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I ROBOT SCENDONO IN CAMPO
L’ESPERIENZA FIELDROBOTICS

Dario Mengoli *Co-fondatore*

- SISTEMA ROBOTICO AUTONOMO PER L’AGRICOLTURA DI PRECISIONE
- APPLICAZIONI DI MONITORAGGIO PER L’AGRICOLTURA DI PRECISIONE

THE TEAM

FIELD ROBOTICS

Field Robotics - A Spin-off company of the University of Bologna

ALMA MATER STUDIORUM UNIVERSITÀ DI BOLOGNA

Founders

Andrea Sala
Mechanical Engineer

Dario Mengoli
Computer Engineer

Lorenzo Marconi
Automation Engineer, Professor

Riccardo Fini
Industrial Engineer, Professor

Collaborators

Bruno Strano, Simone Rossi, Nicolò Omodei — Automation Engineers

Giorgio Bordini — Mechanical Engineer

Partnerships

Bonfiglioli
We engineer dreams

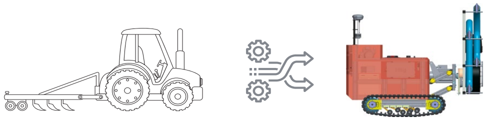
L'ESPERIENZA FIELDROBOTICS

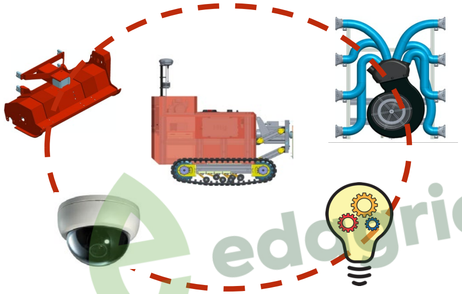
SISTEMA ROBOTICO AUTONOMO

THE CONCEPT

“Motorized implement” vs. “Tractor pulling the implement"

- Integrated compact design
- Lightweight structure (soil compaction, all-weather)



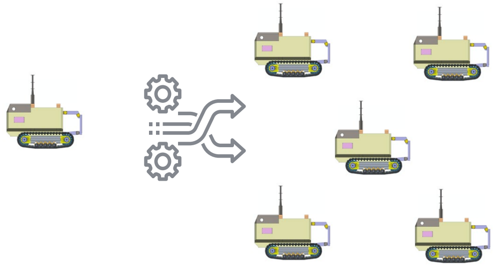


Adaptability and Flexibility

- New generation “plug & play” implements
- (Automatic) Electric plug in the field

Scalability and Expandability

- “Having a larger number of smaller tractors rather than a smaller number of larger ones”



DESIGN OBJECTIVES AND BACKGROUND IDEA

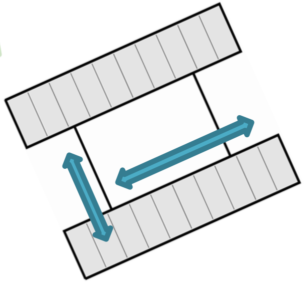
Adaptability and flexibility

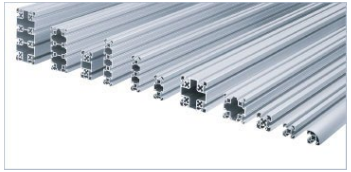
Scalability and Expandability

Versatility

Implement design

- Locomotion Core
- Modular Frame
- Implements Plug&Play





DESIGN OBJECTIVES AND BACKGROUND IDEA

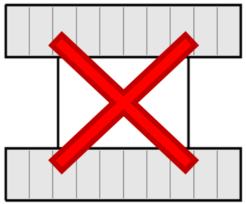
Adaptability and flexibility

Scalability and Expandability

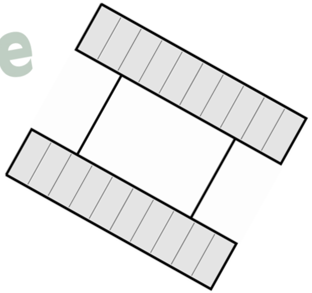
Versatility

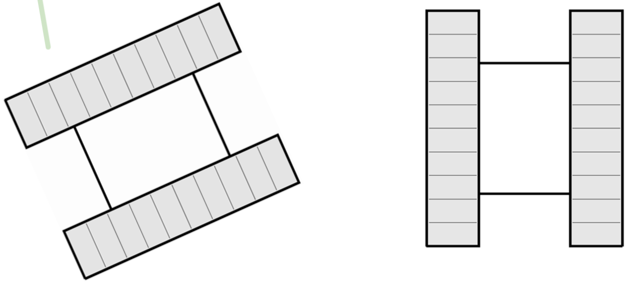
Implement design

- Replication of «Small» units



- Redundancy:
  - Hard time-constraints
  - Fault-tolerant





DESIGN OBJECTIVES AND BACKGROUND IDEA

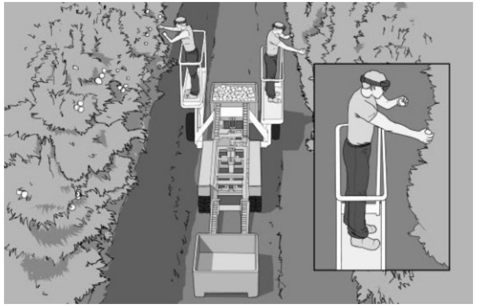
Adaptability and flexibility

Scalability and Expandability

Versatility

Implement design

- Twofold nature:
  - Autonomous platform
  - «Assistant» for human workers (socket in the field)



