fondata nel 1975
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Associazione Italiana di Robotica e Automazione

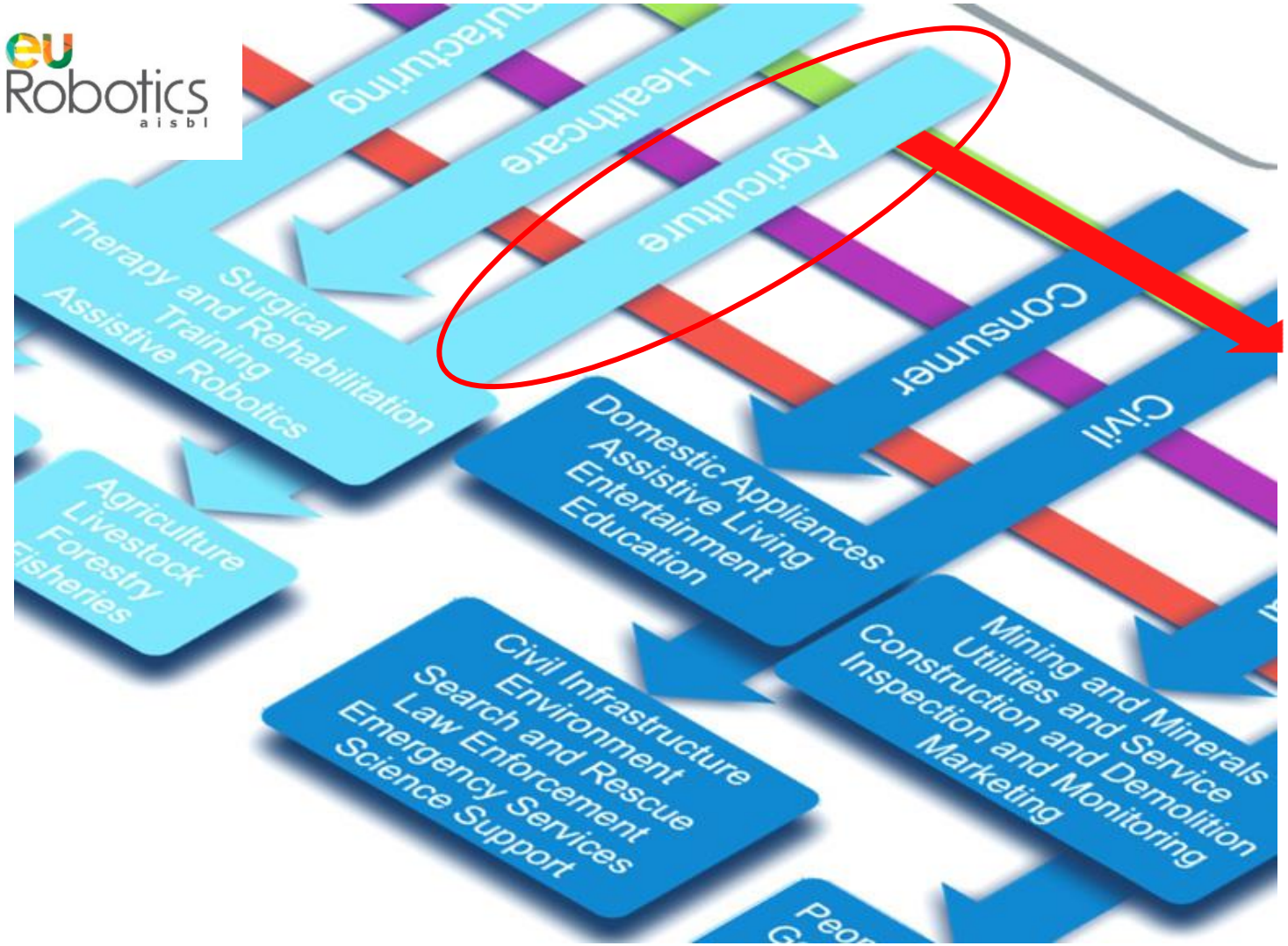
STIIMA
Sistemi e Tecnologie Industriali Intelligenti per il Manifatturiero Avanzato
Consiglio Nazionale delle Ricerche

# Ambient Awareness for Agricultural Robotic Vehicles

*Annalisa Milella, STIIMA-CNR*
*Senior Researcher*

*Corso Nazionale di Robotica e Automazione*
*June 11, 2021*

## MULTI-ANNUAL ROADMAP FOR ROBOTICS IN EUROPE




**Significant advantages:**

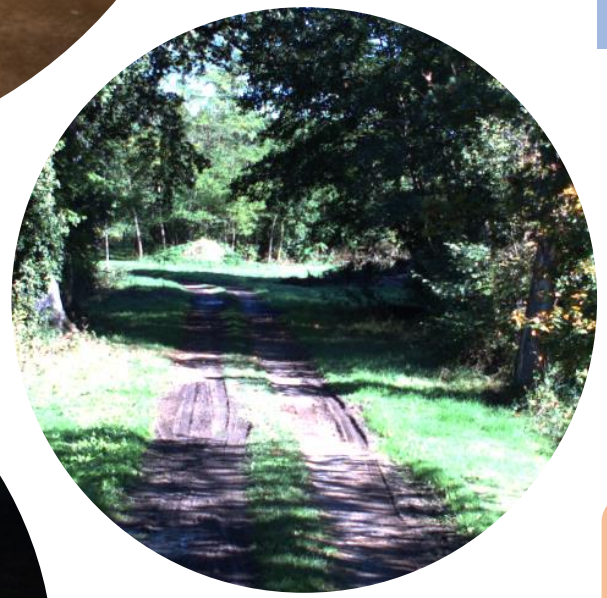
- Increase precision and quality
- Reduce operation time and unit cost
- Provide a quantitative decision base
- Improve interoperability and coordination

**Barriers:**

- **safety**: large and heavy machines in accessible environment
- **privacy**: data acquisition, processing and communication in 3rd party environments
- **cooperation**: autonomous machines in low-deterministic environments

***https://www.eu-robotics.net/cms/upload/topic_groups/H2020_Robotics_Multi-Annual_Roadmap_ICT-2017B.pdf***

# Agricultural Robotic Vehicles



- **Autonomous vehicles** are being increasingly adopted in agriculture to improve productivity and efficiency.
- Environment **perception** and **interpretation** capabilities are fundamental requirements.
- GPS-based navigation systems do not provide information on the dynamics of the environment.

