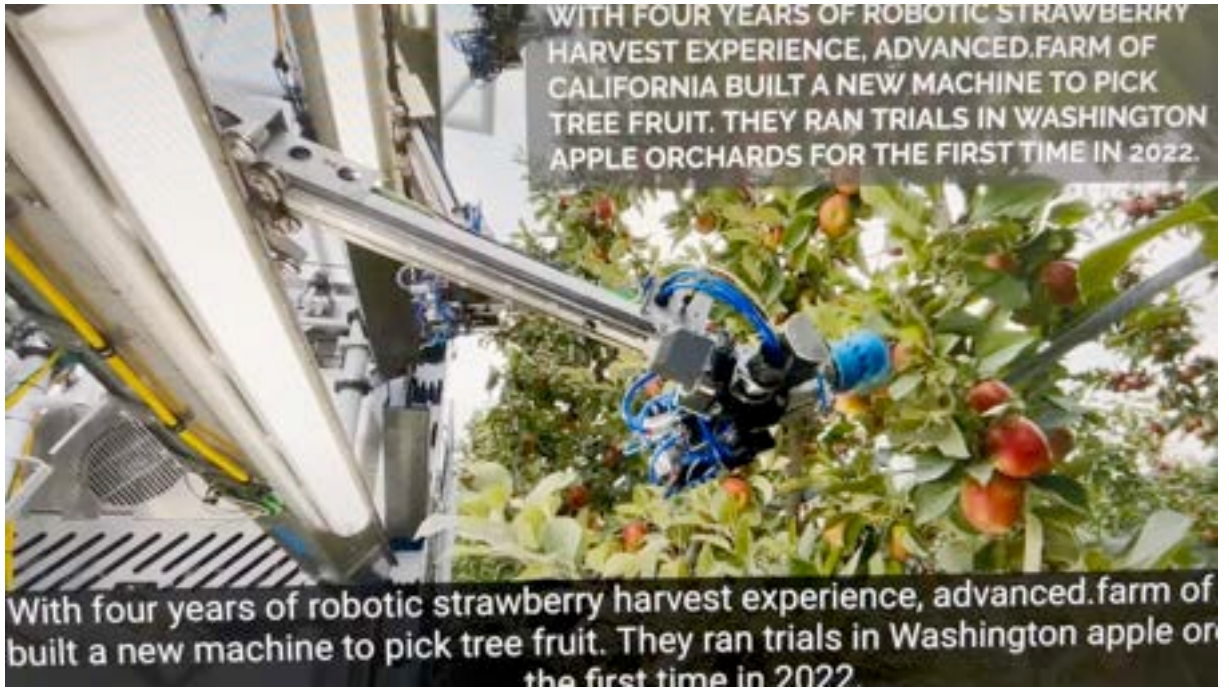
Piattaforme robotiche innovative ad oggi

FIRA - TOLOSA

Kubota dream tractor

Hydrogen-powered

Raccolta/diradamento



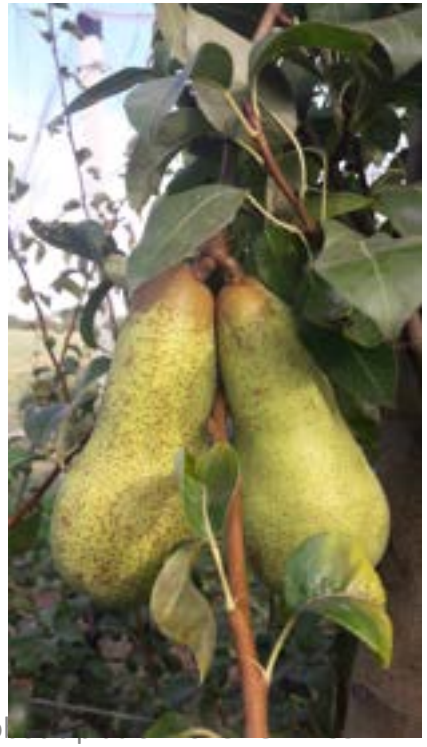
Raccolta/diradamento

- Unity simulation environment

Technical challenges

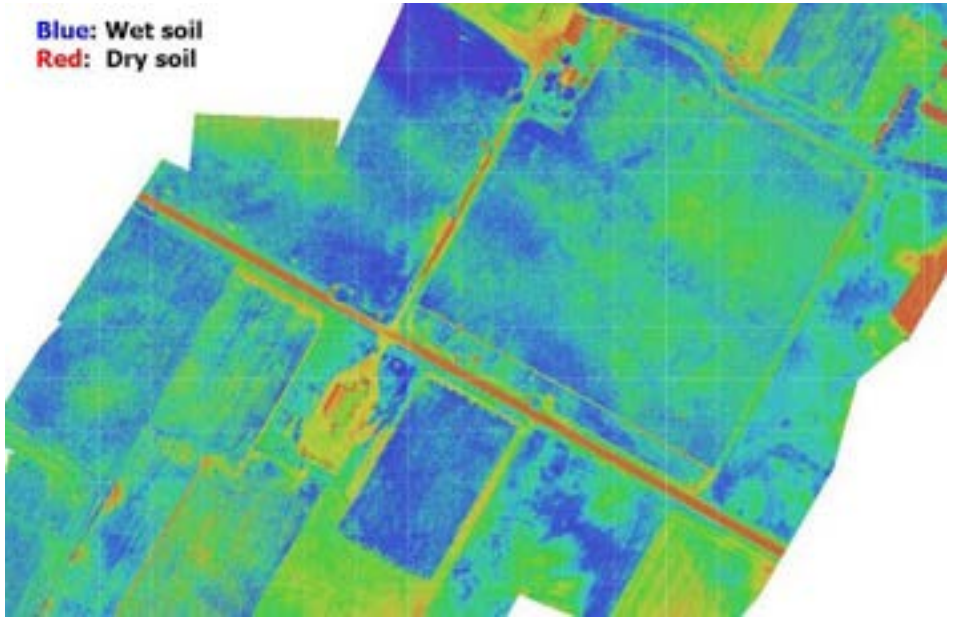
- Perception in hostile conditions
- Soft robotics (the fruit must be handled with care)
- Fast harvest to be competitive against human harvesters (each arm <= 5 sec per fruit)
- Uneven terrains
- Cost effective solutions

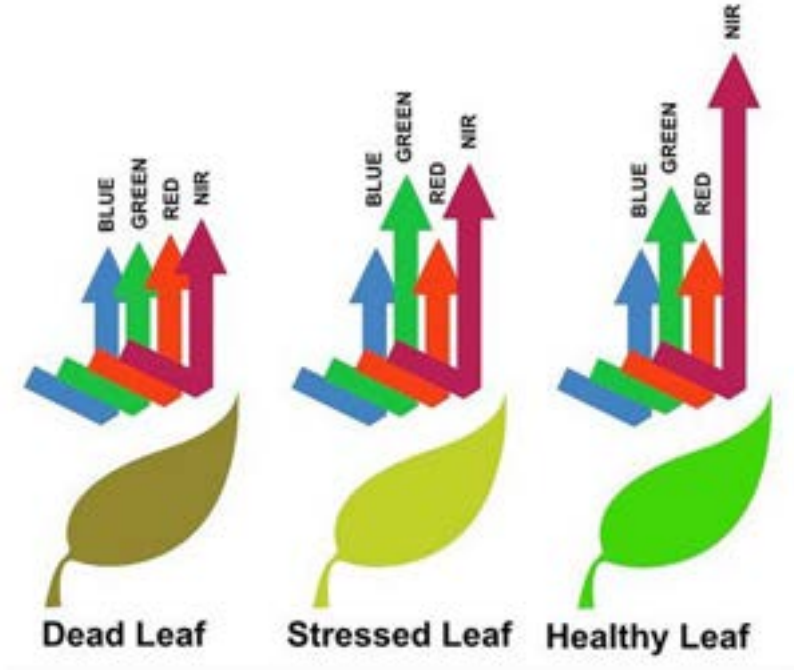
Co/design robot&orchard



Drones: Application contexts

- Scouting/Monitoring Plant Health (drone imagery, NDVI, as alternative to satellite images)





Commercial (DJI MAVIC 3M)

DJI MAVIC 3M: 4 KE, multispectra + RGB cameral

43 minutes per flight, 2 Km^2 mapping per flight)

Commercial (DJI AGRAS T10 E T30) for sprying

T30: 23 KE, 16 hectares/hour,
T10: 13 KE, 6 hectares/hour

5 Km range for image transmission (FPV)
>50.000 sold worldwide

Spray application

- ✓ Regulamentary issues (illegal in many countries)
- ✓ Hoppers of 8 to 10 litres (total weight < 25 Kg)
- ✓ Endurance issues
- ✓ DJI T40 :hopper capacity of 40 L
- ✓ Dedicated atomizer technologies

https://sprayers101.com/drone-sprayers-are-we-ready/

Security

- monitoring the far reaches of a farm
- monitoring fencing and perimeters of more valuable crops like cannabis
- protecting farm animals by locating missing or injured herd animals in far off grazing areas
- keeping wild animals (wild boars) away from cultivated fields
- keeping pigeons away from feed on farms (intelligent scarecrow)

Drones: Application contexts

- Planting & Seeding (forestry industry)

✓UK Project in Birmania

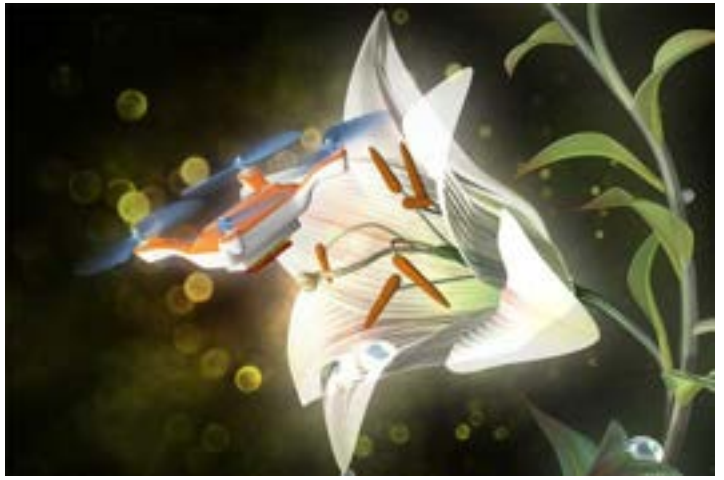
✓Restoration of mangrove forest (Mangrove deforestation is responsible for 24 million tons of CO2)