DESIGN OBJECTIVES AND BACKGROUND IDEA

Adaptability and flexibility

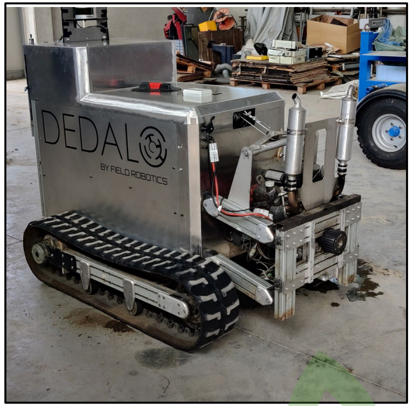
Scalability and Expandability

Versatility

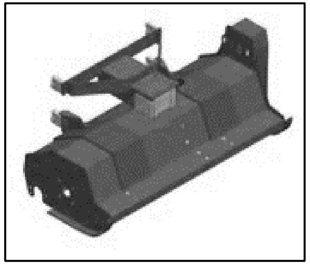
Implement design

- «Motorized Implement»
  - Integrated design
  - Power efficiency

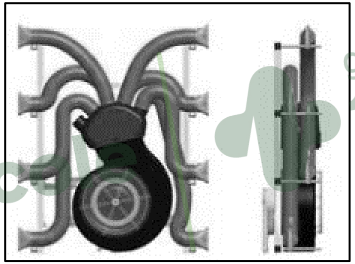
THE ROBOT| Dedalo



MULCHER



SPRAYER



- Power storage configurations (12 Kw, + mult.6 Kw)
- Two power train solutions (Full Electric, Hybrid)

Key Features:

- Small and lightweight structure (600kg)
- Easy to maintain and relocate, efficient
- Superior stability and weight/power ratio, able to carry more than 1000kg payload
- A real all-weather machine (uneven terrains) with reduced soil compaction
- Autonomous in-row navigation able to automatically recognize crop lines
- Almost zero-configuration system, with immediate deploy and operation
- Modularity of implements, battery size, and mechanical configuration

- Un-matched **temporal** and **spatial resolution**
- **Data harvesting** (precision farming)
- **Digital twin** of the crop

PATENTED TECHNOLOGY (pending):
1 patent – navigation
3 patents - mechanics

THE ROBOT| Dedalo

Dedalo is a medium-sized modular robotic platform with interchangeable tools, to be used as a work unit for operations in the field. The modular mechanical structure allows the use of different tools depending on the specific task and environment. The electric locomotion system is suitable for use in challenging/hostile outdoor agricultural areas.

Key Features:

- Superior stability and weight/power ratio
- Lightness and portability
- Adaptability of the mechanical configuration
- Implements and battery modularity
- Technology tested inside a –pilot– innovative orchard of the University of Bologna
- 800+ hours of autonomous navigation

EVOLUTION

- Lower footprint
- Fully electric (implement also electric powered)
- Revamped battery pack (12Kwh)

- Multiple orchard conditions (bench rows, vineyards, orchards, …)