**Challenge:**

*to develop smarter, fully autonomous vehicles able to operate safely in semi-structured or unstructured dynamic environments, in which also humans and animals may be present*

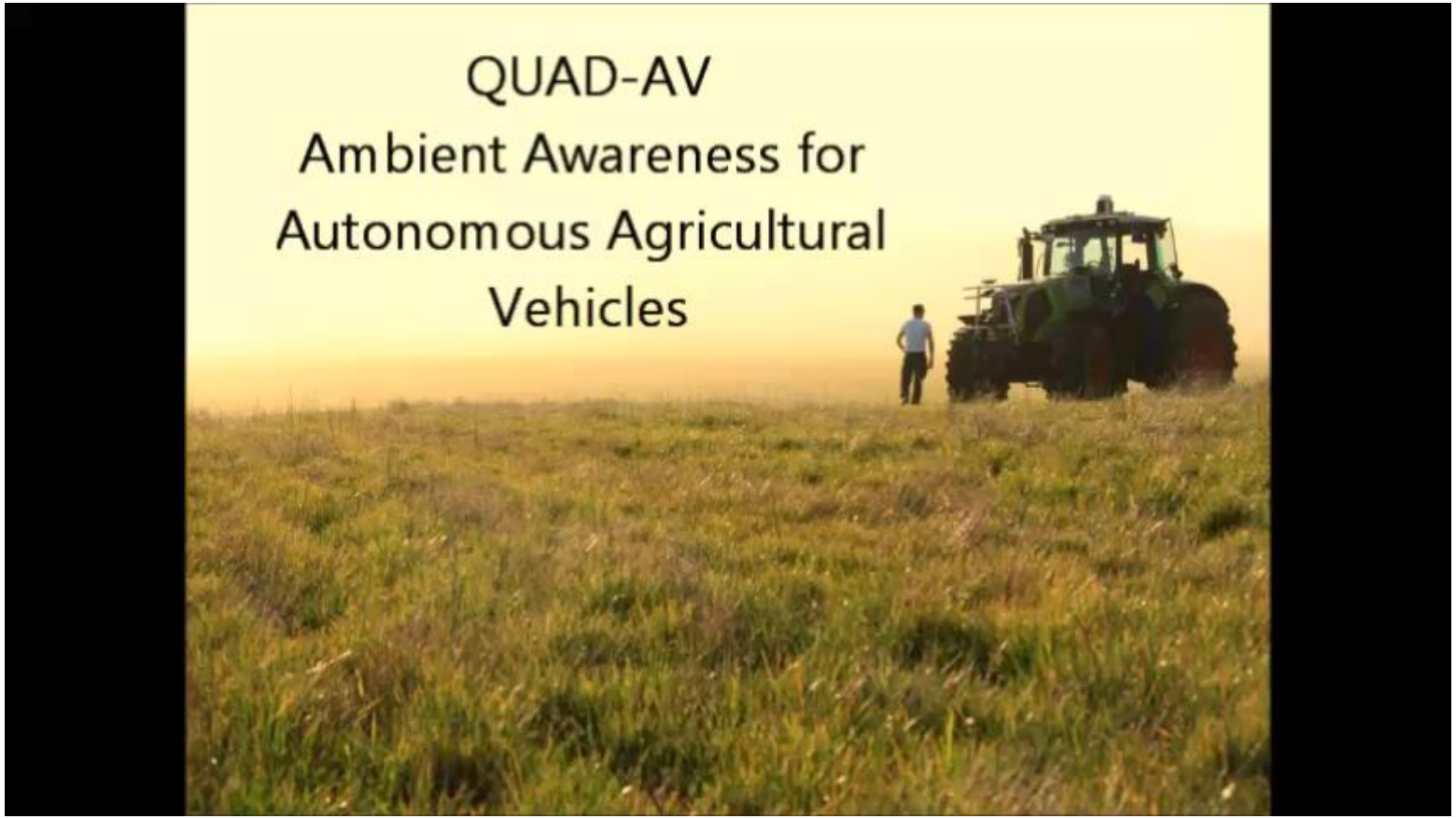
**Development of multi-sensor systems and methods to:**

- Increase autonomous navigation capabilities of the vehicles
- Build digital models of the environments

# Multi-sensor vehicles and robotic platforms

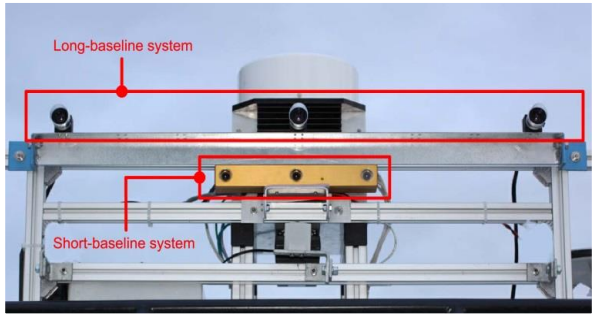
# Multi-sensor obstacle/ground detection

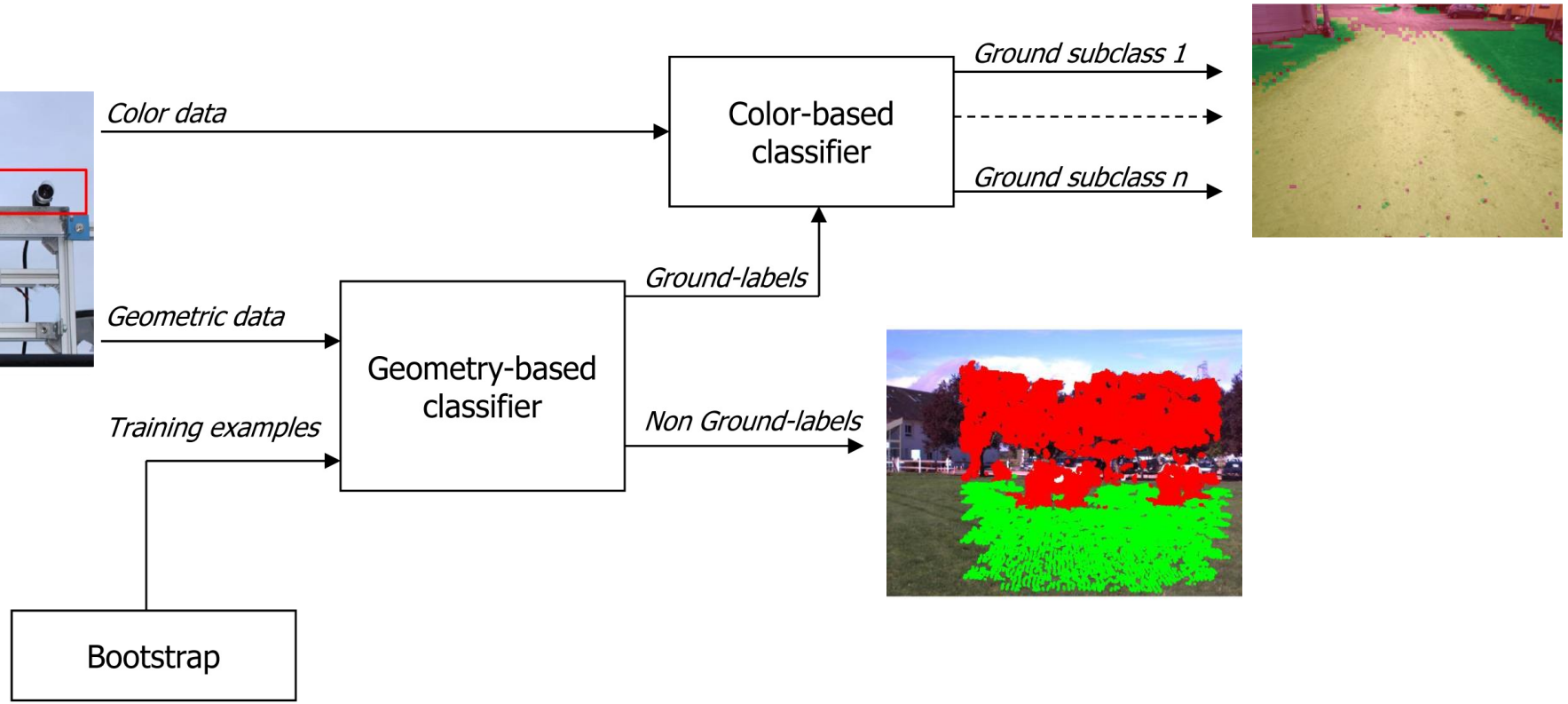
QUAD-AV




G. Reina, A. **Milella**, R. Rouveure, M. Nielsen, R. Worst and M. R. Blas, “Ambient awareness for agricultural robotic vehicles,” Biosystems Engineering, Volume 146, June 2016, Pages 114–132

