Rovitis 4.0: Robot autonomo connesso a DSS per la gestione sostenibile ed efficiente del vigneto e la robotica in viticultura

Rovitis 4.0: Autonomous robot connected to a DSS for a sustainable and efficient management of the vineyard and viticulture robotics

www.rovitisveneto.it - https://www.aziendapantano.it/

Azienda Agricola Giorgio Pantano
Via Stradelle, 40 – Candiana
35020 – Italy
https://www.aziendapantano.it/

Dott. Giorgio Pantano
CEO

M.Eng. Matteo Pantano
R&D project engineer

Candiana, 2021-09-29

Who we are

PANTANO

AZ. AGRICOLA
PANTANO

Azienda Agricola Pantano is a family-owned company in northeast Italy founded in 1872. Our company produces many different varieties of grapes, including Glera, Chardonnay, and Pinot Grigio. However, grapes are not only our main interest. We are also developing a new way of growing grapes in the era of automation with this simple idea in mind [1].

MAKE VINE GROWING SAFER AND MORE ENVIRONMENTALLY FRIENDLY

Our main focuses:

- Robot development
- Robot evaluation in open field
- Robot integration within the company

Sources:
[1] (2020) Azienda Agricola Giorgio Pantano – Corporate website, available online: www.aziendapantano.it (URL accessed on 29/09/2021)

Agricultural context

The average size of a company is three Ha

PANTANO

VENETO AGRICOLTURA

REGIONE DEL VENETO

Rapporto strutturale 2008-2018 dell'agricoltura veneta

Lavoro eseguito da Veneto Agricoltura, Osservatorio Economico Agroalimentare, con il coordinamento di *Alessandro Censori* e *Alessandra Liviero*

La stesura dei singoli capitoli si deve a:

Parte 1: *Renzo Rossetto* (capitoli 1, 2 e 3), *Alessandra Liviero* e *Gabriele Zampieri* (capitolo 4)
Parte 2: *Renzo Rossetto* (capitoli 5, 6 e 7), *Nicola Severini* (capitoli 8, 11 e 12), *Gabriele Zampieri* (capitoli 9 e 10)
Parte 3: *Gabriele Zampieri* (capitolo 13), *Nicola Severini* (capitolo 14), *Renzo Rossetto* (capitoli 15 e 16)

Revisione editoriale: *Antonio De Zanche*

Tabella 2.1 – Andamento valore della produzione agricola per le principali agricole (in .000 di euro).

Nr dichiarazione uve 2018 = 29.565

Superfice media di vigneto 2018 = 3,19 Ha

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	var %
Coltivazioni agricole (produzione vegetale)	**2.583.046**	**2.334.629**	**2.419.623**	**2.670.316**	**2.499.280**	**2.718.616**	**2.533.769**	**2.630.953**	**2.736.517**	**2.737.920**	**3.061.759**	**18,53**
coltivazioni erbacee	1.460.316	1.296.277	1.371.808	1.583.157	1.365.967	1.474.866	1.441.558	1.357.382	1.408.799	1.395.762	1.329.527	**-8,96**
cereali (incluse sementi)	572.297	417.366	518.872	740.028	568.380	662.939	667.491	486.666	506.112	441.994	447.090	**-21,88**
patate e ortaggi	629.453	620.589	595.689	598.921	602.534	570.435	452.813	605.536	630.786	677.215	594.028	**-5,63**
coltivazioni industriali	180.252	187.808	188.322	178.235	131.884	183.899	265.542	210.287	215.211	213.837	228.181	**26,59**
fiori e piante da vaso	76.632	68.978	67.177	64.025	61.157	55.933	54.594	53.070	53.116	55.968	57.172	**-25,39**
coltivazioni foraggere	157.928	144.863	154.602	154.023	140.058	113.473	89.839	65.696	54.797	71.866	89.519	**-43,32**
coltivazioni legnose	964.802	893.489	893.212	933.136	993.254	1.130.277	1.002.372	1.207.874	1.272.922	1.270.292	1.642.713	**70,26**
prodotti vitivinicoli	638.582	624.261	623.045	687.604	745.112	885.270	787.239	918.269	973.499	1.017.250	1.324.526	**107,42**
prodotti ovilicoltura	5.340	4.729	4.436	5.196	16.460	22.217	8.380	22.451	19.945	13.322	31.198	**484,19**
fruttiferi	275.337	220.976	222.894	198.388	204.784	201.828	167.718	235.408	244.285	199.860	264.428	**-3,96**
Allevamenti zootecnici	**2.008.962**	**1.895.505**	**1.898.561**	**2.122.963**	**2.285.178**	**2.295.499**	**2.226.758**	**2.140.875**	**2.035.578**	**2.180.028**	**2.141.610**	**6,60**
carni	1.419.867	1.353.133	1.349.077	1.523.329	1.619.863	1.632.993	1.572.368	1.531.832	1.478.589	1.564.209	1.509.372	**6,30**
bovine	475.770	459.969	452.962	487.419	505.296	475.340	448.308	417.597	410.211	420.433	420.710	**-11,57**
suine	171.978	165.467	162.258	185.160	196.632	203.914	196.818	182.133	197.825	223.107	201.767	**17,32**
pollame	613.817	570.815	583.691	697.654	760.753	793.931	765.299	781.210	721.384	776.860	758.693	**23,60**
latte	425.882	371.897	379.826	426.657	440.287	448.062	447.148	409.984	382.323	418.820	417.100	**-2,06**
Attività di supporto	**537.618**	**544.760**	**564.818**	**581.588**	**613.422**	**631.213**	**643.034**	**649.387**	**668.876**	**675.613**	**678.512**	**26,21**