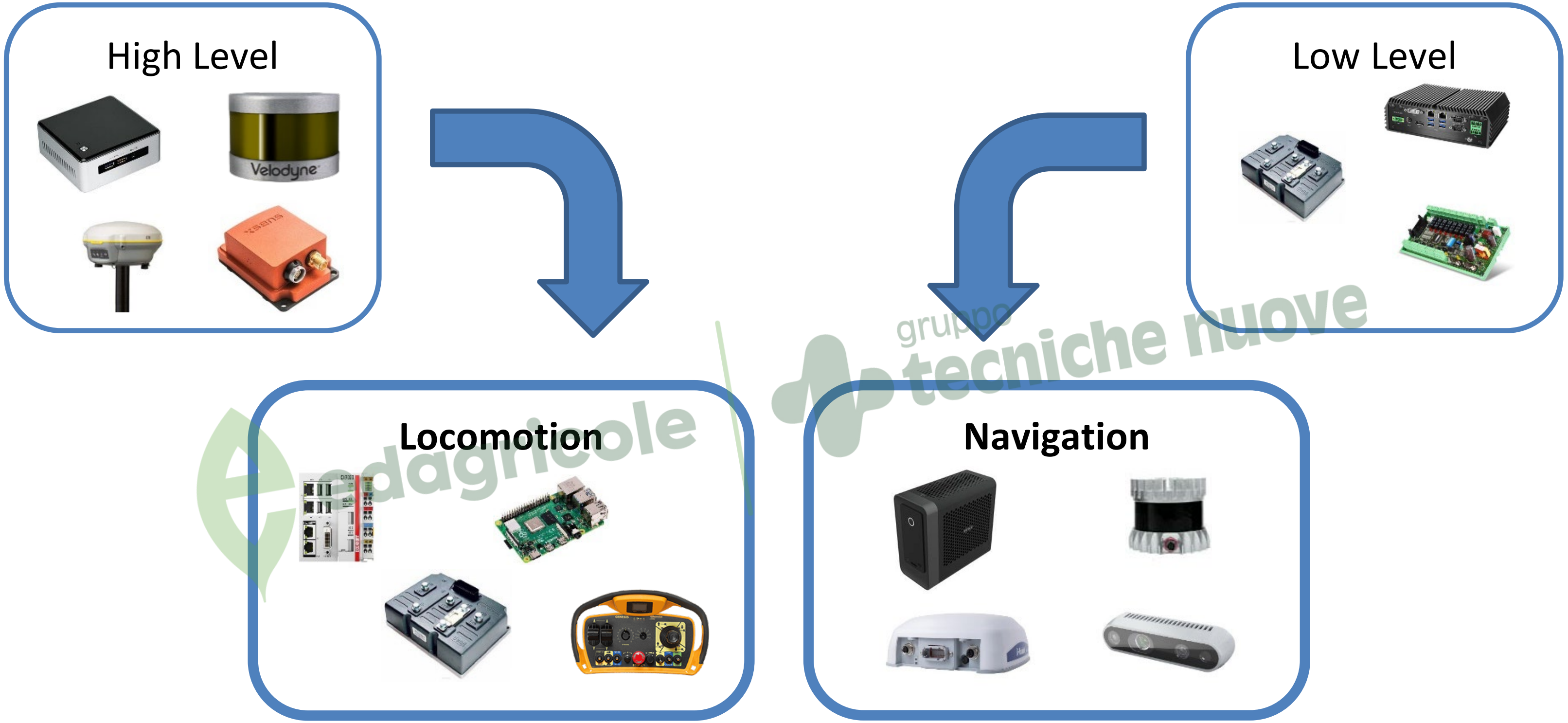
CURRENT VEHICLE | HAMMERHEAD

NEW PROTOTYPE

Key Features:

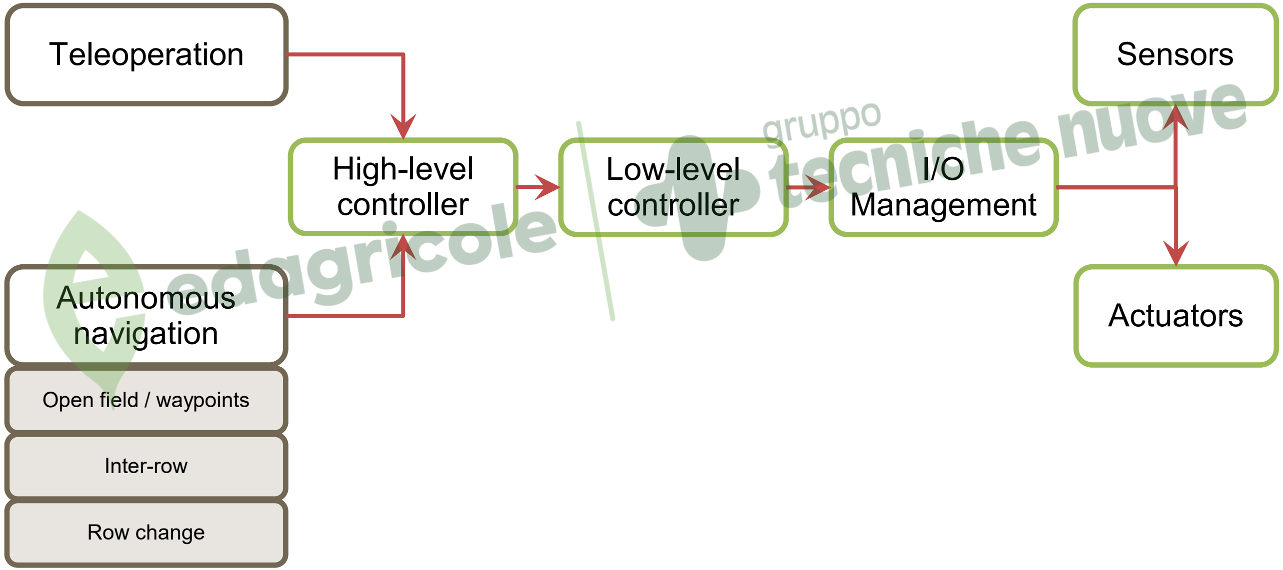
- Revamped design
- Added stereocameras for navigation
- Increased locomotion power (2x5kW)
- Small and lightweight structure (600kg)
- Easy to maintain and relocate, efficient
- Superior stability and weight/power ratio, able to carry more than 1000kg payload
- 3-points hitch for legacy implements compatibility
- Revamped hardware and software suite
- Modularity of implements, battery size, and mechanical configuration

HARDWARE AND SOFTWARE ARCHITECTURE



IN-ROW ORCHARD AUTONOMOUS NAVIGATION

The tracked prototype was entirely designed and built “in-house”, starting from the chassis, track module, implement interface, I/O management, control and navigation software.
All parts of the project maintain a modularity scheme (both HW and SW) where each software component performs a specific function to control a submodule or add a new functionality to the vehicle.