# Ground/obstacle detection using multi-baseline stereo




***Short baseline system***:
- Uses Bumblebee XB3
- 2 baselines: 12-24 cm
- 3.8 mm focal length lenses

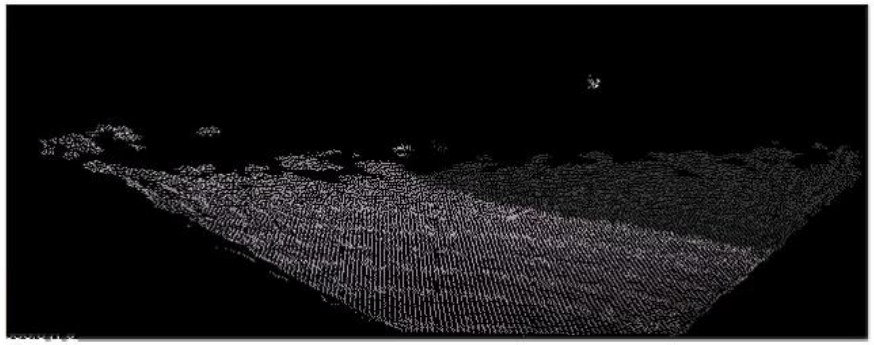
***Long baseline system***:
- Custom-built with 3 Flea3 cameras
- 2 baselines: 40-80 cm
- 12 mm focal length lenses

Reina, G.; Milella, A. Towards Autonomous Agriculture: Automatic Ground Detection Using Trinocular Stereovision. Sensors 2012, 12, 12405-12423. https://doi.org/10.3390/s120912405