Fonte: elaborazione e stime Veneto Agricoltura su dati Istat – Contabilità nazionale.

Figure 1: Key indicators of agricultural productions in Italy [1]

Sources:
[1] (2020) Veneto Agricoltura – Rapporto strutturale 2008-2018 dell'agricoltura veneta, ISBN 978-88-6337-230-4

Previous work

An autonomous robot was already in Italy in 2011

Placeholder for video, for further information see link below

Placeholder for video, for further information see link below

Video 1: The Dodich robot autonomously navigating the vineyard with a backward implement in 2011

Video 2: The Dodich robot autonomously navigating the vineyard with a backward implement in 2011

Sources: https://youtu.be/TcVJ3UStm7I , https://youtu.be/pW47p9zdC24

Robots and existing infrastructure in a brown field application

There are pain points that must be addressed

Robots need to be integrated also with conventional machines “not-robots”

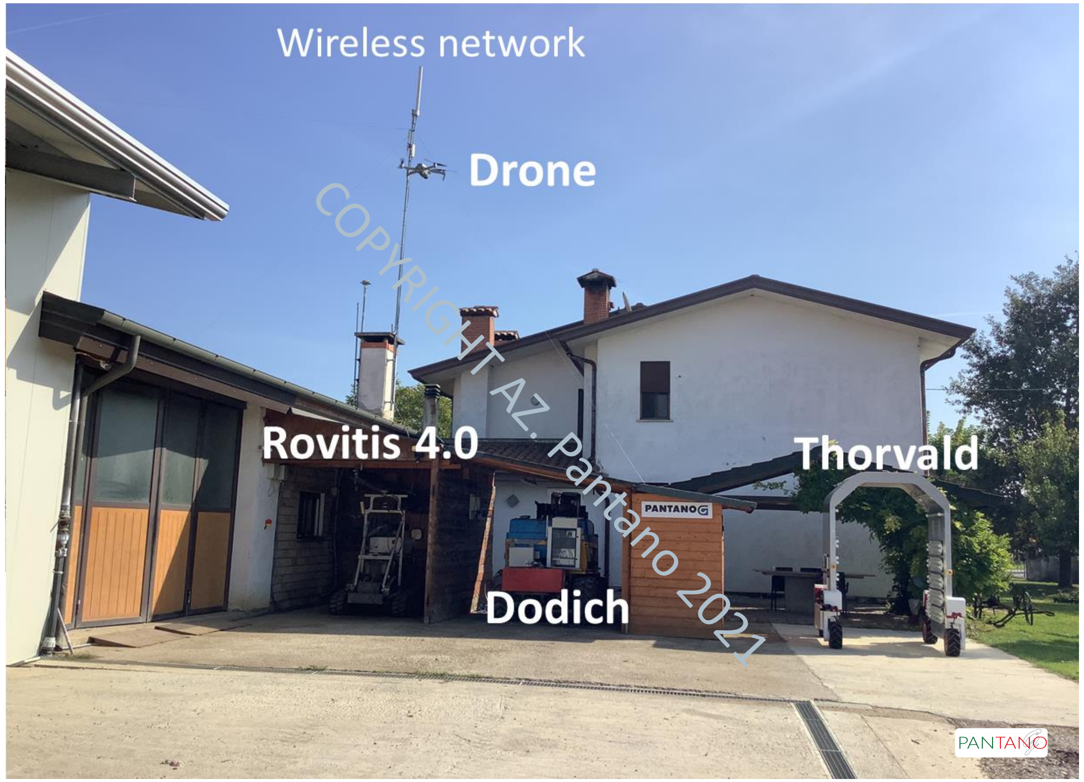


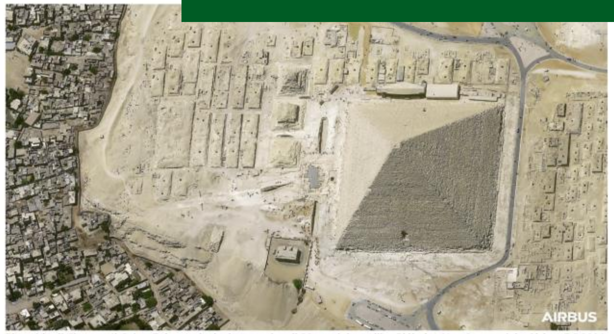
Figure 1: Azienda Pantano and the deployed robots with the infrastructure

Figure 2: Azienda Pantano and the conventional machines still needed to manage the crop

Future research

DSS and drone scouting for plants diseases’ forecasting

Satellites nowadays have a resolution of 30cm/pp



Piramide di Cheope, Il Cairo, Egitto a risoluzione nativa di 30 cm dal satellite Pléiades Neo 3, copyright Airbus DS 2021