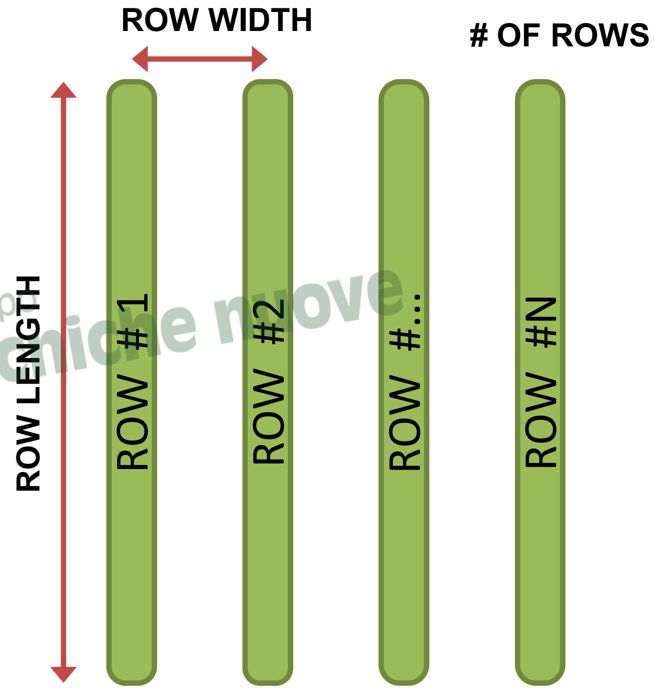


IN-ROW ORCHARD AUTONOMOUS NAVIGATION

Easy and quick configuration, exploiting the semi-structured environment

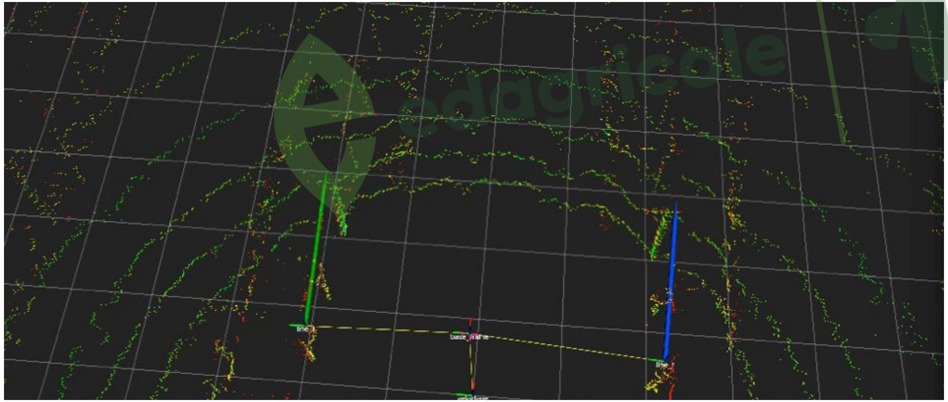
- Row length (approximate)
- Row width (approximate)
- Number of rows

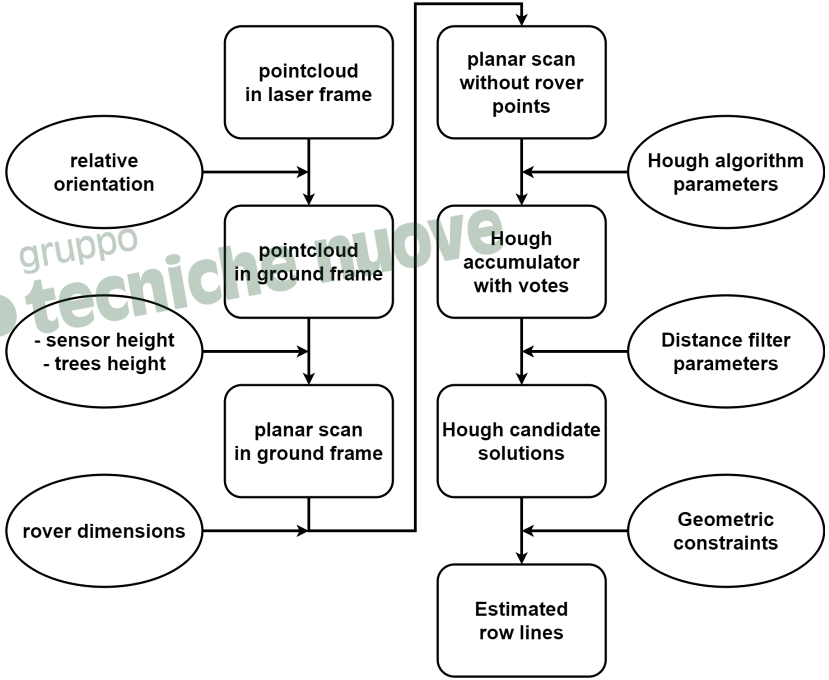
Also, different parameters for each row



POINTCLOUD PROCESSING

HT works for 2D data (images)
Process and clean 3D lidar pointclouds for HT
Add robustness to the estimated lines exploiting dynamic and geometric contraints