✓Roughly 350,000 hectares of coastal forest need to be restored, which translates to more than a billion trees

✓Ten drones capable of planting 400,000 trees a day.

https://www.standard.co.uk/news/world/treeplanting-drones-could-help-restore-world-s-forests-a4116376.html

Drone Pollination



Japan’s National Institute of Advanced Industrial Science and Technology.

https://m.andnowuknow.com/quick-dish/drone-bee-developed-potentially-pollinate-crops/eva-roethler/52572

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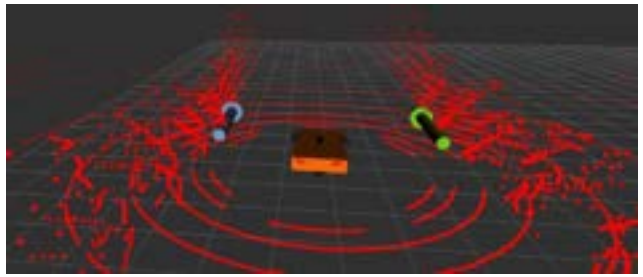
Le competenze



- Sistemi di guida autonoma in ambienti vincolati e priv
  di GPS
- Soluzioni basate sull'intelligenza artificiale:
  riconoscimento di oggetti, predizione, segmentazione
  di immagini
- Progettazione e sviluppo di piattaforme robotiche,
  integrazione di sistemi, operazioni a distanza
- Acquisizione ed elaborazione di dati sul campo

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La Sfida Robotica

agritech
National Center for Technology in Agriculture

- Progetto "da zero" (no "trattore elettrico autonomo")
- Sistemi flessibili (espandibilità a scenari "inimmaginabili")
- Sistemi sostenibili (non solo ambientali...)
- Sistemi sicuri (morti sul lavoro)
- Sistemi integrati ("ecosistema digitale", integrazione con il "campo")

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Perchè Elettrico...

- Semplicità di costruzione della macchina e scalabilità verso il basso

2

BTM 300-300-045

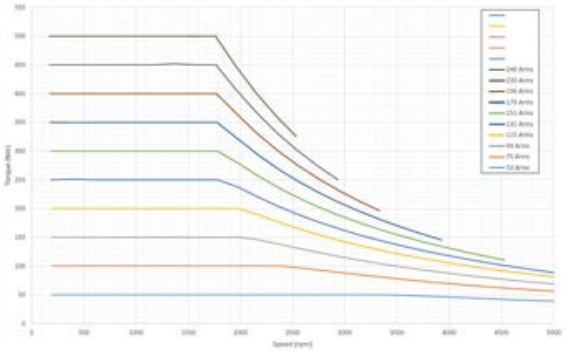
Induction Motor

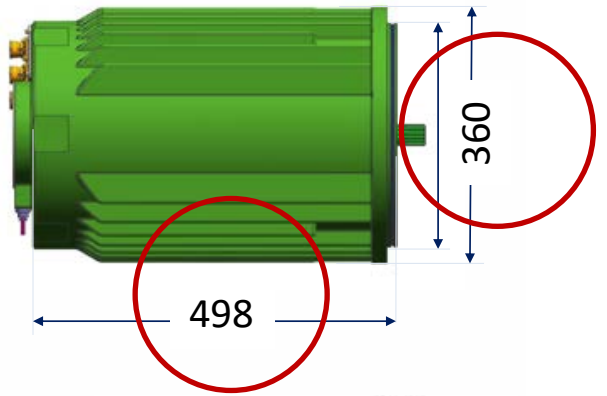
Performances	
Rated Power [S2- 60']	41.5 kW
Rated Torque	200 Nm
Rated Speed	1983 rpm
Rated Current	115 Arms
Rated Voltage	280 Vrms
Efficiency	94.6 %
Frequency	100 Hz

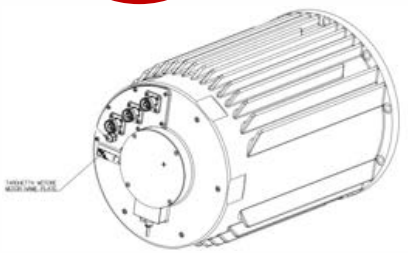
Brake (Not Equipped)	
Type	-
Brake Torque	- Nm
Brake Voltage	- Vdc

Features	
Motor type	Induction
Motor size	300-300
Protection degree	IP54
Insulation Class	H
Pole Pairs	3
Power factor	0.79
Thermal type	2xPT1000
Speed sensor type	Halld 64 pulses
Design Status	Series

3







Bonfiglioli

60 CV

Densità di potenza ineguagliabile

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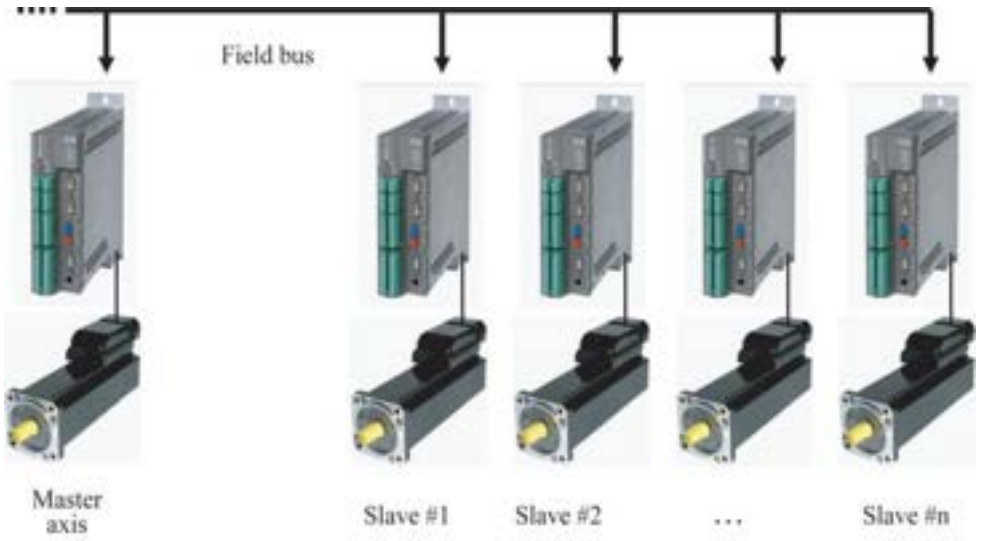
Perchè Elettrico...

- Controllo «fine» (agricoltura di precisione)
- Automazione industriale portata sul campo



Mechanics

Mechatronics

Perchè Elettrico...

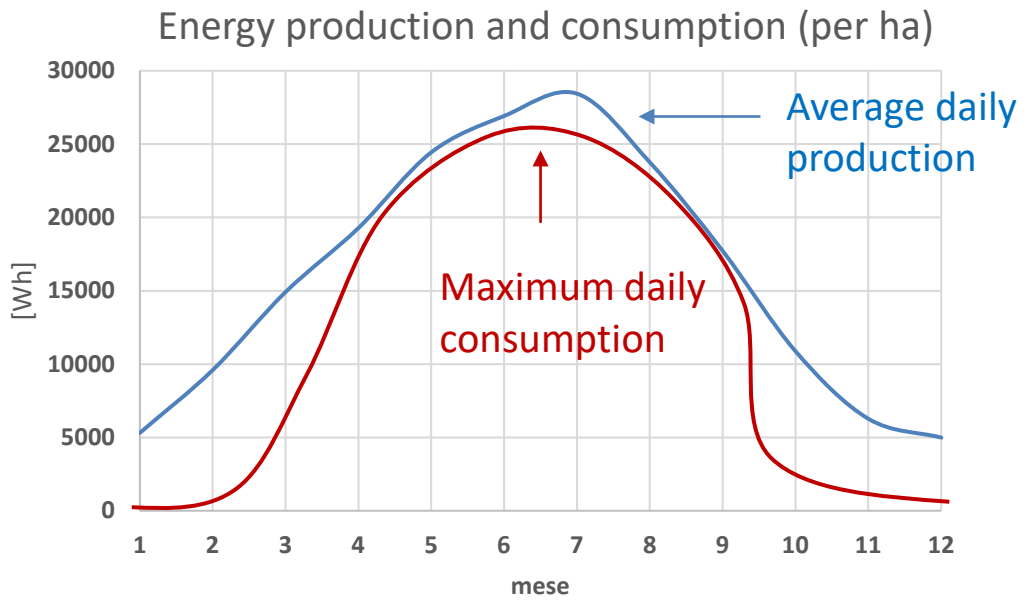
- Sostenibilità

S3O SMART SPECIALIZED SUSTAINABLE ORCHARD

Ref. Prof. Claudio Rossi claudio.rossi@unibo.it

Ref. Prof. Luca Corelli luca.corelli@unibo.it

- ✓ Progetto regionale RER. Frutteto sostenibile intelligente-specializzato
- ✓ Risultato: consumo di energia agricola compatibile con la produzione in loco
- ✓ Tecnologia: Sistema di produzione fotovoltaico modulare



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La rivoluzione…

Automazione industriale in campo

Le sfide

- **Elettrificazione** (con chiari vantaggi economici per gli utenti)
- **Percezione** (robusta a condizioni ambientali non controllabili)
- **Controllo** (ambienti reali solo parzialmente strutturati)

“Makita Concept”