https://rivistageomedia.it/2021052417344/Terra-e-Spazio/prime-immagini-dettagliate-dal-satellite-pleiades-neo-3

Figure 1: Cheops Pyramid, Cairo, Egypt at 30cm native resolution by Pléiades Neo 3 satellite, copyright Airbus DS 2021 [1]

Figure 2: AgNeo © is the new solution of Airbus to help integrating precision agricolture [2]

To monitor plant diseases we need a technology with 1.2µm/pp

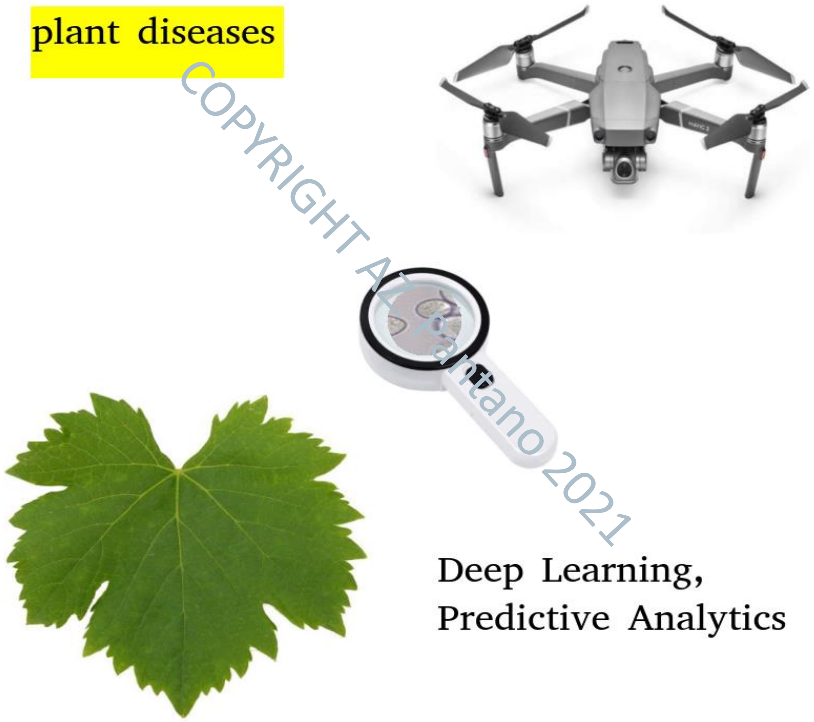


Figure 3: The concept of Azienda Pantano is to use drones to monitor diseases on a micrometer scale using drones and deep learning

Sources:
[1] (2021) Airbus – Piramide di Cheope, Il Cairo, Egitto a risoluzione native di 30cm dal satellite Pleiades Neo 3, available online: https://www.intelligence-airbusds.com/en/5751-image-gallery-details?img=65938#.YVP6GLhLhjE (URL accessed on 29/09/2021)
[2] (2021) Spazionews – Satelliti e agricoltura di precisione: Airbus presenta agneo, available online: http://spazio-news.it/satelliti-e-agricoltura-di-precisione-airbus-presenta-agneo (URL accessed on 29/09/2021)

Autonomous systems
Definitions

Robot derives from the slavic word robota ("work"), it was used to **define an artificial humanlike creature built as replacement of workers** in the theatrical performance Rossum's Universal Robots (R.U.R.) written by Karel Capek in 1920 [1].

Nowadays, types of robots are numerous, therefore one definition starts to be limiting for the field. At the actual **status we can distinguish among two main classes**: *stationary or mobile robots*.