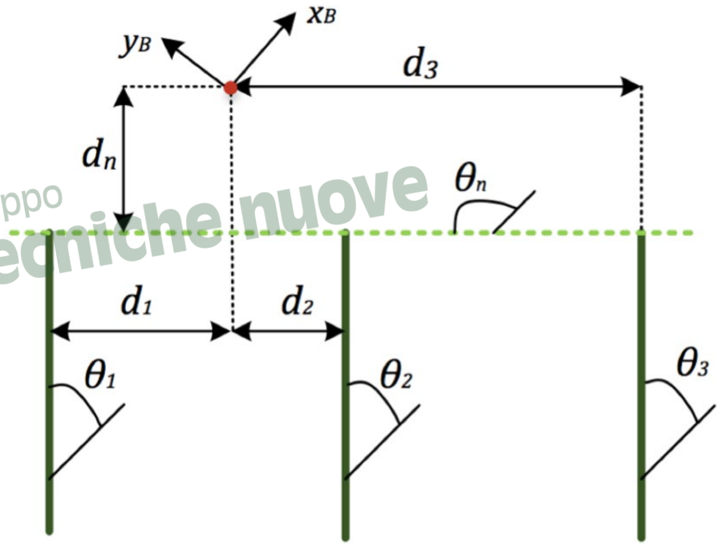
ROW DETECTION AND ROW CHANGE MANEUVER

Required information:

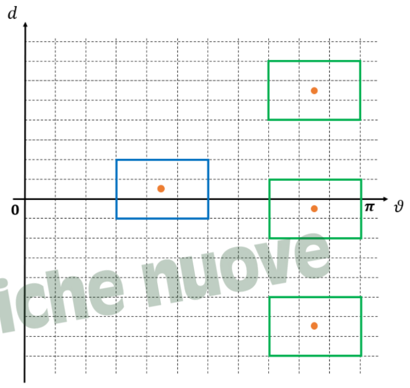
- Row width (+/-25% tolerance)
- Row length

Outputs:

- End of the row
- Position and orientation of 4 lines (**pivot position**)



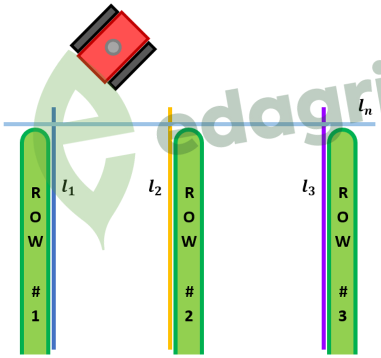
CHANGE-ROW LINES ESTIMATION



Exploit last solution from the In-row

Parallelism and distance constraints

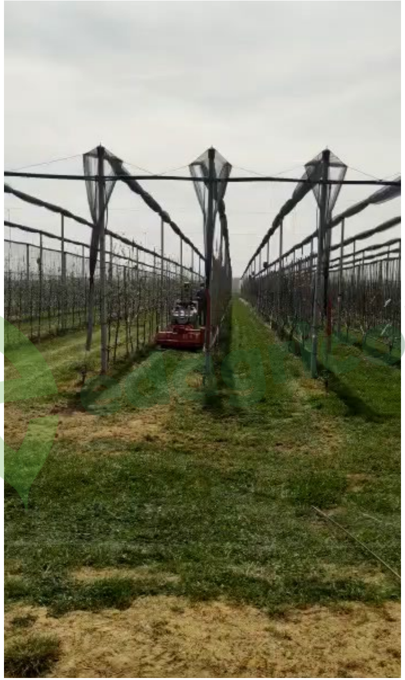
- (l_1 // l_2 // l_3) orthogonal to l_n



- Reduced search solution space
  - In the previous solution neighborhood
- «Dark» side

Field testing (TRL7)

The robotic system is currently used inside the UNIBO experimental field and orchards in Cadriano to perform spraying and mowing tasks



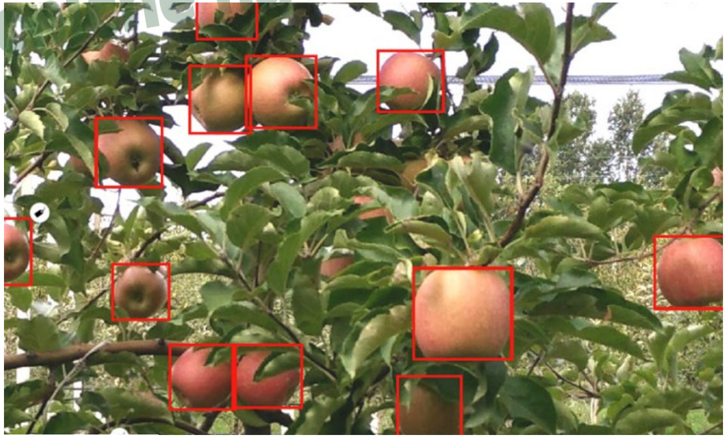
DEMONSTRATIONS

L'ESPERIENZA FIELDROBOTICS

APPLICAZIONI DI MONITORAGGIO

FRUIT DETECTION AND TRACKING

- Custom Yolov5 trained models for apples, grapes and kiwifruit
- 90% accuracy (approx.)



- Further models to be developed during the next season (peach, pear, apricot, …)

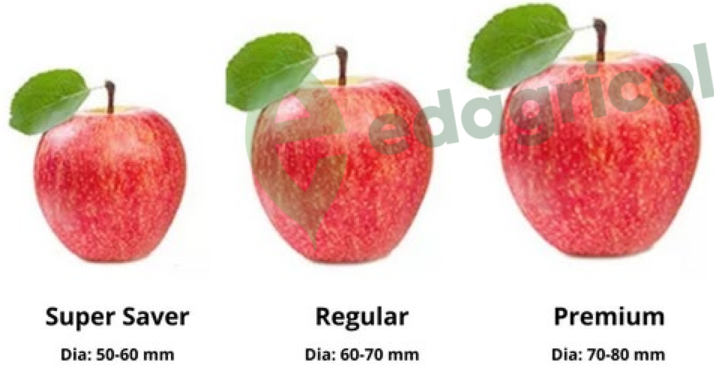
FRUIT TRACKING AND COUNTING

- Multiple Object Tracking using several algorithms:
    - SORT
    - DeepSort
    - ByteSort