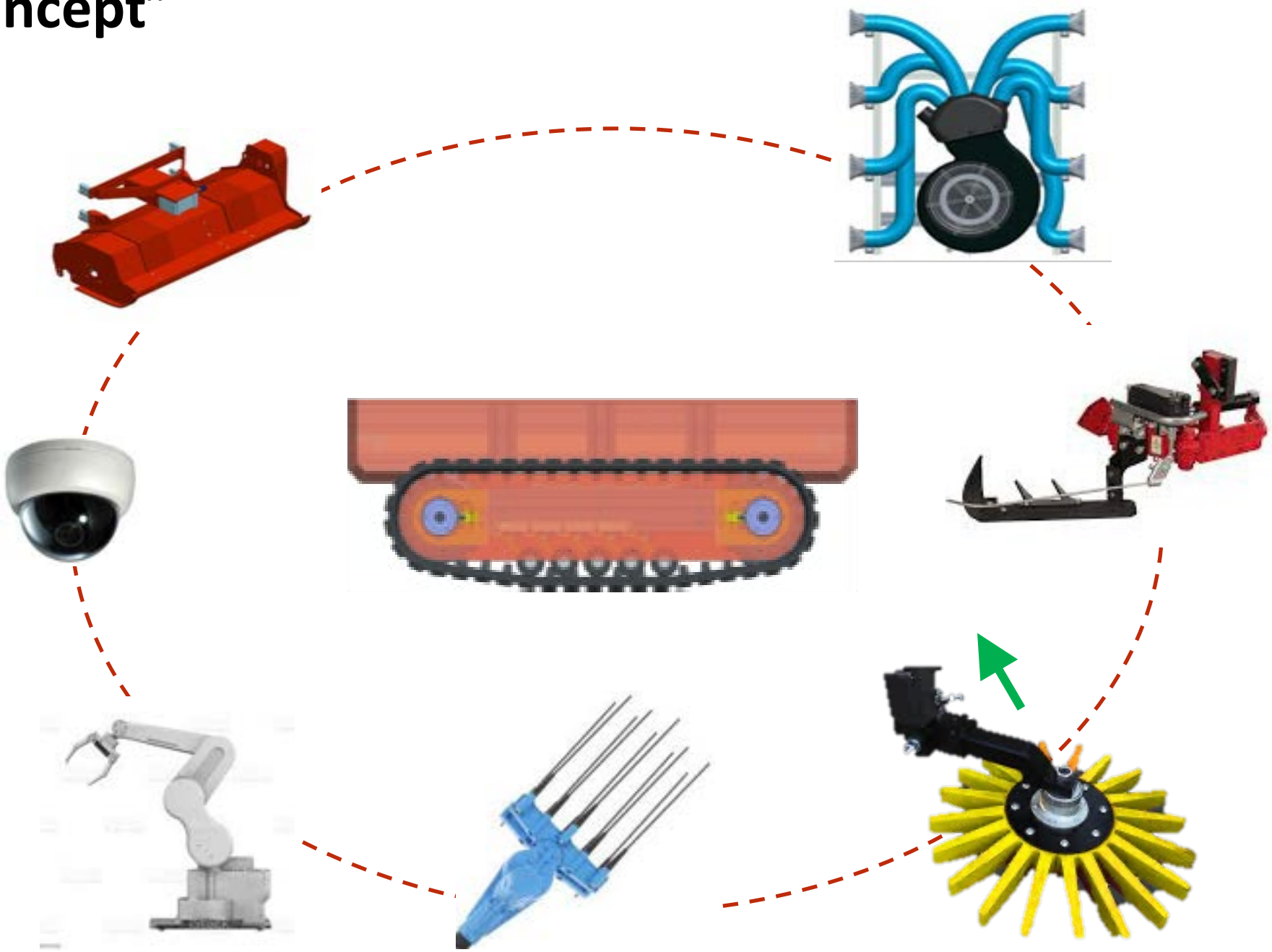
Una batteria

Tanti strumenti

“FieldRobotics Concept”

Una batteria
Autonoma

Molti
“attrezzi”



L'HammerHead

Powerbank autonomo in campo

Specifiche Elettriche:

- 24 kWh battery pack (with battery swap)
- Battery charging time: up to 2.5 h
- Docking station with autonomous charging and photovoltaic panels (in progress)
- Power take-off (standard PTO) electric 5kW

Specifiche Meccaniche:

- Load: 1 ton
- Maximum speed (full load): 7 km/h
- Maximum longitudinal/lateral slope: 100%, 50%
- Total weight (with 24 kWh battery pack): 900 kg
- Total weight without batteries: 750 kg
- Ground clearance: 170 mm

Powered by

www.liberbattery.it

4 brevetti:
- 1 Navigazione
- 3 Meccanica

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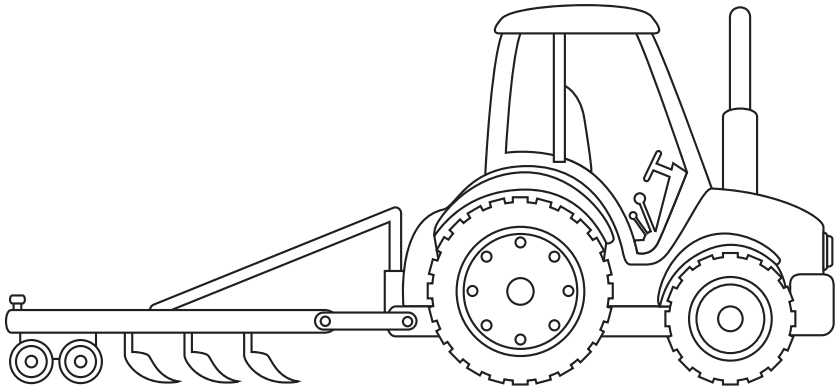
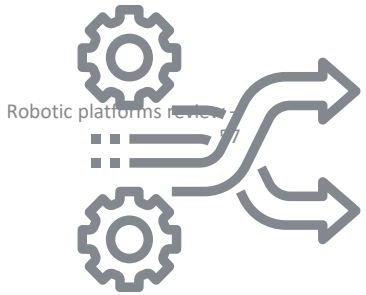
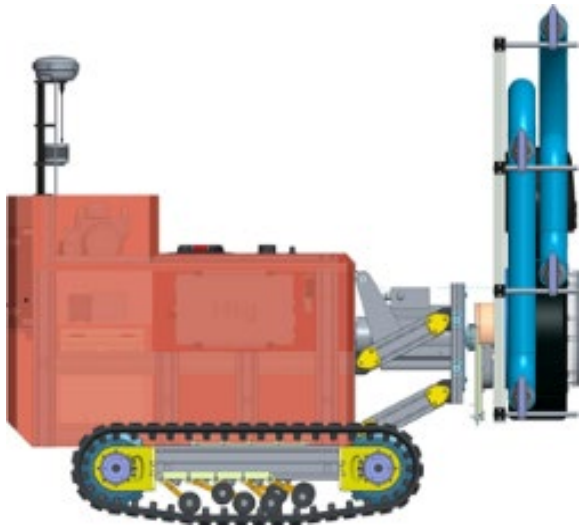
“FieldRobotics Concept”

- **“Implement motorizzato ”** Vs. **“trattore che traina l’implement”**
  - ✓Compattezza e progertto integrato
  - ✓Light weight structure (soil compaction, all-weather)

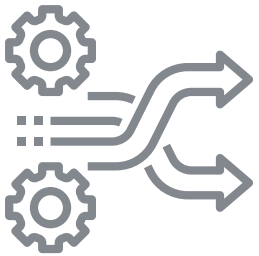






“FieldRobotics Concept”

Un numero maggiore di trattori piccoli piuttosto che un numero ridotto di trattori grandi



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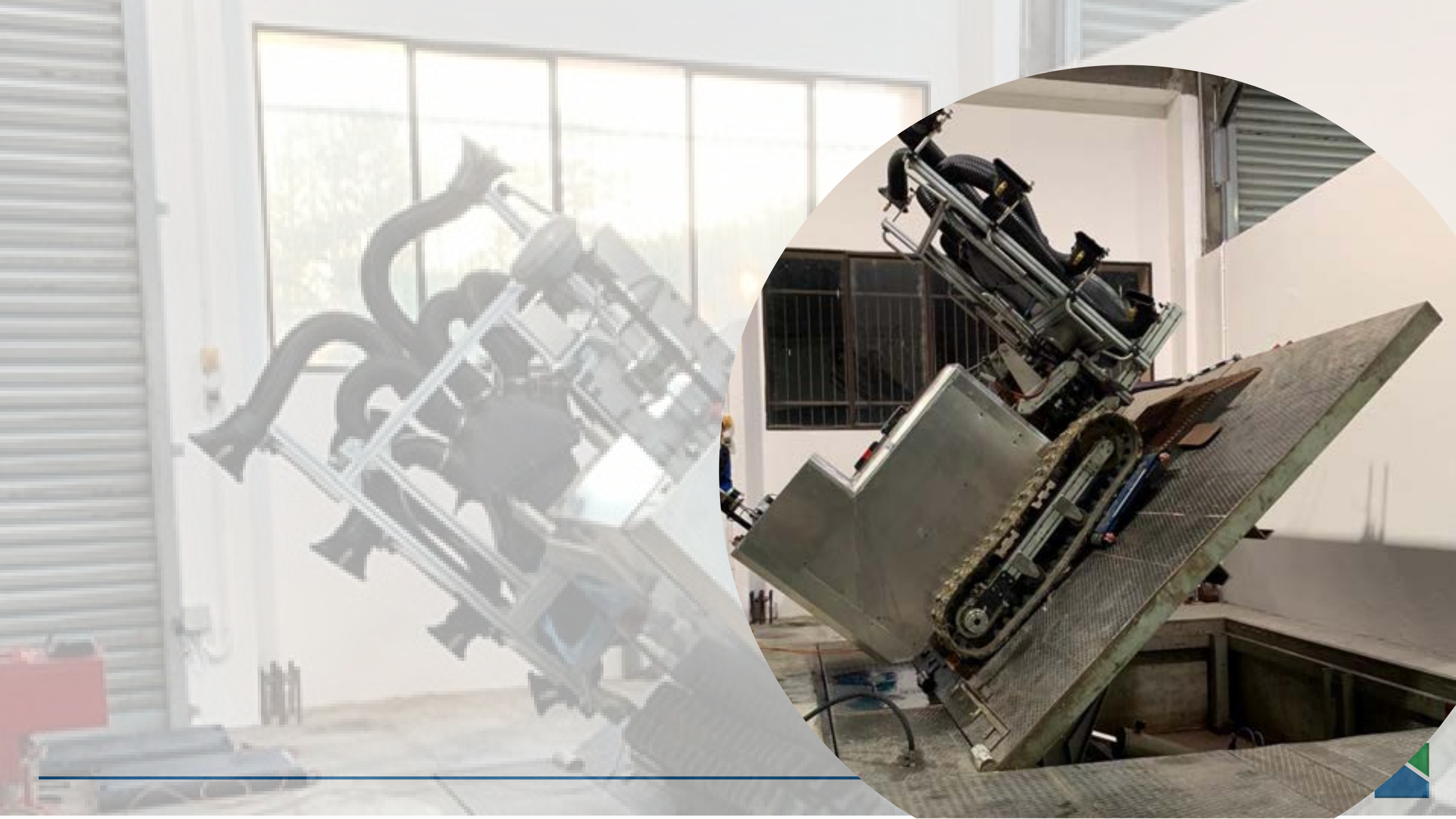
Trasportabilità e leggerezza («all weather»)



“FieldRobotics Concept”

- **Operatività continua**
- **Bassa velocità**

⇨ **Minor potenza richiesta**

Autonomia !