Sources:
[1] (2021) Jordan, The Czech Play that gave us the word «Robot», The MIT Press reader, available online: https://thereader.mitpress.mit.edu/origin-word-robot-rur/ (URL accessed on 12/04/2021)

Autonomous systems
Stationary and Mobile robots

Stationary robots (commonly known as manipulators)

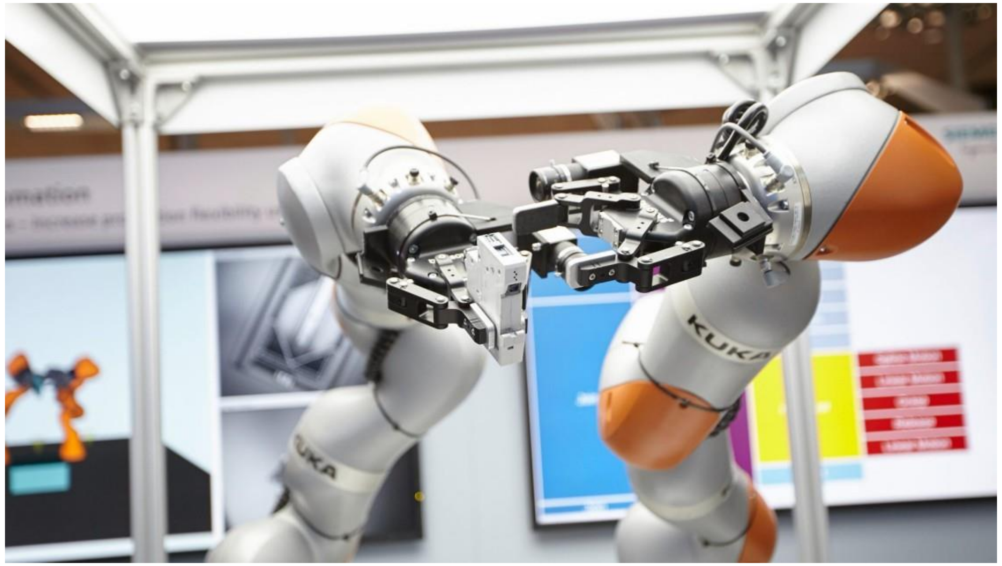


Figure 1: An example of industrial robots solving an assembly task [1]

Re-programmable multi-functional manipulator designed to move materials, parts, tools, or specialized devices through variable programmed motions for the performance of a variety of tasks, which also acquire information from the environment and move intelligently in response [3].

Mobile robots (commonly known as Autonomous Guided Vehicles (AGVs))

Figure 2: An example of mobile robot moving a dashboard in a factory shop floor[2]

A mobile robot is a device that can move autonomously on a surface without assistance of human operators. It is considered autonomous when has the capabilities to determine the actions to be taken to perform a task based on a perception system [4].

Sources:
[1] (2020) CIO, Porsche steigt bei serva transport systems ein, available online: https://www.cio.de/a/porsche-steigt-bei-serva-transport-systems-ein,3638242 (URL accessed on 12/04/2021)
[2] (2018) Sundaram and Natarajan, Artificial intelligence in the shop floor, white paper, available online: https://new.siemens.com/global/en/products/automation/topic-areas/tia/future-topics/whitepaper-shopfloor-ai.html (URL accessed on 12/04/2021)
[3] ANSI/RIA R15.06-1999 National Robot Safety Standard
[4] (2019) Rubio et al., A review of mobile robots: Concepts, methods, theoretical framework, and applications, International Journal of Advanced Robotic Systems, March 2019 doi:10.1177/1729881419839596

Mobile robots

The main components

Lidar: or Light detection and Ranging, **paints a 3D picture of the vehicle's surroundings**. This is possible through laser pulses that are sent from the vehicle and then bounced back by objects thus giving distance information during day and night.

Cameras: visual sensors to **detect complex information that need to be interpreted** (e.g., construction zones, traffic lights). They usually have a 360º view on the environment. They can suffer from visibility problems.

Control unit: It is the brain of the autonomous vehicle, and it is usually an ensemble of CPUs and GPUs which **analyze sensor data and computes plans**. However, also control of physical hardware is part of it (e.g., steering wheel).