- Confidence adjustment to help tracking algorithm and maximize left-to-right correlation

- Robust external counter exploiting object IDs and the vehicle motion direction

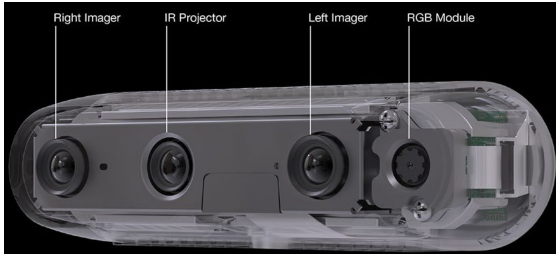
FRUIT SIZING



- Crop reward affected by fruit size
- Early size measurements is important for early crop yield estimation
- It make possible timeliness and flexible agronomic intervention.
- On-line estimation may enable large scale monitoring and autonomous data harvesting

CAMERA SENSOR

Intel RealSense D435i



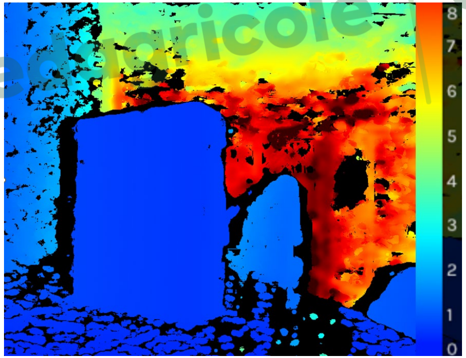
Color image

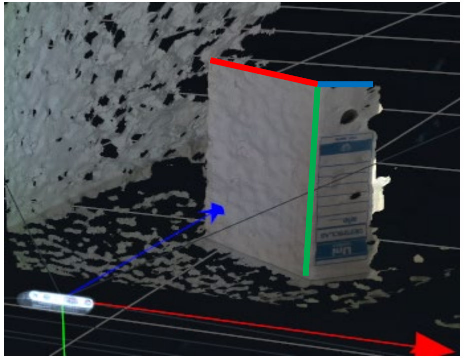
Stereoscopic depth estimation (**Infrared sensors**)

Structured Light principles (**Infrared projector**)

Active stereovision (depth information)

Depth map





3D coloured point cloud (x,y,z)