# Scene reconstruction

XB3 image

Short range reconstruction by XB3



Flea3 image

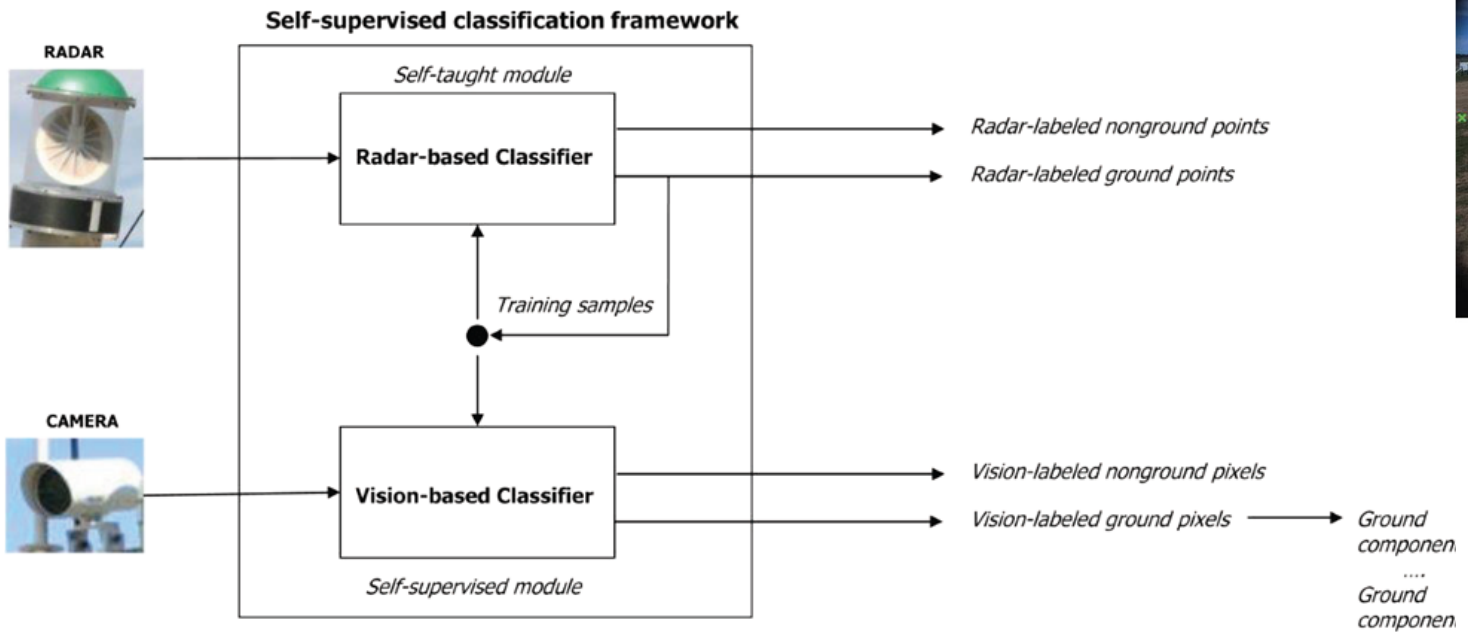
Long range reconstruction by Flea3

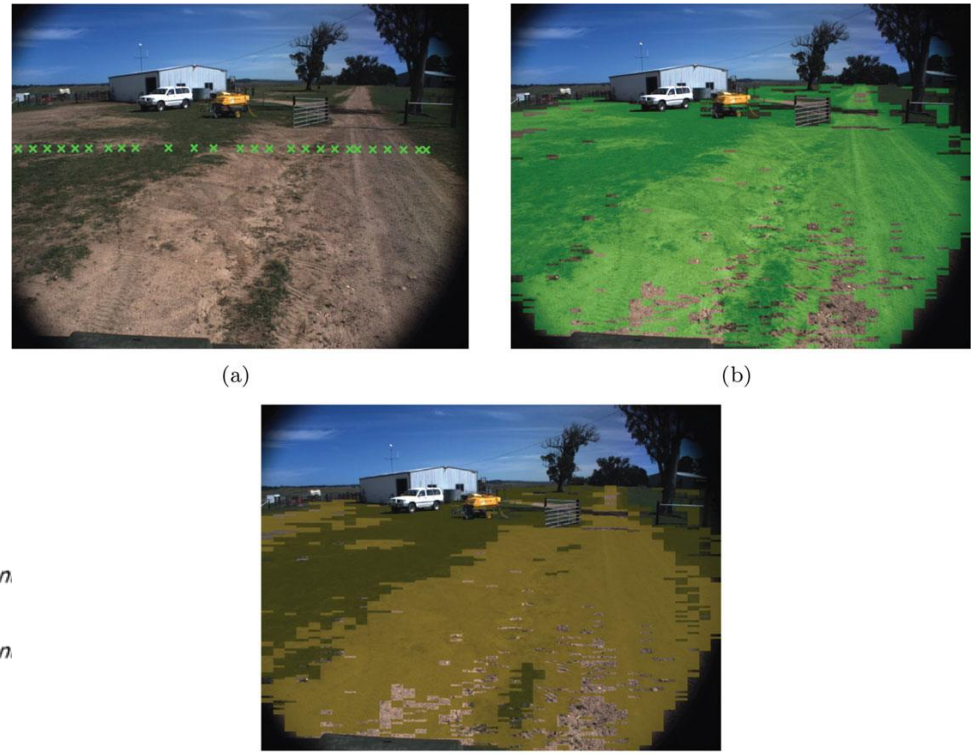
QUAD-AV

# Scene segmentation

QUAD-AV

# Radar-vision integration for ground detection



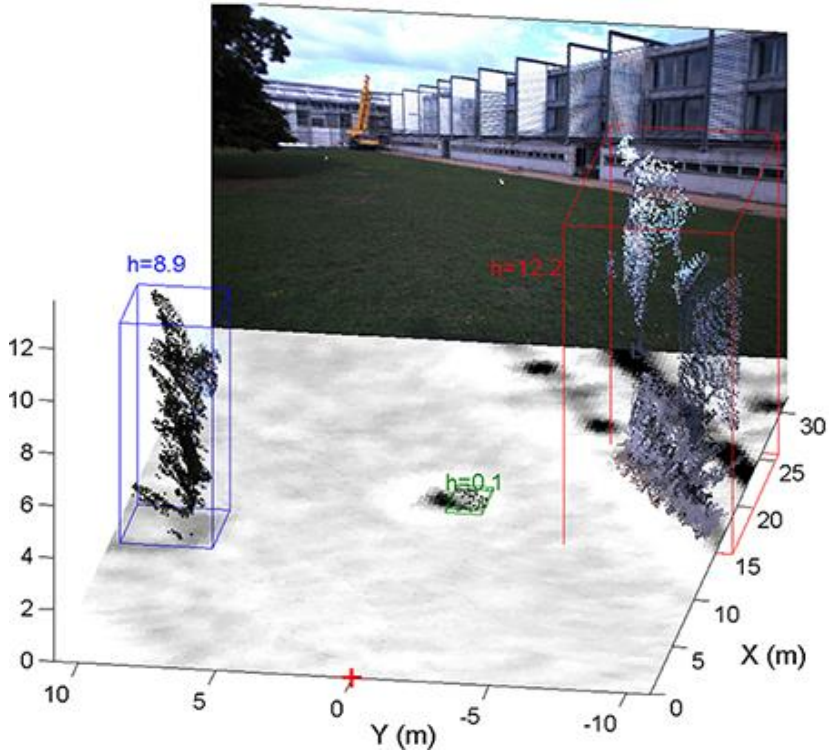

Milella A., Reina G., and Underwood J., (2015) *A Self-Learning Framework for Statistical Ground Classification using Radar and Monocular Vision*, Journal of Field Robotics, Volume 32, Issue 1, pages 20–41.

(a) radar-labeled ground points projected on the colocated visual image (green crosses);
(b) segmented ground (green pixels)
(c) identification of two ground subclasses.

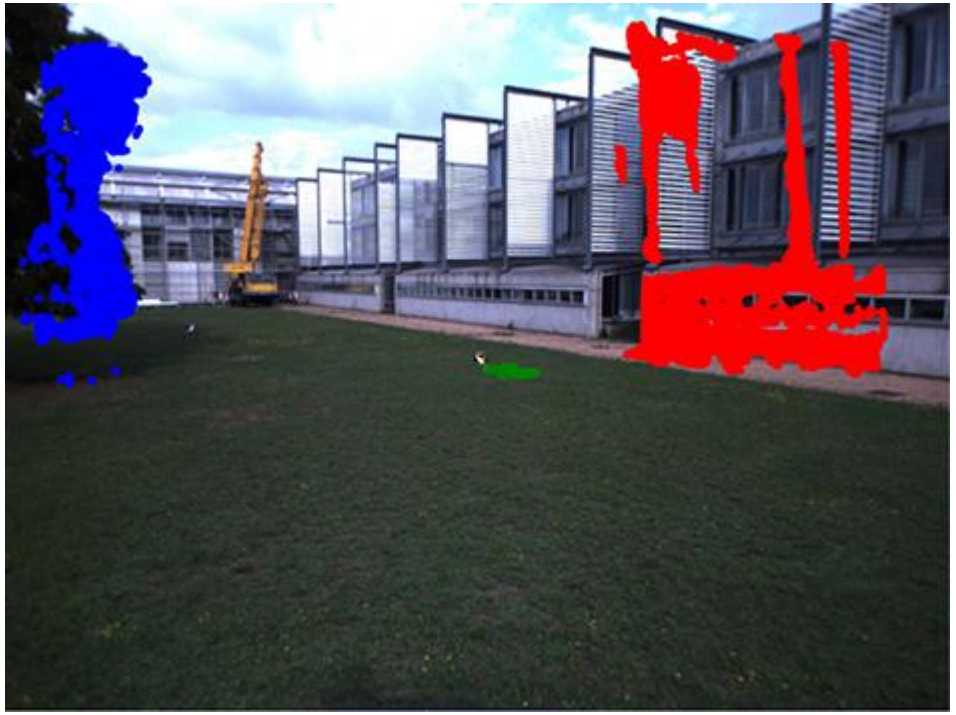
# Radar-stereo combination for 3D target analysis