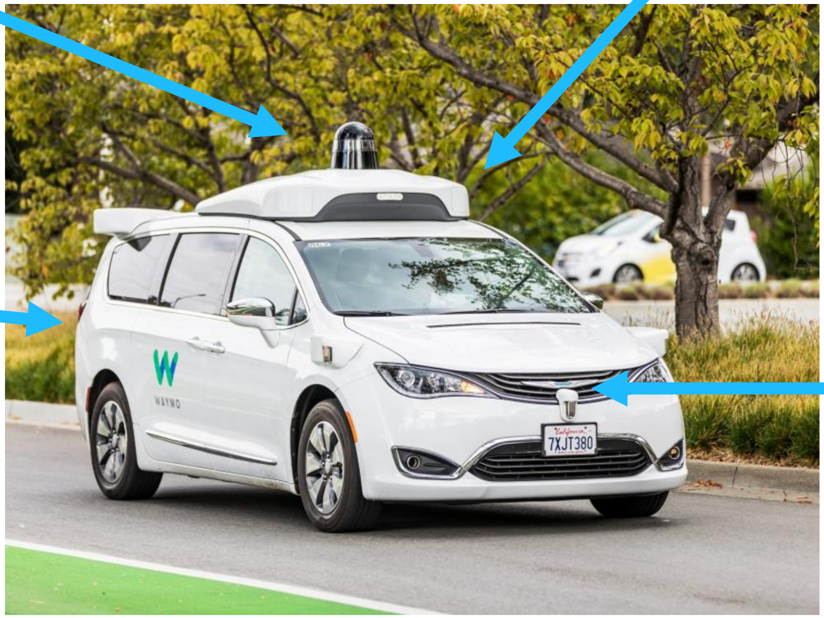


Figure 1: An autonomous car developed by the Google start-up Waymo[1]

Radars: They use millimetric wave frequencies to **provide distances in adverse scenarios** (e.g., rain, fog and snow). Usually, several of these sensors are present on the vehicle.

Sources:
[1] (2018) Marshall, the end of waymo v. Uber marks a new era for self-driving cars: reality, wired, available online: https://www.wired.com/story/uber-waymo-trial-settlement-self-driving-cars/ (URL accessed on 2021/04/12)
[2] (2019) Rubio et al., A review of mobile robots: Concepts, methods, theoretical framework, and applications, International Journal of Advanced Robotic Systems. March 2019. doi:10.1177/1729881419839596
[3] (2021) Waymo, Waymo Driver, available online: https://waymo.com/waymo-driver/ (URL accessed on: 12/04/2021)

Mobile robots

The relevant components in agriculture

Implement: Autonomous robots in agriculture are worthless without an implement. Usually standard implements are used, however, due to the different geometries of mobile agricultural robots, new breed of implements are now being developed.

GPS RTK: A GPS receiver with **real-time kinematic** which, through the usage of a base station, can provide global positions with accuracies up to 1cm.

Power Train: Adequate power should be supplied to the system upon the task. Therefore, differently from normal tractors. Agricultural robots have a power train fit to the task (e.g., diesel engine for intensive tasks)

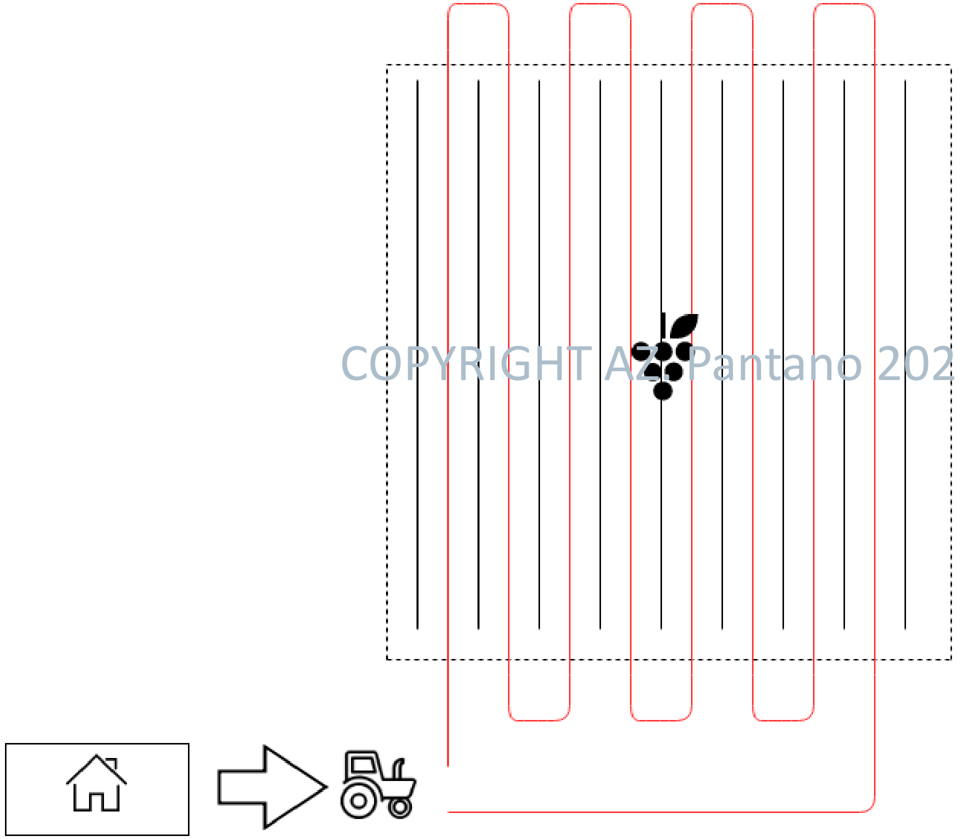
Figure 1: The concept of autonomous robot from the company John Deere[1]