IMAGE PROCESSING

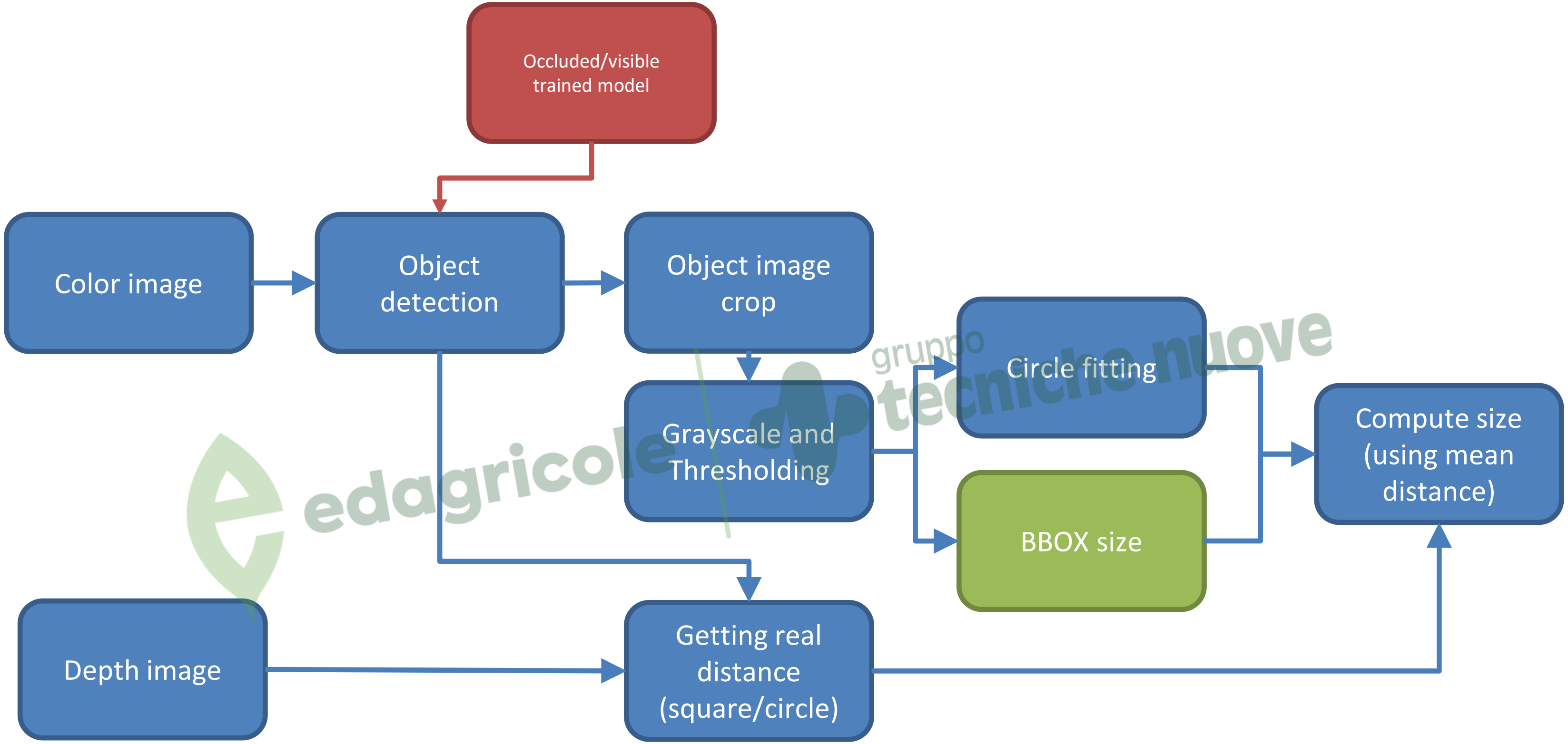
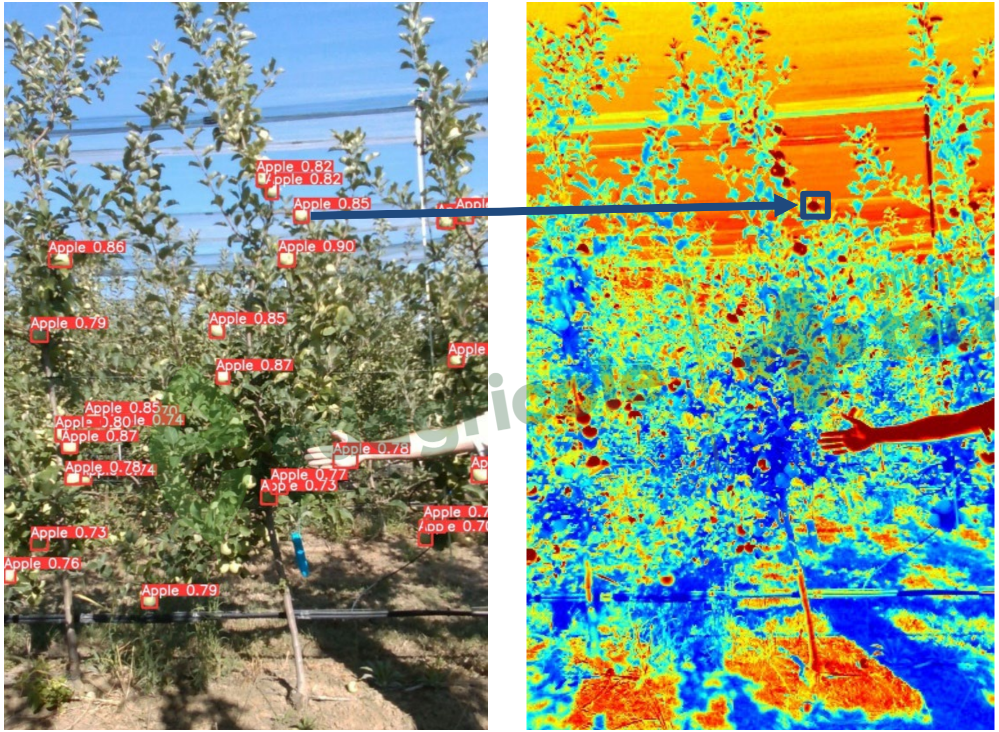
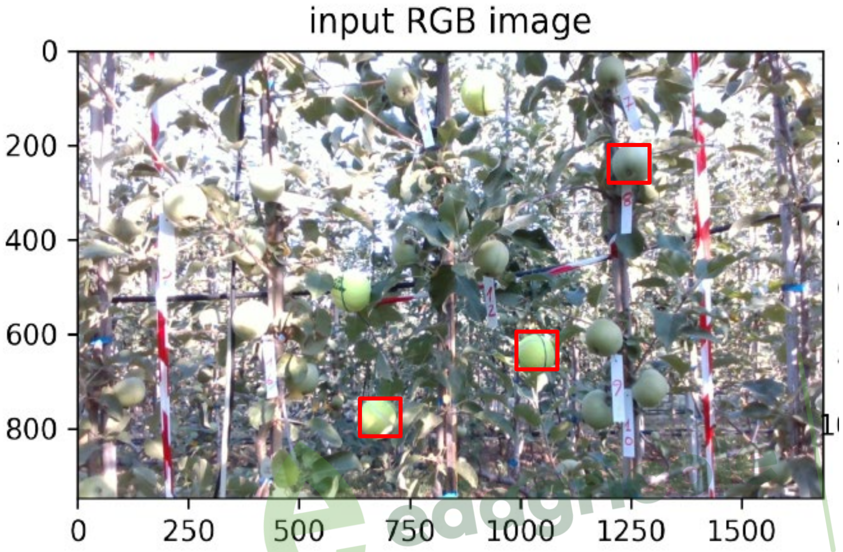