⇨

FIELD ROBOTICS

“FieldRobotics Concept”

- **Impianti**

  “Robotic-friendly”

  ✓ Frutteto "planare"
  ✓ Inter-fila m 1.5 - 2

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“FieldRobotics Concept”

SHE is .. BELLISSIMA!!!

GOOD FRUIT GROWER

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IFTA in Italy: Your tractor... she is bellissima!

Style matters in Italian farm equipment and trade shows.

February 1st 2023 Issue

Ross Courtney // February 2, 2023

Blaine Smith, left, of Bountiful Orchards near Wenatchee, Washington, checks out a robotic tractor from Bologna-based Field Robotics in November at the FIMA agricultural equipment

eima INTERNATIONAL TWENTY · TWO
BOLOGNA
9-13 Novembre 2022

The HammerHead

TRL8: Sistema completo e qualificato

- ✓ 5 anni di progettazione, 2 anni di test sul campo
- ✓ > 1000 ore di test sul campo

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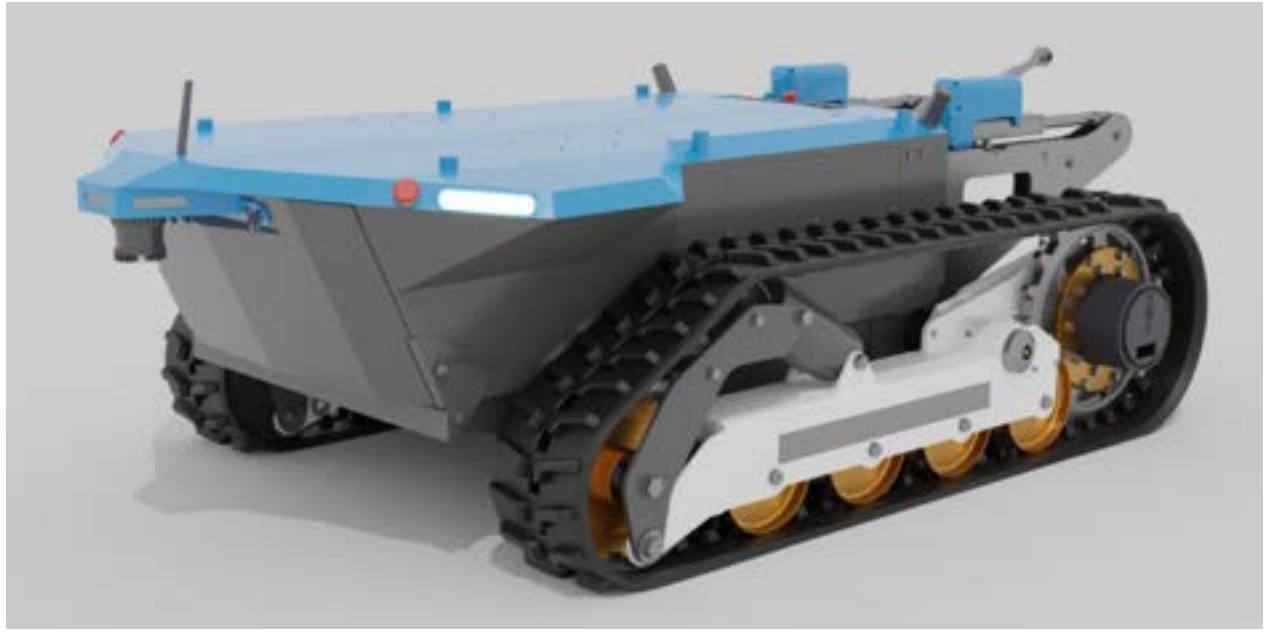
The HammerHead 2.0 (Agritechnica 23- Hannover, EIMA 24 - Bologna)



E ora …

- Sicurezza
- Certificazione
- Prodotto

E ora …

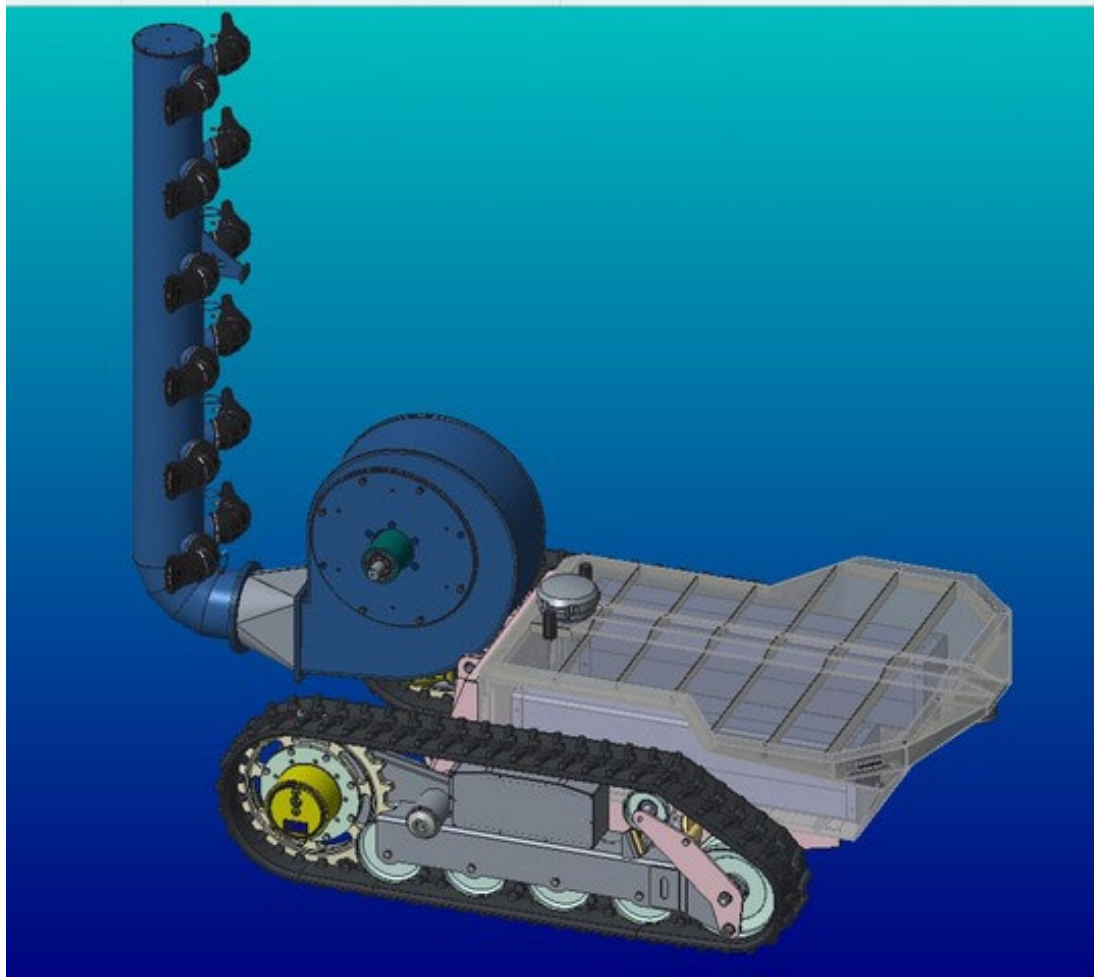
Autonomo

Spesso Lento

“Leggero”