Locomotion: Adequate wheels for movements on uneven terrains. Often tracked vehicles are preferred. However, locomotion can be different from usual tractors due to the lack of the driver's cabin.

Sources:
[1] (2019) Trattori web, Monoasse autonomo elettrico. Il futuro second John Deere, available online: https://www.trattoriweb.com/il-futuro-secondo-john-deere/ (URL accessed on: 12/04/2021)

Need for autonomous robots

The processes in vineyards



x 17 times: spraying

x 2 times: weedkilling with chemicals

x 3 times: grass mowing

x 3 times: branches trimming

x 2 times: chemical/organic fertilizer

x 1 times: old canes cutting

=

TOTAL: 28* (for each season)

* this considers a vineyard located on a flat land in north-east Italy

Sources: (2018) CondifesaTV, Studio dei costi per gli investimenti in agricoltura

The idea becomes a prototype

History

Placeholder for figure, for further information contact Az. Pantano

2008

2011

2014

2017

2009

2013

2015

2020

Placeholder for figure, for further information contact Az. Pantano

Early prototype
The components

A prototype with worthy views

- **Skid steer**: a machine base with independent left and right wheel control
- **High-Low level control**: a decoupled control structure with different Real Time (RT) capabilities
- **Laser scanner and encoders**: sensors for local navigation

How to industrialize the concept?

Rovitis 4.0 project

Partners

PSR Veneto Region 16.1 – 16.2 - 2017

Leader Partner

The Rovitis4.0 project
A decision making for robot agents

- **Teaching**

Operator decides where to go

- **Home station**

Parking and automatic filling of liquids

- **In-field sensors**

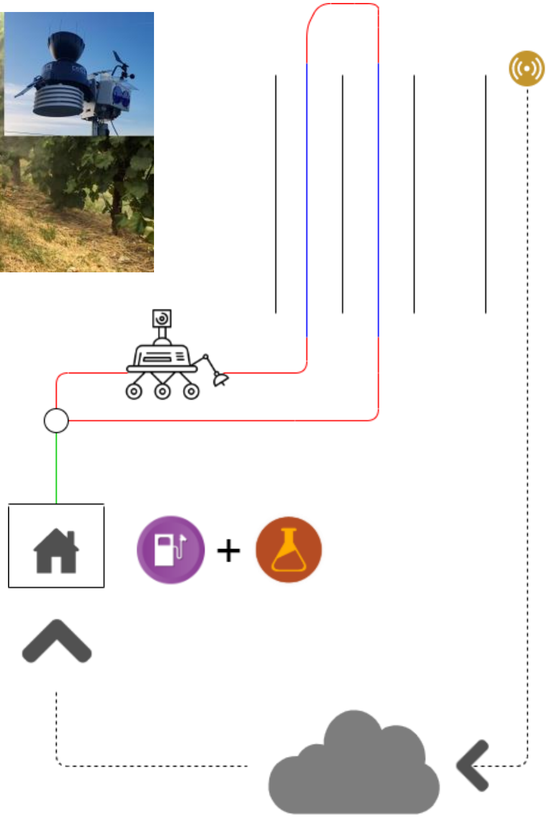
Information is coming from the real field, better knowledge of crop status

- **On-board sensors for AD**

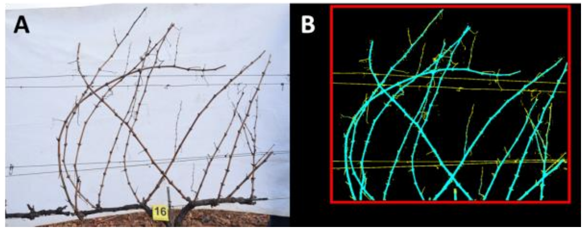
Information directly from the robot

- **DSS**

Choose best spraying timing



Source: [1]



Source: [2]

Sources:
[1] (2018) DLR, Dionysos, available online (https://www.dlr.de/content/en/images/2019/4/dionysos-en.html)
[2] (2019) Millan, Vineyard pruning weight assessment by machine vision: towards an on-the-go measurement system, 21th GIESCO International Meeting, Thessaloniki, Greece

Autonomous systems “operating system”

Robot operating system

Robot Operating System (ROS) is an **open-source middleware** for the programming of robots. It was initially developed at Stanford and then further developed from Willow Garage (Menlo Park, California) research labs starting from 2007. Nowadays its development is maintained by Open Robotics (Mountain View, California) a non-profit company.