**2D target detection using radar data**

**3D obstacle characterization using stereo 3D and color information**



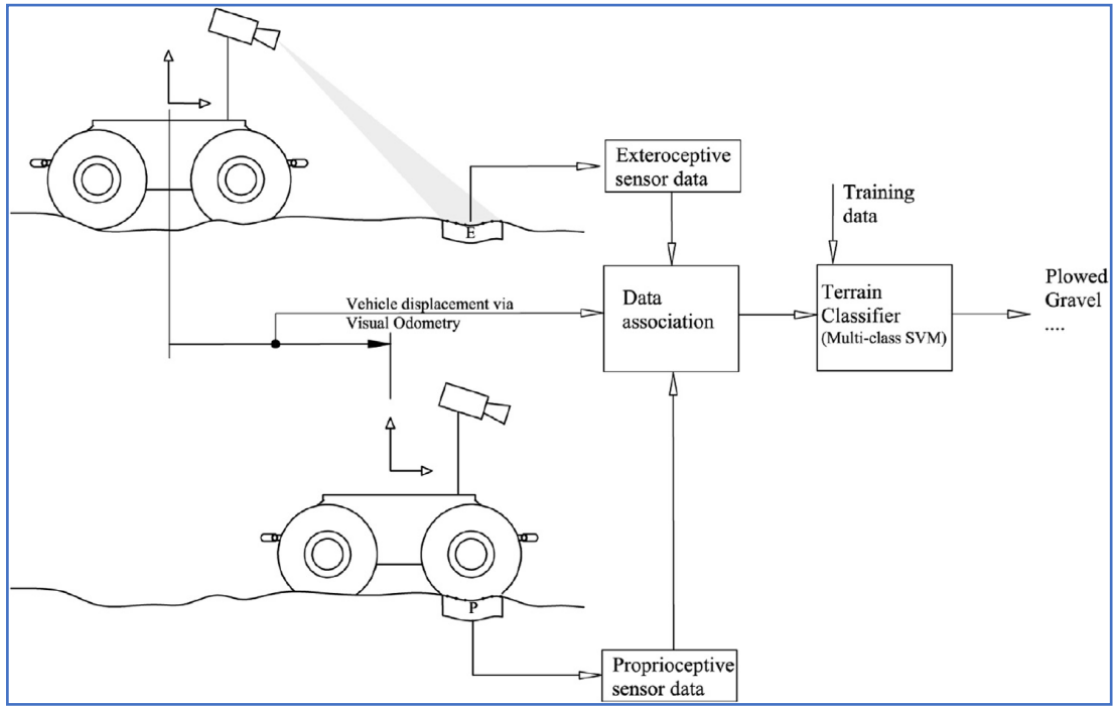

**Stereovision reconstruction of radar-labeled obstacles**



**Sub-clouds associated to obstacles and projected over the original camera image**

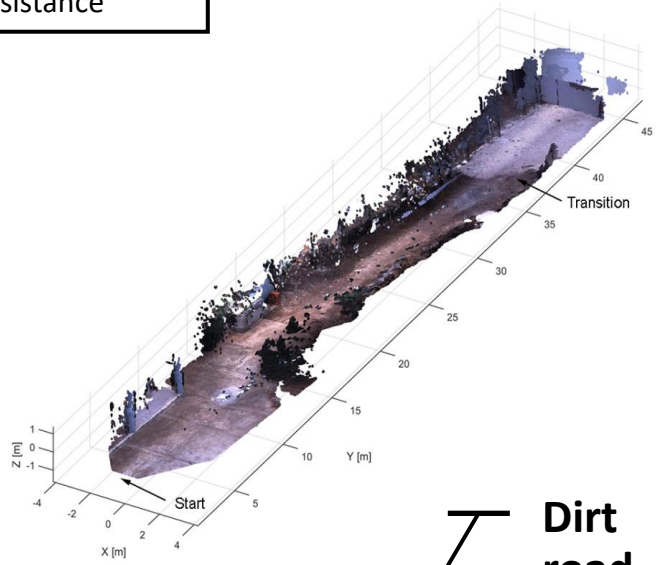
Reina G., Milella A., Rouveure R., Nielsen M., Worst R., and Blas M.R. (2016) *Ambient awareness for agricultural robotic vehicles*, Biosystems Engineering, Volume 146, Pages 114–132, ISSN: 1537-5110

# Integration of stereovision and proprioceptive sensors

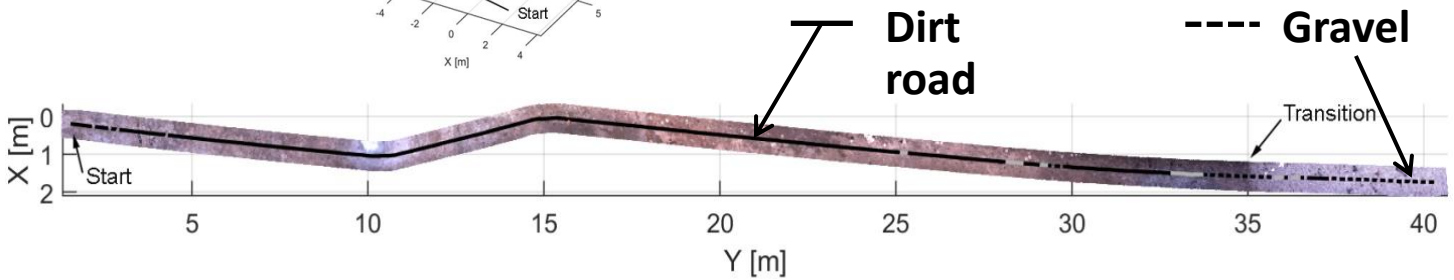



**Input data:**
- Color
- 3D geometry
- Acceleration
- Slip
- Rolling resistance

**Output:**
- Terrain type
- Asphalt, gravel, soft terrain, etc



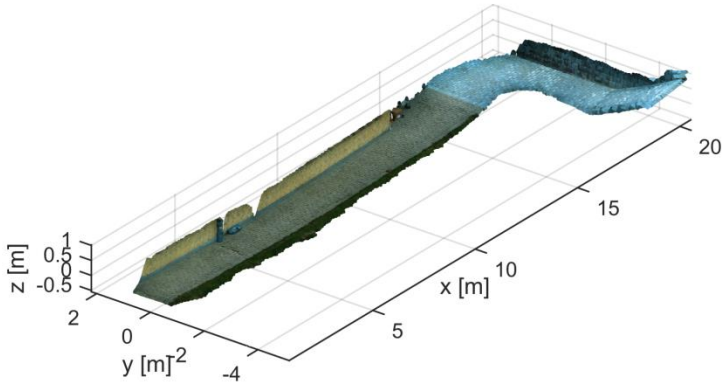

3D reconstruction



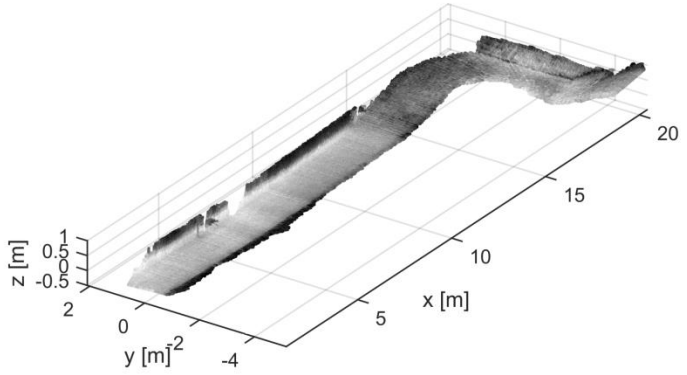

Reina G., Milella A., Galati R. (2017) *Terrain assessment for precision agriculture using vehicle dynamic modelling*, **Biosystems Engineering**, Vol. 162, pp. 124-139.