Sostenibile

E ora …



In collaboration con

MARTIGNANI
FOR A GREENER WORLD

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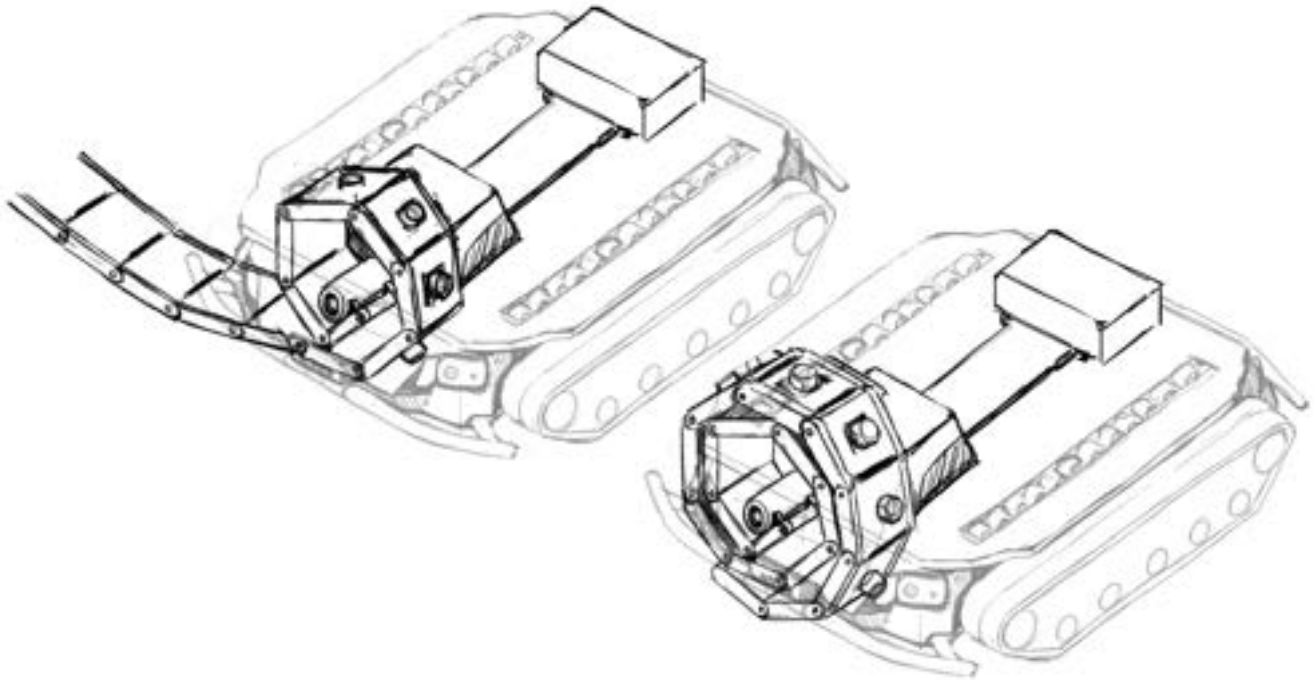
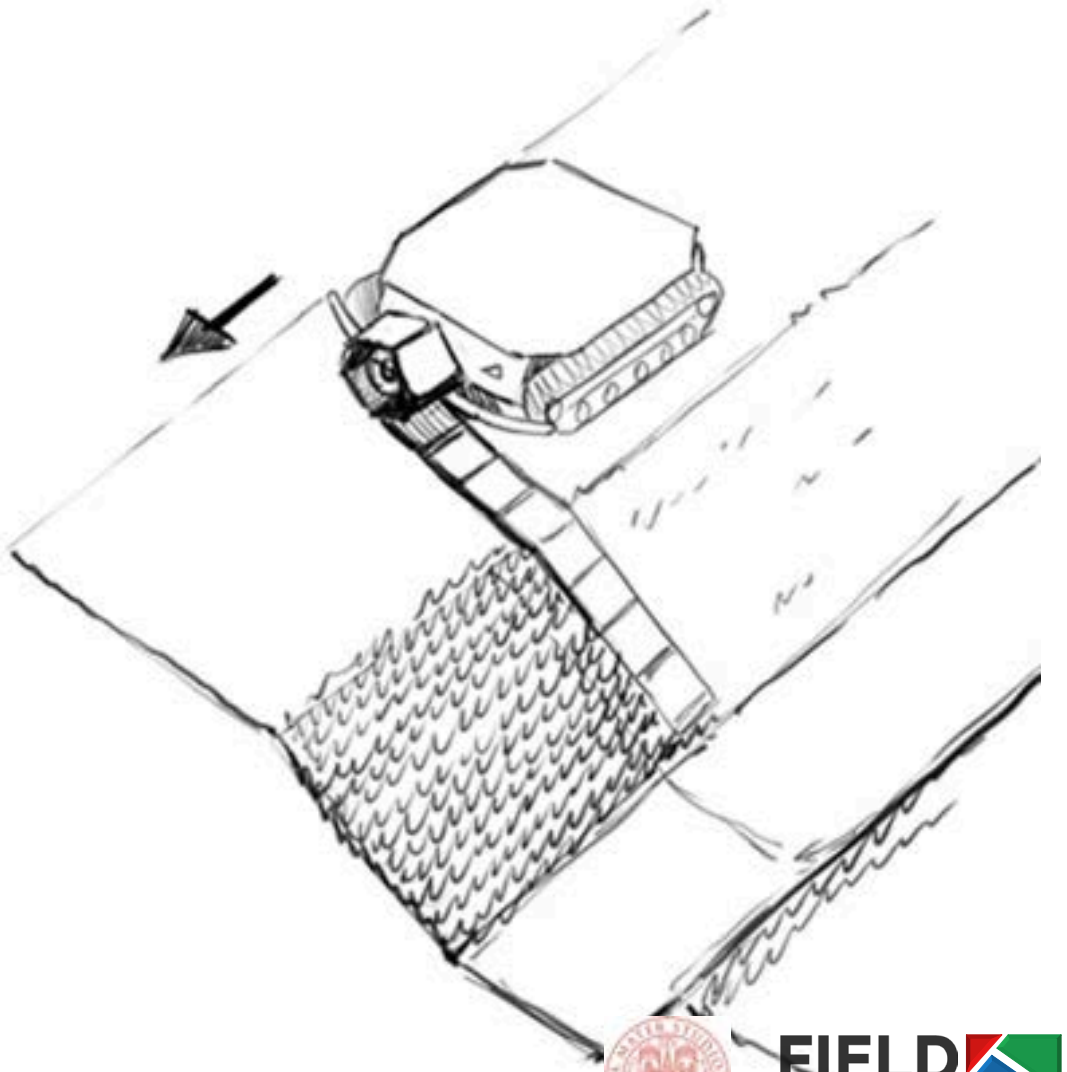
E ora …





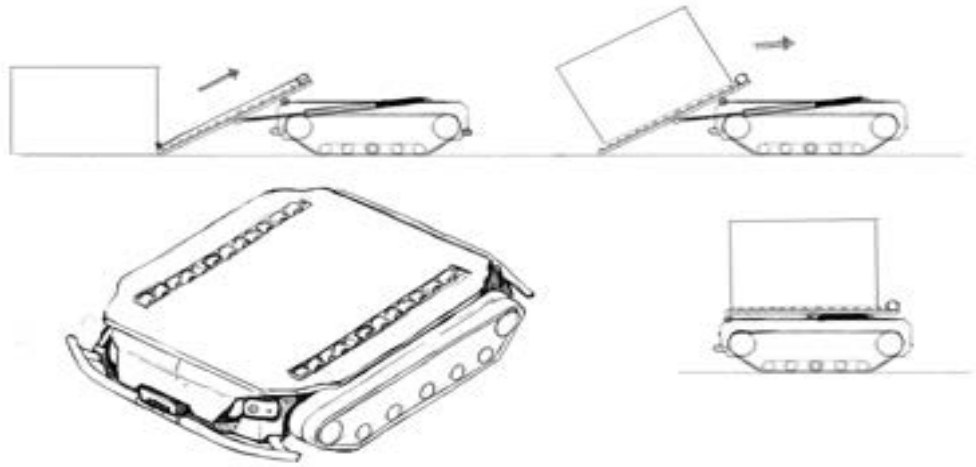
Patent pending

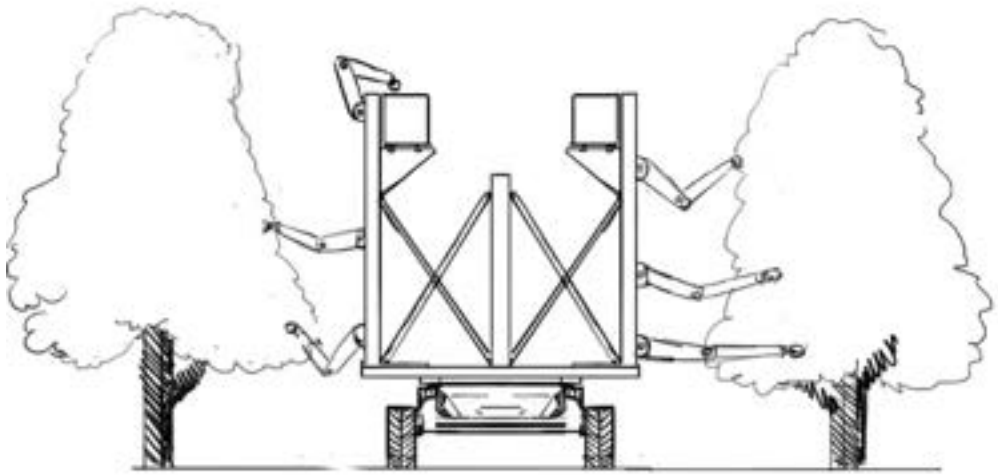
E ora …

Automazione industriale in campo

AgriCobot

RegioneEmilia-Romagna





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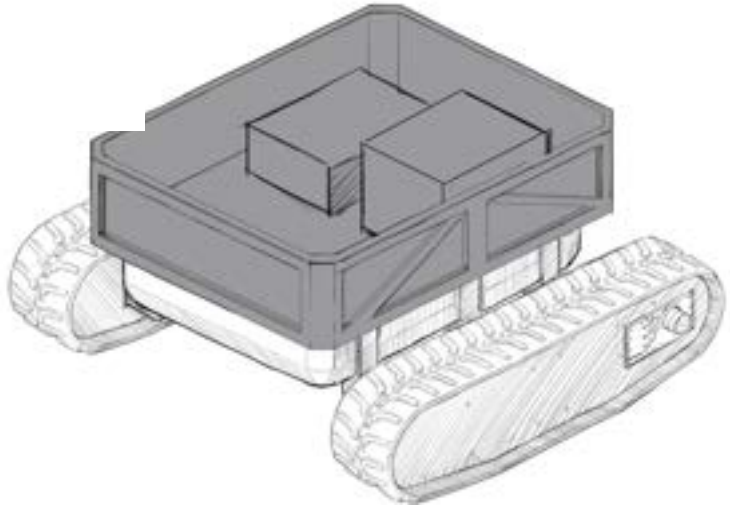
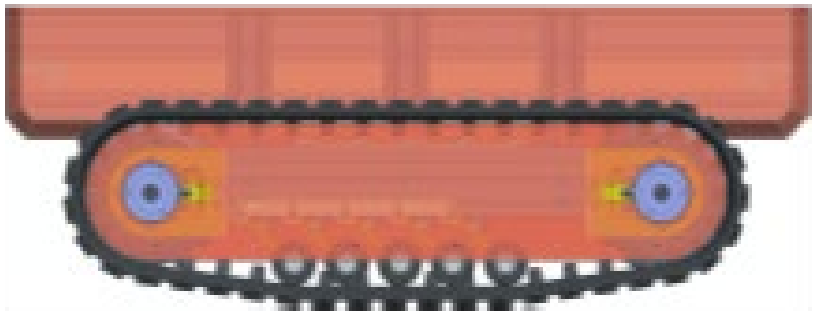
E ora …

- Co-botics: capacità 'follow-me'