ROS is an ensemble of **tools**, **conventions** and **libraries** for the behavior programming of different robotic tasks (e.g., localization, path planning).

https://vimeo.com/245826128

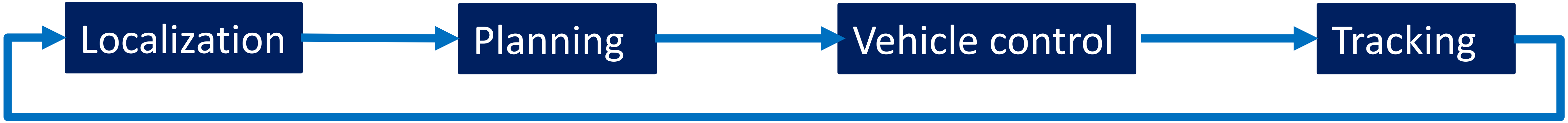
https://www.youtube.com/watch?v=Ek8GKqmJ7n0

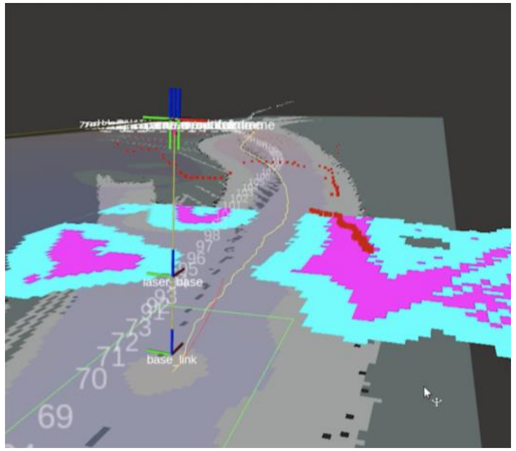
Sources: Robot Operating System website, https://www.ros.org/ (URL accessed on 12/04/2021)

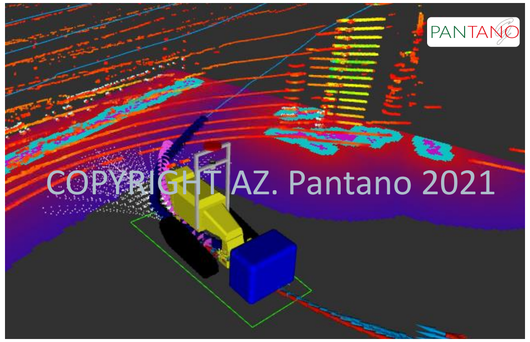
Autonomous systems

The problem statement of mobile robots

Where am I? Where do I need to go? How do I go there? What should I do at the target location?







Sources:
[1] (2019) Rubio et al., A review of mobile robots: Concepts, methods, theoretical framework, and applications, International Journal of Advanced Robotic Systems. March 2019. doi:10.1177/1729881419839596
[2] (2019) Neil Nie, Self-Driving Golf Cart: Autonomous Navigation with the ROS Navigation Stack – Part 2: Path Planning, available online: https://neilnie.com/2019/07/09/self-driving-golf-cart-autonomous-navigation-with-the-ros-navigation-stack-part-2-path-planning/ (URL accessed on 13/04/2021)

Autonomous systems
Perception and Localization

Where am I?

This is achieved through sensor fusion. A fusion of data based on nonlinear state estimator. As the name suggests, starting from multitude of inputs it generates an estimation of the robot position in real time. This is based on an estimator which uses probabilities related to the different input sources.

Lidar: 

Local information about obstacles and rows position

IMU:  Heading information for turns and rotary movements

Encoders:  Displacement information regarding translational movements

GPS RTK:  Global position for location on the open field

Where do I need to go?

This is a task that deals with goal definition and trajectory generation (route computation) for the achievement of the objective. The route computation considers also obstacles (fixed or moving). This part is achieved through an ensemble of maps (global and local) and path planners (local and global).