# Sensing beyond the visible spectrum

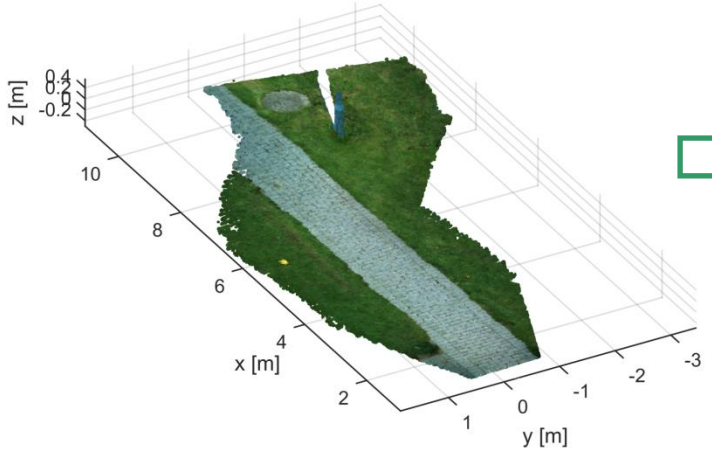
**STEREO**



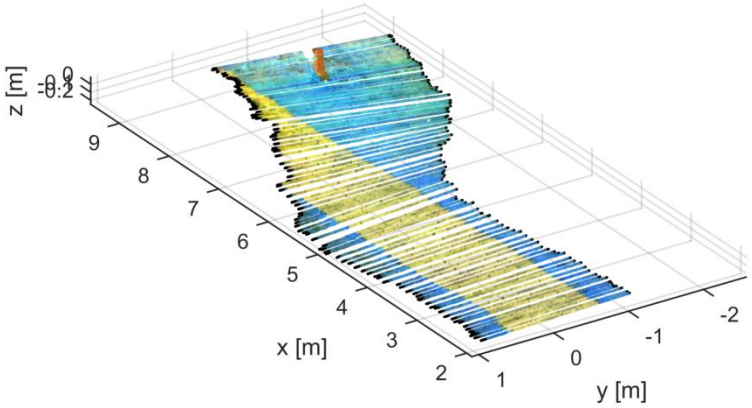

**STEREO-THERMAL**




**STEREO**



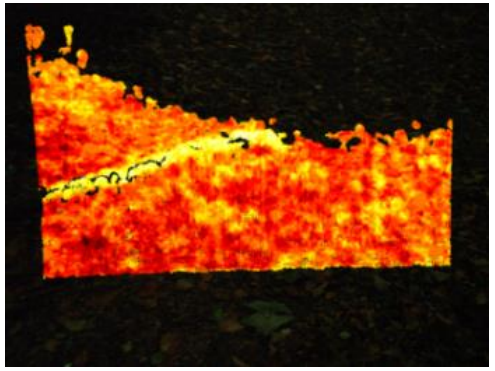

**STEREO-VISNIR**



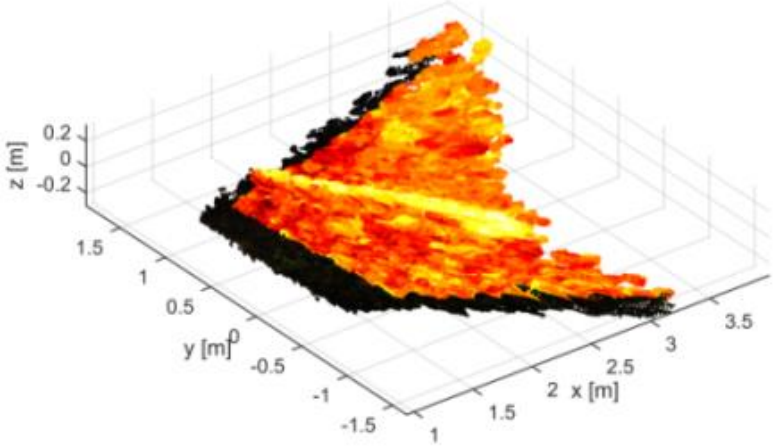

Milella A., Reina G., Nielsen M., (2019) *A multi-sensor robotic platform for ground mapping and estimation beyond the visible spectrum*, **Precision Agriculture**, 20(2), 423-444.

# Thermography is good at detecting abnomalies

(a)



(b)




(c)

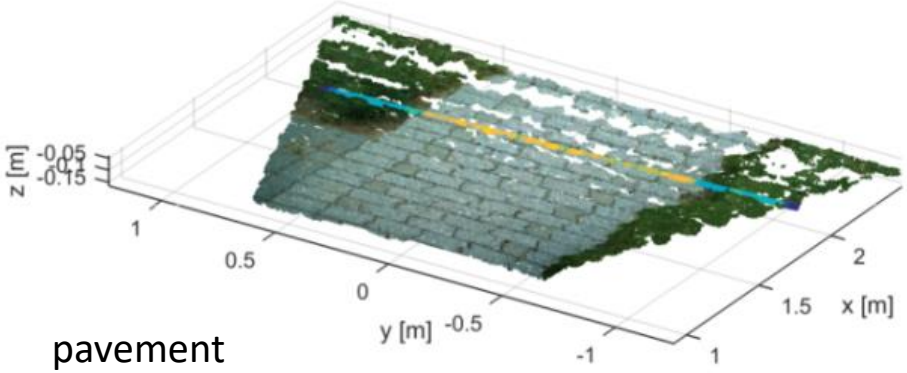
**Thermal and stereo integration for a sample test case:**

(a) visual image from left camera of the stereo system;
(b) visual image with overlaid thermal data;
(c) thermal data overlaid on the stereo 3D point cloud.

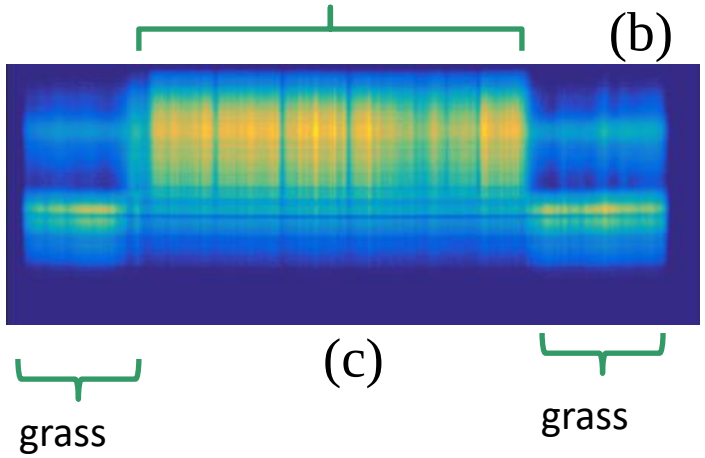
A **trunk** lays on the ground in front of the vehicle and is clearly visible in the thermal point cloud, while it is not easily detectable in the visual image due to low contrast and poor illumination condition.

# VIS-NIR is good at semantic labelling

(a)




(b)



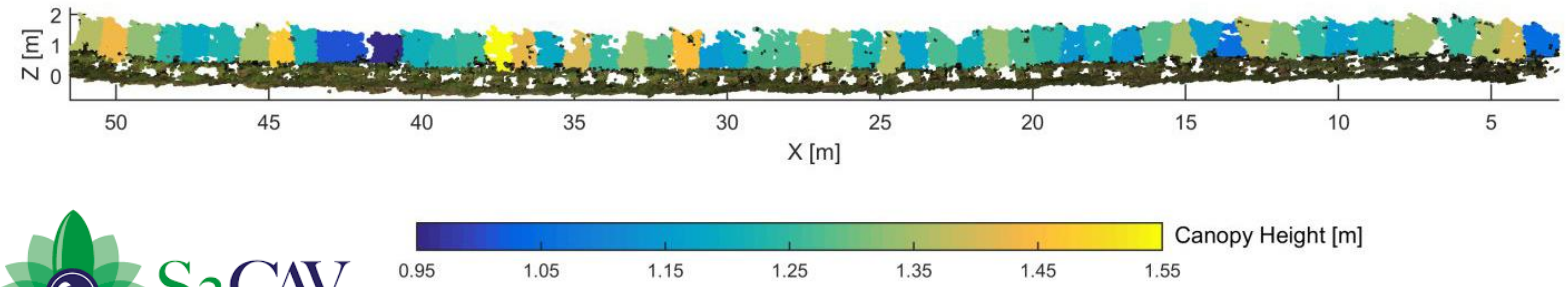

(c)

**Integration of stereo and VIS-NIR data for a sample case:**

(a) Visual image with VIS-NIR scan line overlaid.
(b) 3D stereo reconstruction with VIS-NIR scan line overlaid in false colors.
(c) VIS-NIR image.