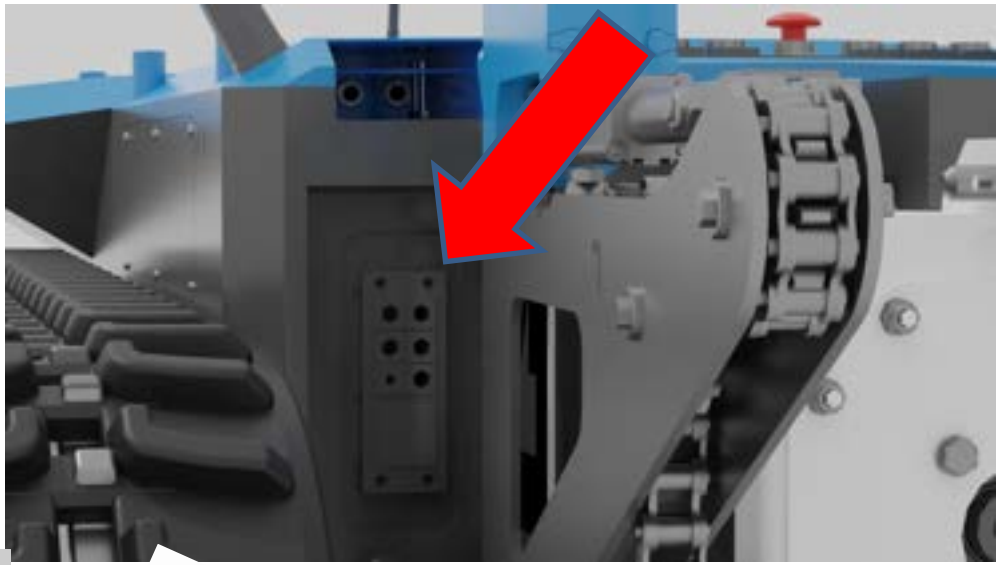


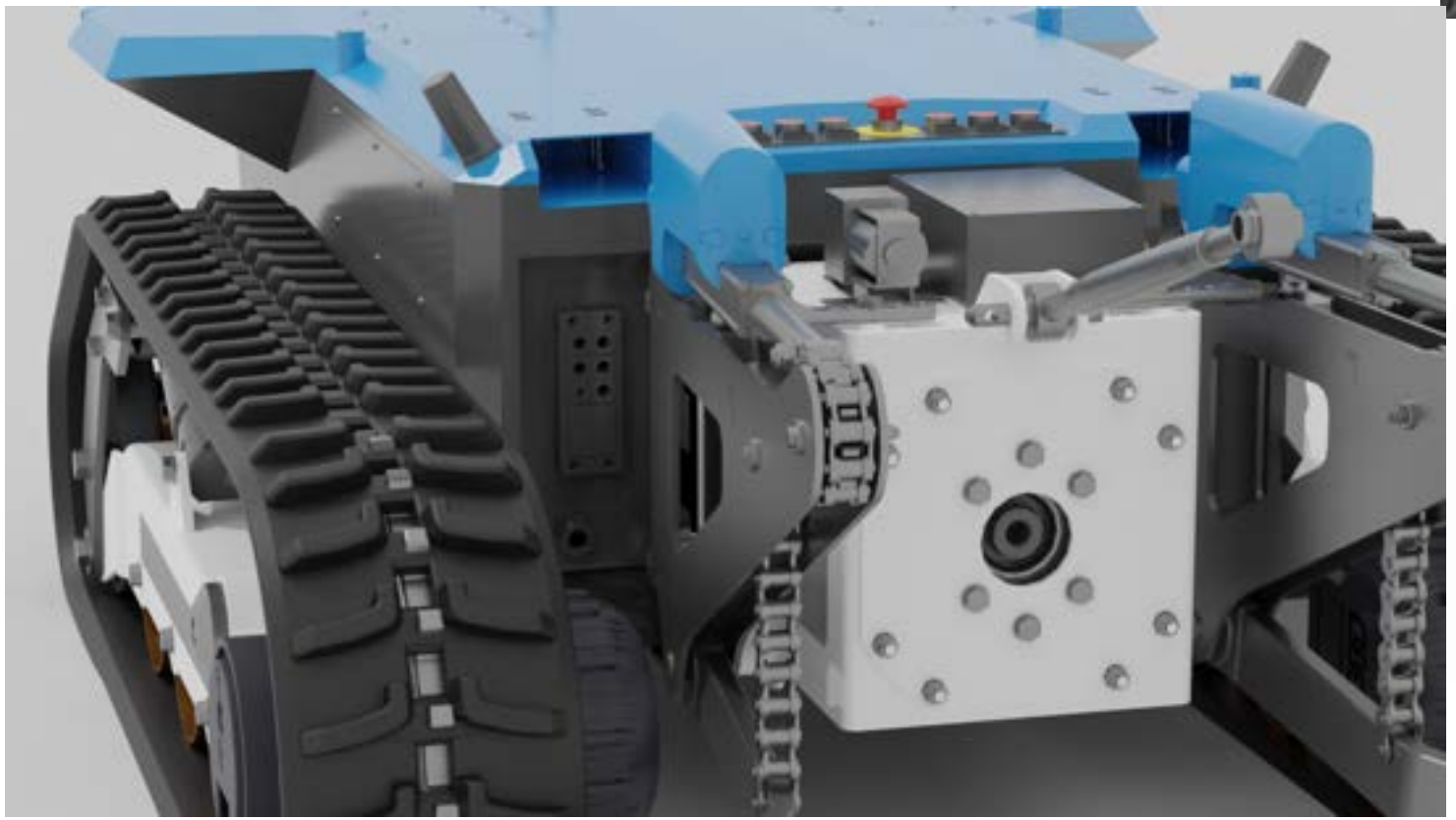
1 TON di payload!



E ora …

- Presa elettrica in campo

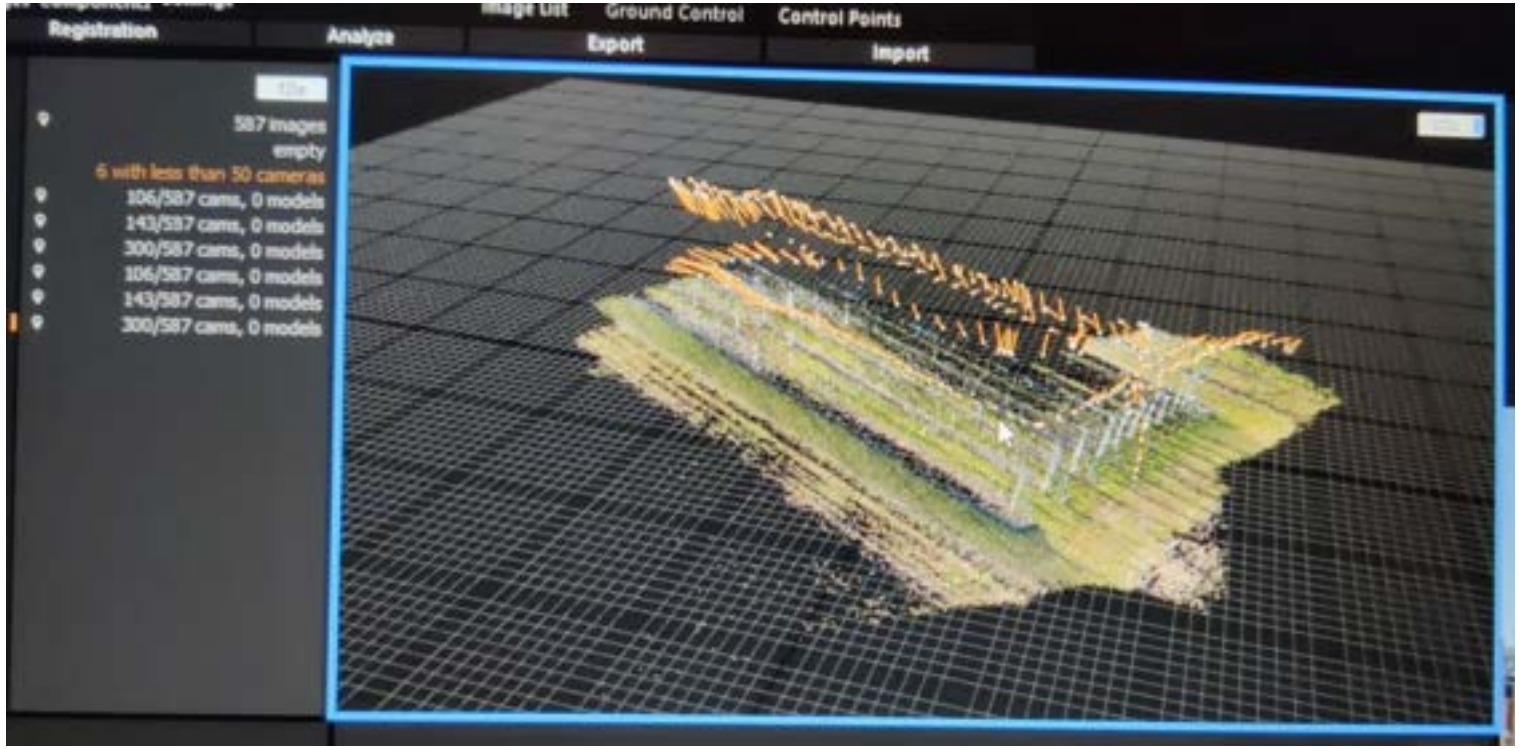




E ora …

Data Harvesting (Precision Farming)