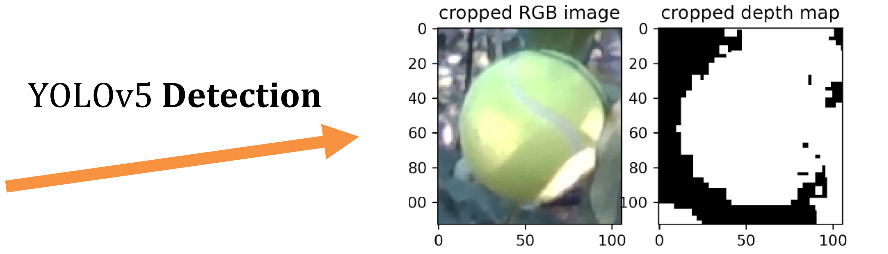
IMAGE PROCESSING

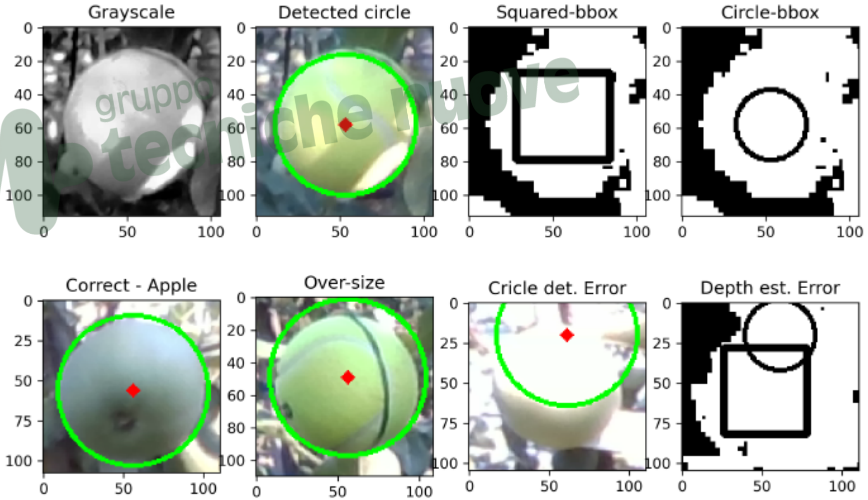


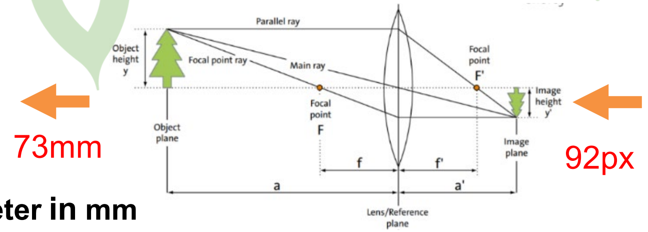
- Comparison with manual caliper measurements
- Depth map and color image aligned
- Full resolution 1920x1080 color image
- Depth image adapted to color resolution

SIZE ESTIMATION EXAMPLES



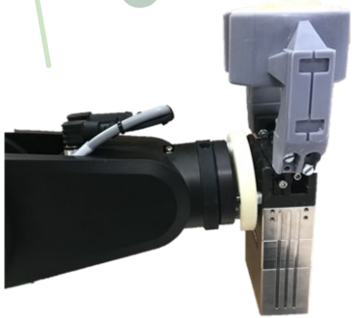






Single Fruit **diameter in mm**

AUTONOMOUS FRUIT HARVESTING

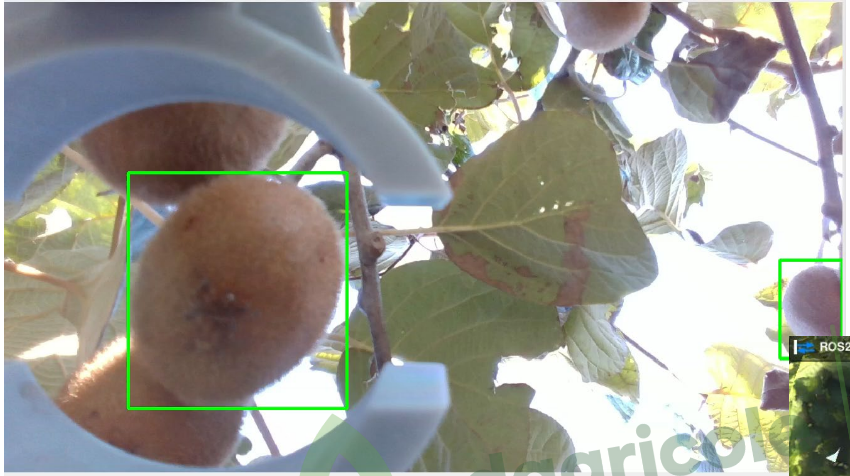


- Preliminary testing using a 5DOF low-cost robotic arm
- Custom 3d printed gripper design
- Kiwifruit harvesting with vision-based fruit detection and tracking

AUTONOMOUS FRUIT HARVESTING

- Preliminary testing with manually given fruit position
- Autonomous motion with trajectory generation starting from fruit position

AUTONOMOUS FRUIT HARVESTING



- ROS integration

- Unity simulation environment

CONCLUSIONS

- Autonomous Ground Vehicle prototype for Precision Agriculture
- Complete autonomous navigation inside and outside orchards/vineyards/greenhouses
- Foundations for complete autonomous operation and autonomous recharge
- PA Applications in orchards
  - Fruit detection and counting
  - Fruit sizing
  - Fruit harvesting