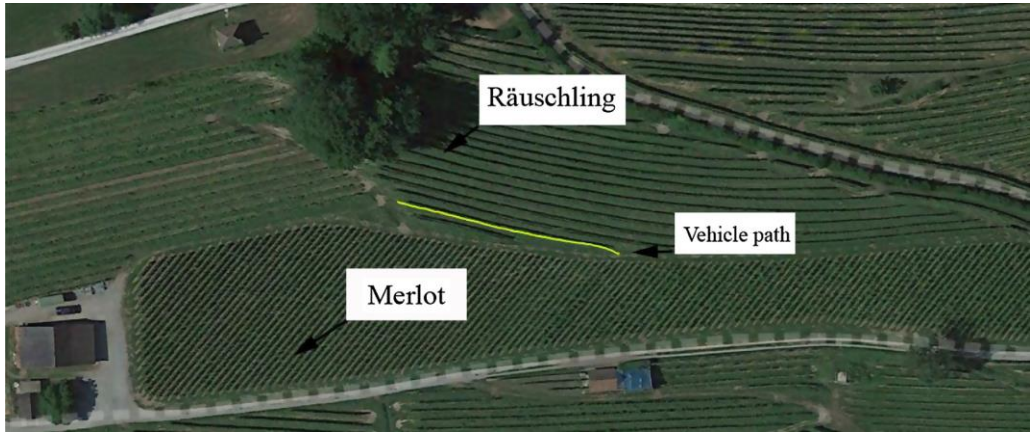
# In-field phenotyping using ground vehicles

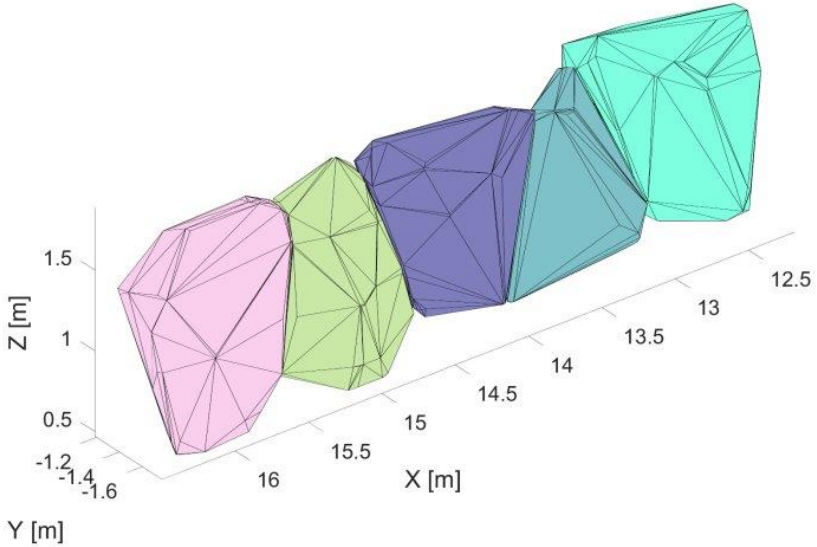
Agricultural vehicle equipped with a multi-sensor system for in-field grapevine phenotyping




S3CAV
Simultaneous Safety and Surveying for Collaborative Agricultural Vehicles

**Height and volume estimation using RGB-D data**




Milella A., Marani R., Petitti A., Reina G. (2019) *In-field high throughput grapevine phenotyping with a consumer-grade depth camera*, **Computers and Electronics in Agriculture**, 156, 293-306

# In-field phenotyping using ground vehicles

# E-Crops Project

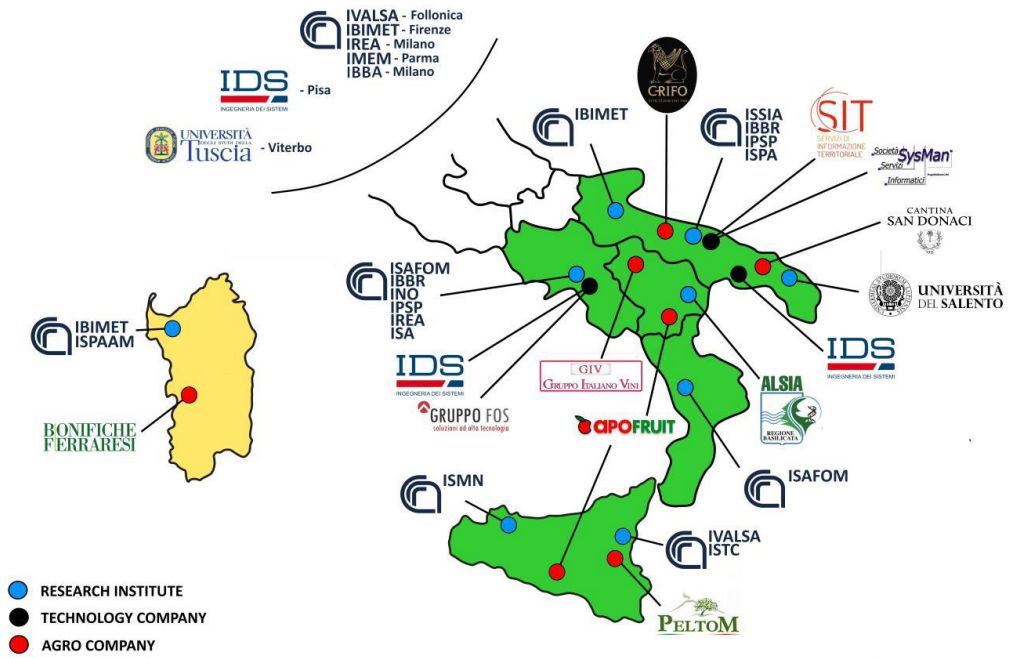
UNIONE EUROPEA
Fondo Sociale Europeo
Fondo Europeo di Sviluppo Regionale