- Camere
- Multispettrali
- Lidar



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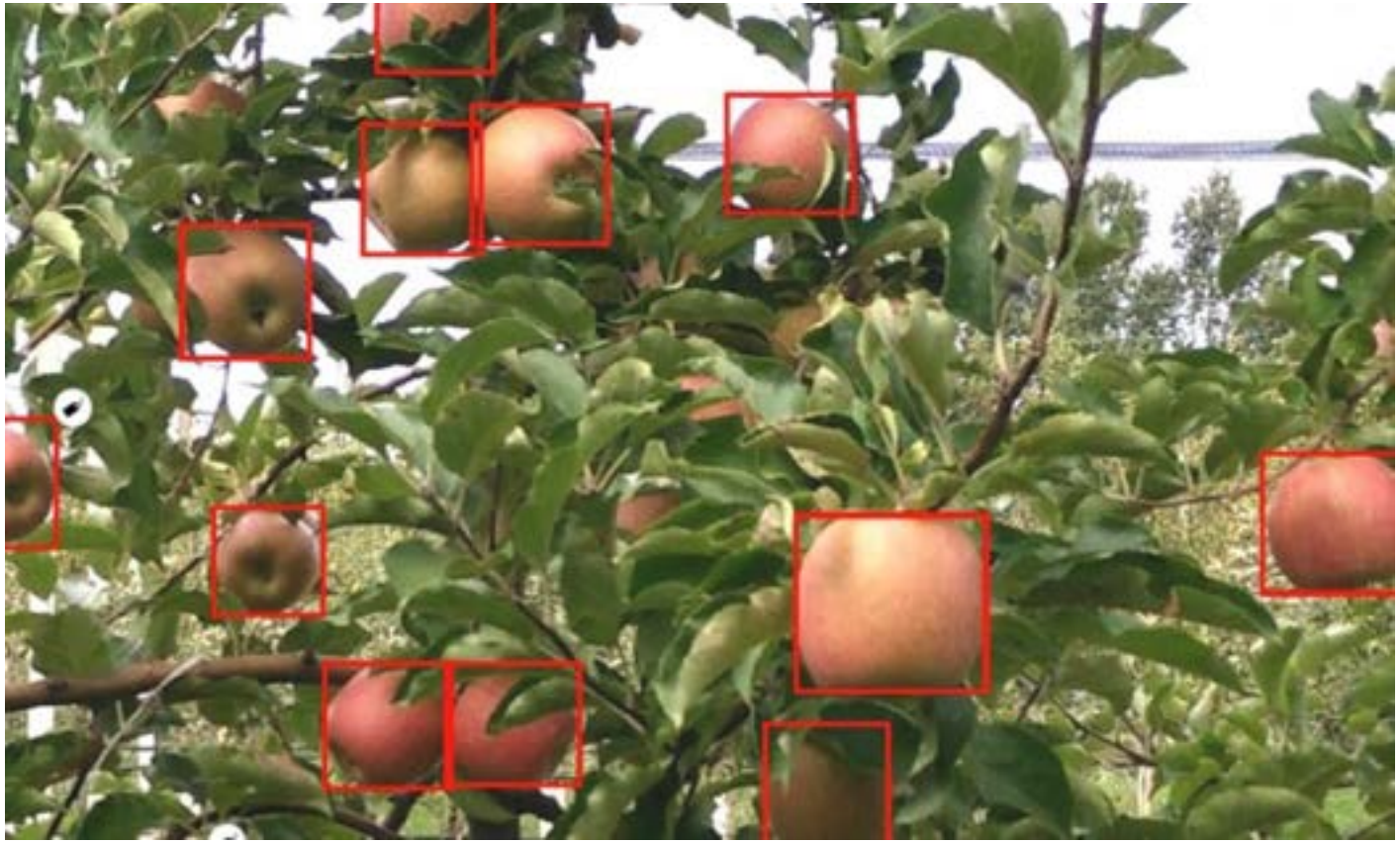
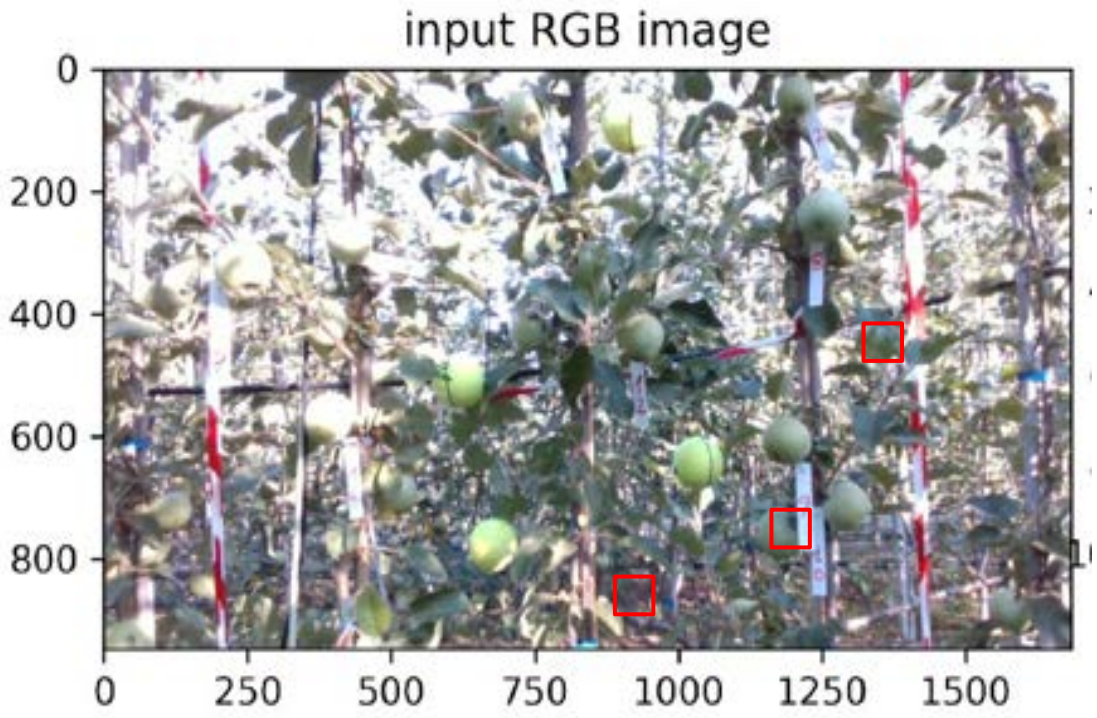
E ora …

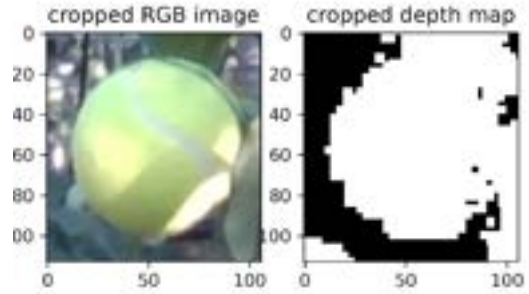


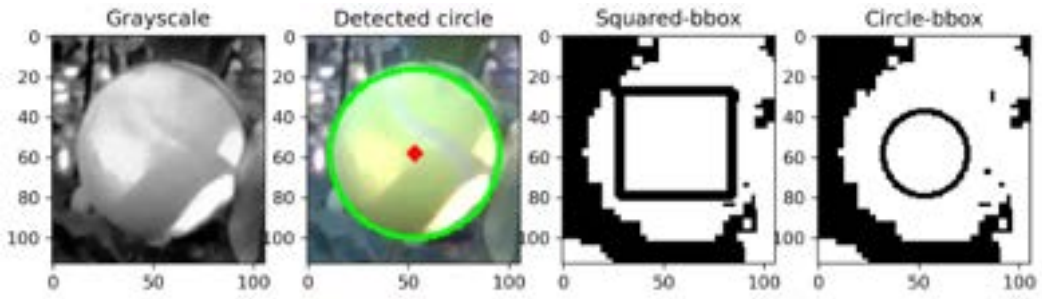

29.0 Apple 0.65
14.0 Apple 0.69
50.0
26.0 Apple 0.65
31.0 Apple 0.65
38.0 Apple 0.58
45.0 Apple 0.53
35.0 Apple 0.64
12.0 Apple 0.70
37.0 Apple 0.60
42.0 Apple 0.56
22.0 Apple
19.0 Apple 0.68
yo 0.68