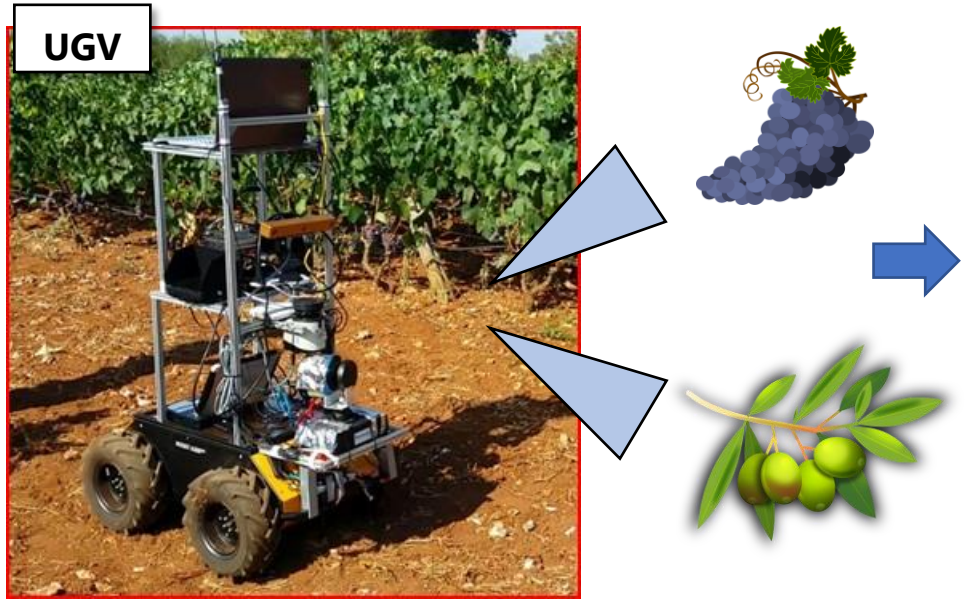
PON

## TECNOLOGIE PER L'AGRICOLTURA DIGITALE SOSTENIBILE

crops

- Funded by MUR, Italy
- E-CROPS will run over 30 months
- Start: October 1, 2020
- 2 Universities, ALSIA, 7 PMI and 3 large-scale industries
- 9.265.229,89€ grant requested






**Fruit segmentation**

**Yeild estimation**

# ANTONIO Project

ERA-NET COFUND ICT AGRI FOOD

**ANTONIO:**
**Multimodal sensing for individual plant phenotyping in agriculture robotics**

- ANTONIO will run over 24 months
- Start: December 31, 2020
- 639,500.00 € grant requested

ARISTOTLE UNIVERSITY OF THESSALONIKI

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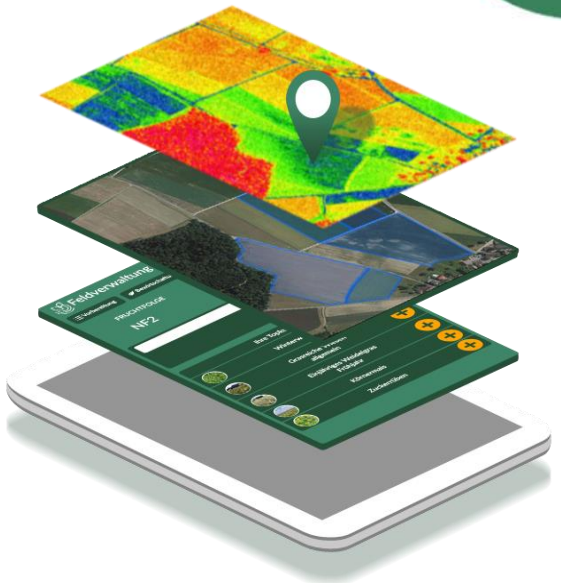
Fraunhofer IAIS

agri circle

Politecnico di Bari



# ATLAS Project

**HORIZON 2020**

ATLAS
AGRICULTURAL INTEROPERABILITY AND ANALYSIS SYSTEM

- ATLAS will run over 42 months
- Start: October 1, 2019
- 30 partners from 8 different European countries
- 12,890,976.25€ grant requested

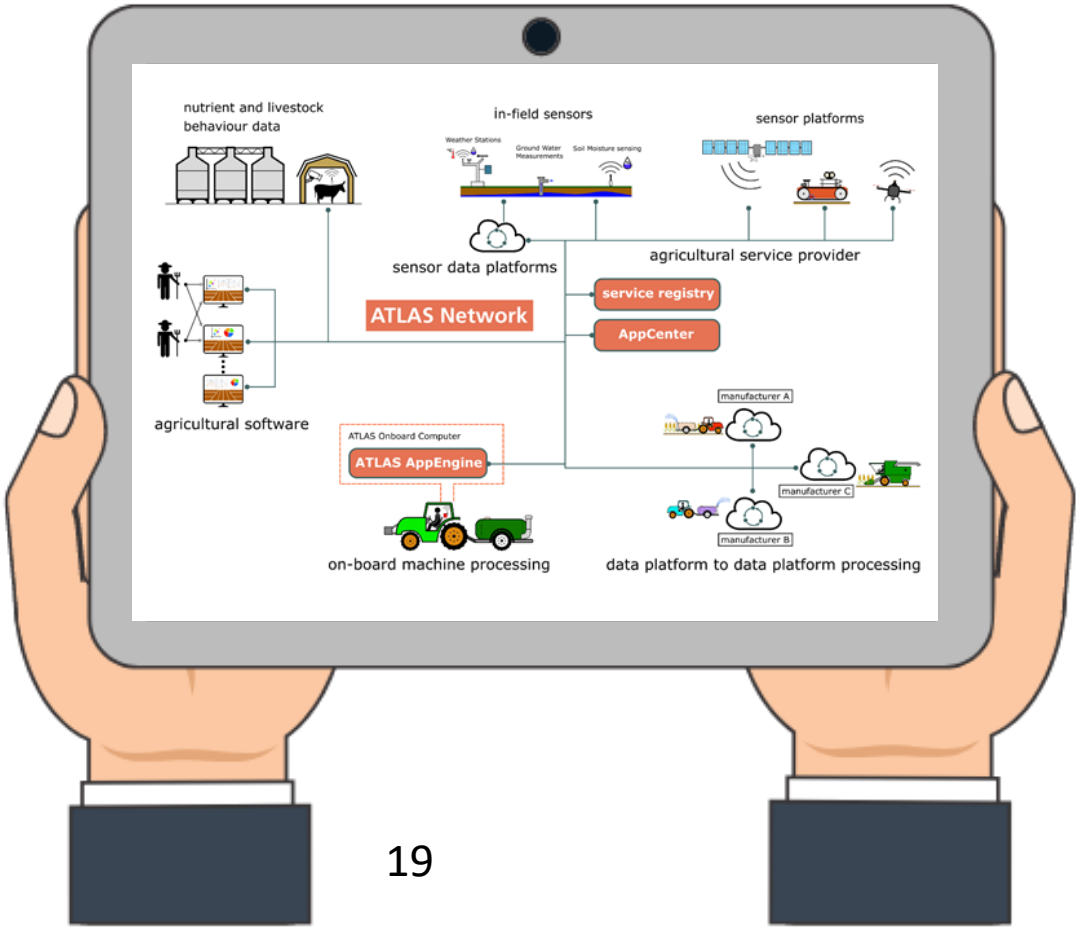
https://www.atlas-h2020.eu/

1

Data-platform based data exchange and processing.

2

On-board / on-site computing and processing capabilities.



# Conclusions and Future perspectives

Development of **multi-sensor systems and methods for agricultural vehicles** in crop fields

***Further research will consider methods:***

- to create **persistent perception** based on sensor data fusion for sensing in adverse visibility conditions;
- to improve ambient awareness (traversable terrain, obstacles, crop assessment, etc.) from the fused sensor data using methods of **semantic classification**;
- to enable a team of agricultural vehicles for **cooperative interaction** (master-slave setup) as well as for interaction with the human operator (HRI).

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# Thank you!

fondata nel 1975
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Robotica e Automazione

*annalisa.milella@stiima.cnr.it*