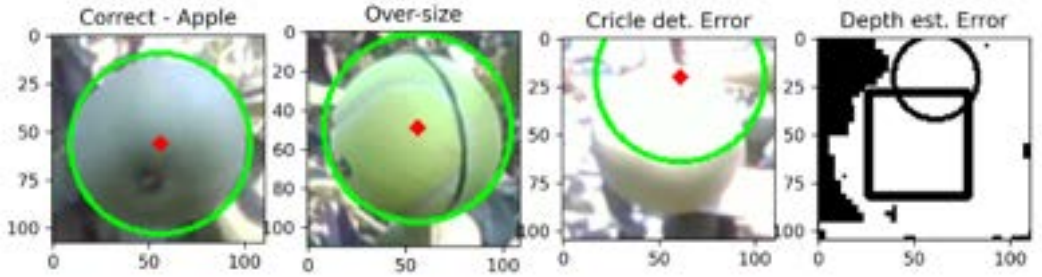
E ora …



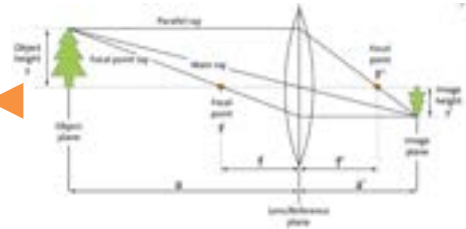
YOLOv5 **Detection**







73mm



92p
x

Single Fruit **diameter in mm**

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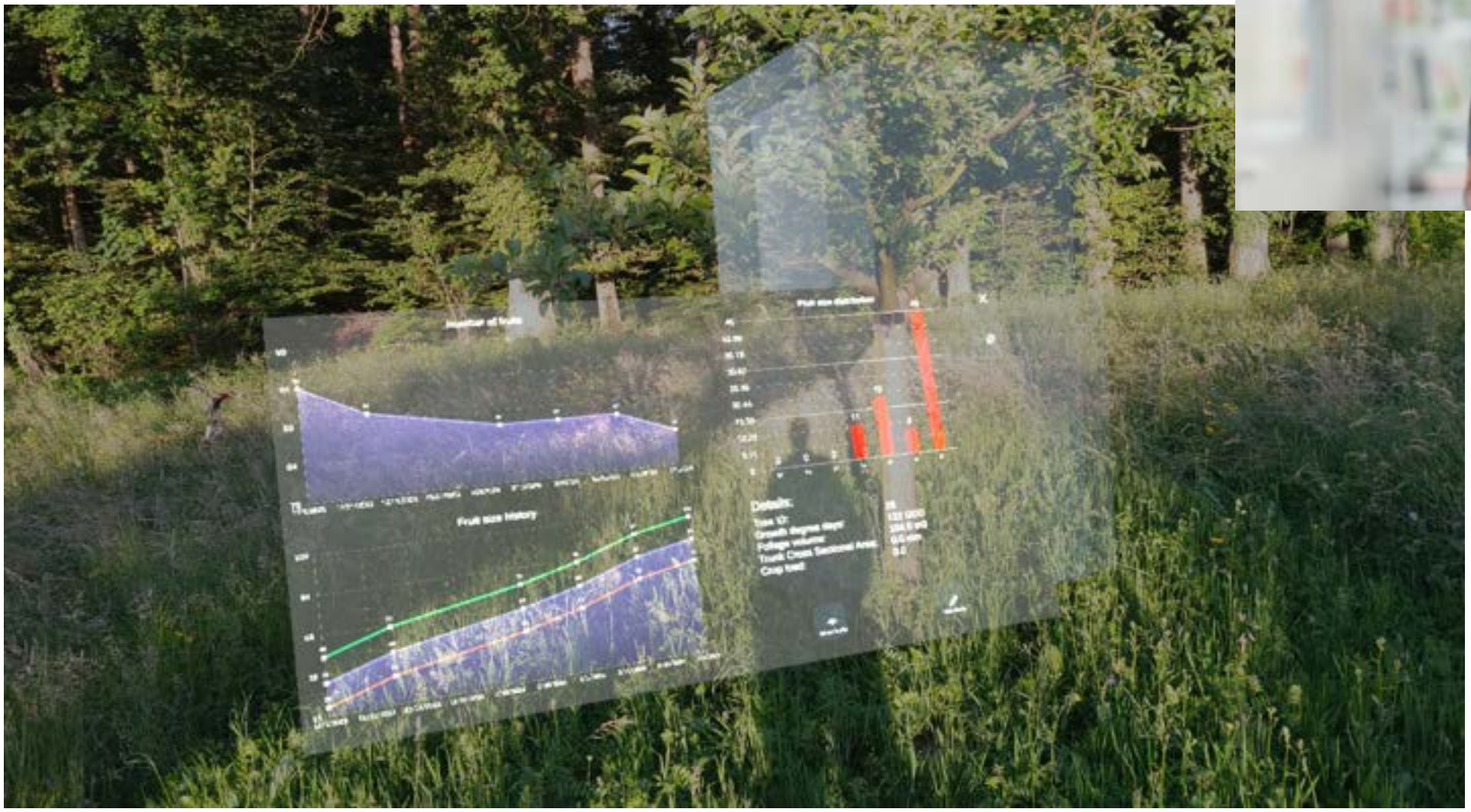
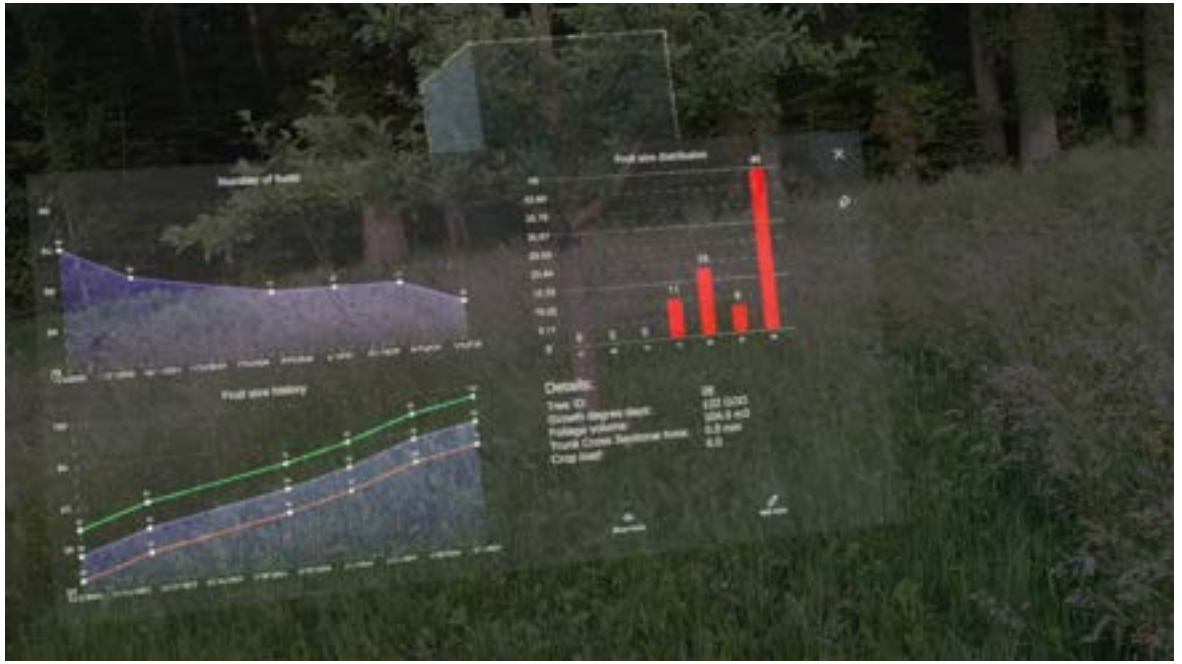
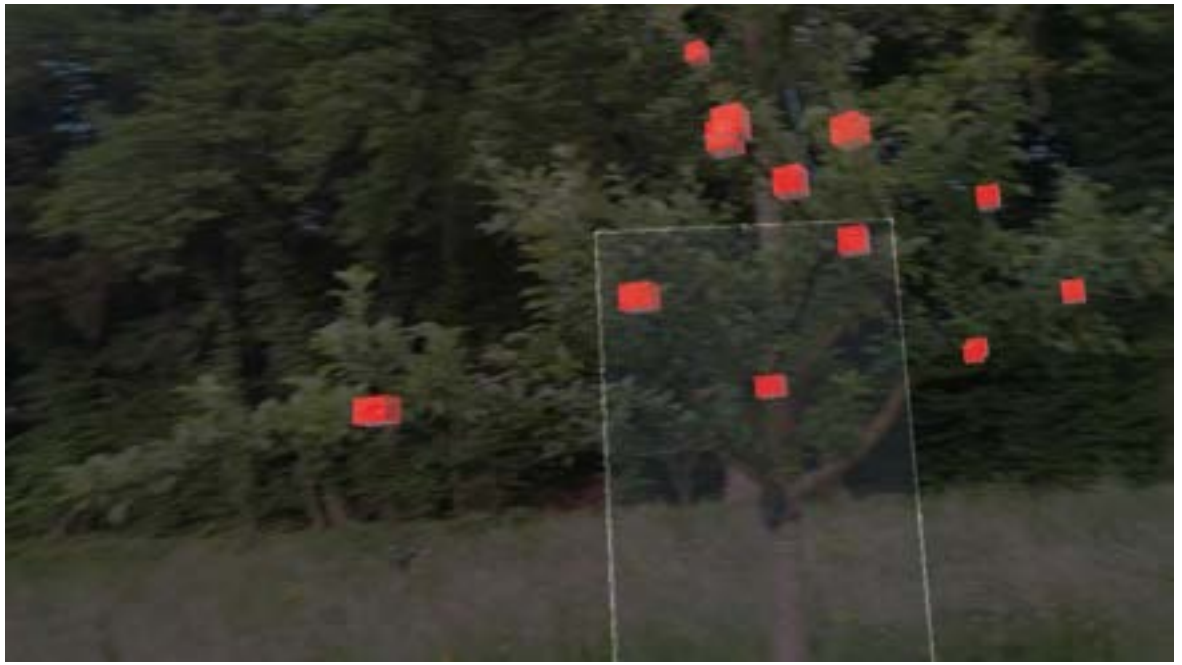
HUMAN INTERFACE



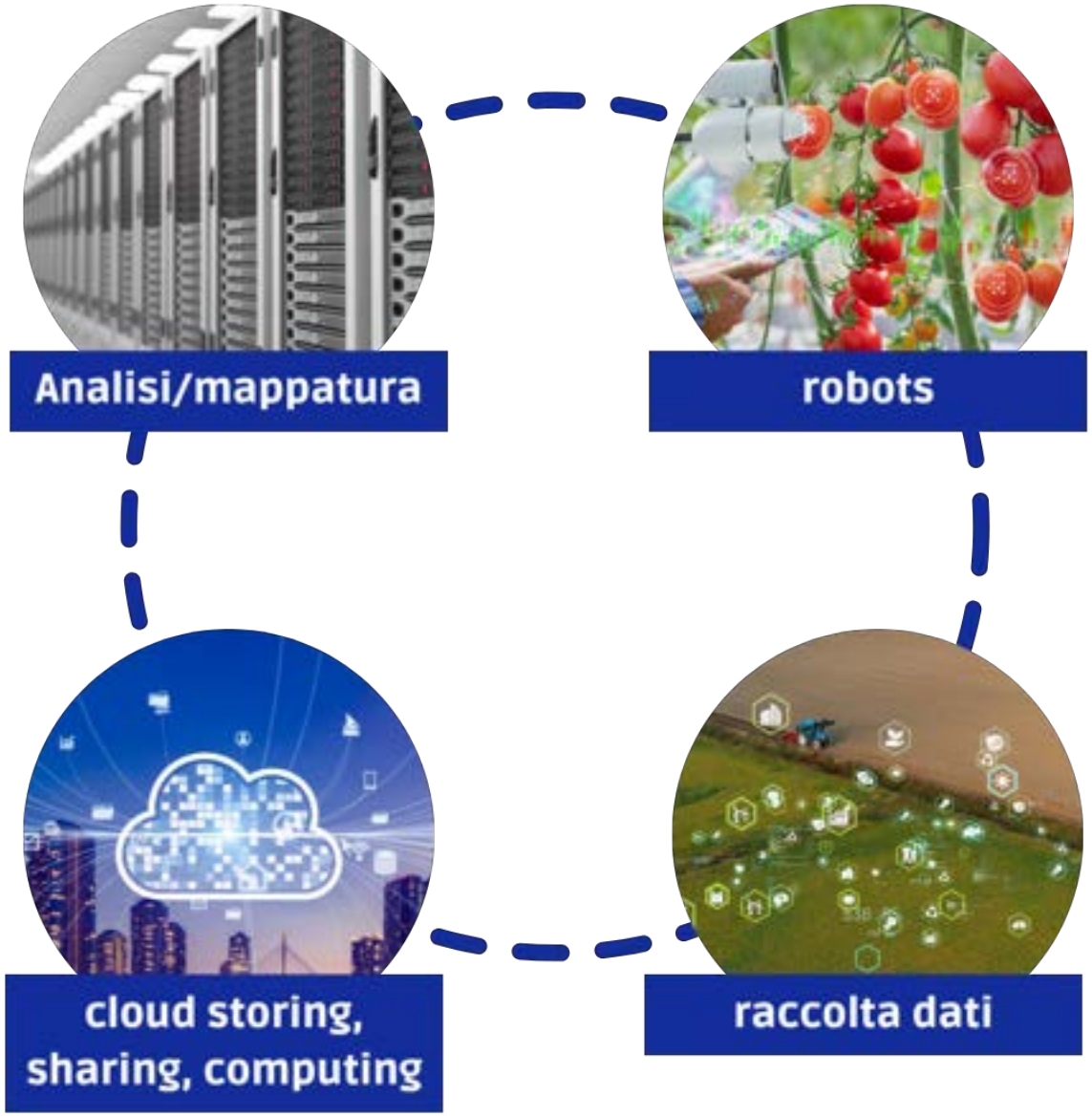

Tree Data
Tree ID: 28
Number of fruits: 84
Growth degree days: 122 GDD
Foliage volume: 104.0 m3
Ok
Delete
Data




40.89
35.78
30.67
25.56
20.44
15.33
10.22
5.11
0
0
0
0
11
19
8
Details:
Tree ID: 28
Growth degree days: 122 GDD
Foliage volume: 104.0 m3
Trunk Cross Sectional Area: 0.0 mm
Crop load: 0.0



Il Loop dell’agricoltura di precisione



Conclusioni:

- Rivoluzione non solo tecnologica
- Elettrico ⟷ Autonomo
- Politiche di Decarbonizazzione
- Certificazione
- <u>Ultimo miglio insieme!</u>

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Impariamo dalla storia .. Bisogna crederci!

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Grazie!