Figure 1: The vineyard field where the map has been taken

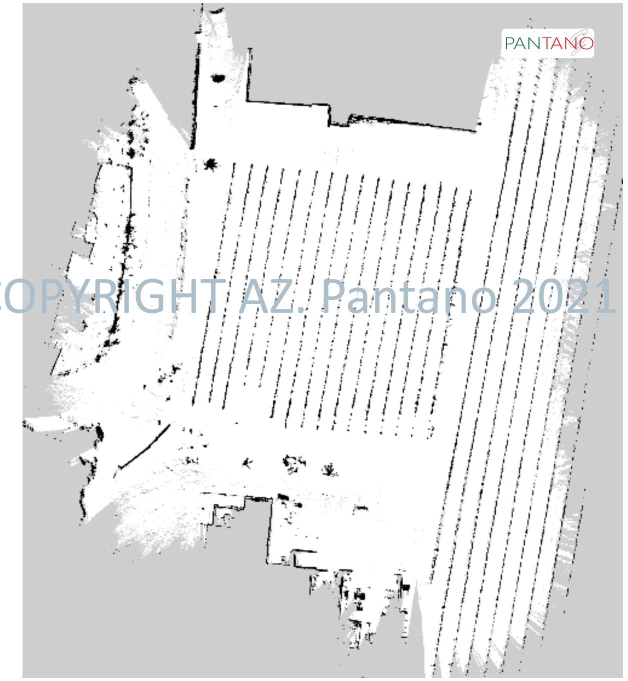


Figure 2: The global map of the vineyard field represented in black and white

Autonomous systems

Planning (2) – Global plan

The global plan tells the robot the overall trajectory that it should follow. However, it is a best effort trajectory. Meaning that it is a general "recommendation" to the system and slight changes are possible (e.g., track slippage, obstacle).

Figure 1: The vineyard field where the global path has been obtained

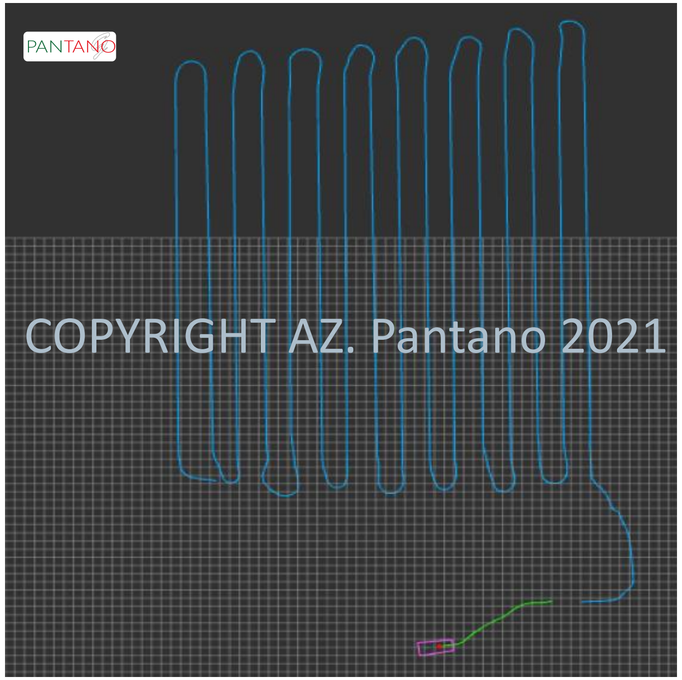


Figure 2: The global path of the vineyard field represented in blue and green

Autonomous systems
Planning (3) – Local map

The local plan is an instance of the global map created during runtime. It is used by the planning system (see next slides) for understanding where obstacles are. The local map shows obstacles which are permanent and temporary and have been obtained from the perception layer. This is possible through the so-called costmap (the rainbow map in Figure 1 and 2).

Figure 1: Example of costmap for highlighting local runtime obstacles, in this case permanent obstacles are shown.

Placeholder for figure, for further information contact Az. Pantano

Figure 2: The costmap can be updated at runtime with obstacles which will be temporary.

Autonomous systems

Planning (4) – Local plan

The local plan is a plan elaborated at runtime by the autonomous system of the robot and considers both the global plan and the local map with obstacles (i.e., costmap). This results in trajectories generated at run time hence, obstacle detection in new situations.

Placeholder for video, for further information see link below

Video 1: The robot, through the usage of the global/local plan and maps can react and avoid obstacles

Sources: https://youtu.be/D4LC81_bTGM

PANTANO

How do I go there?

In order to then have the robot actuate the commands computed in the previous steps, hence, avoiding obstacles or following plans a controller must be integrated. In the case of Rovitis we are using a cascade controller. The autonomous system calculates the required velocities to follow a trajectory and sends them to the base. The base then actuates the commands and gives a feedback back.

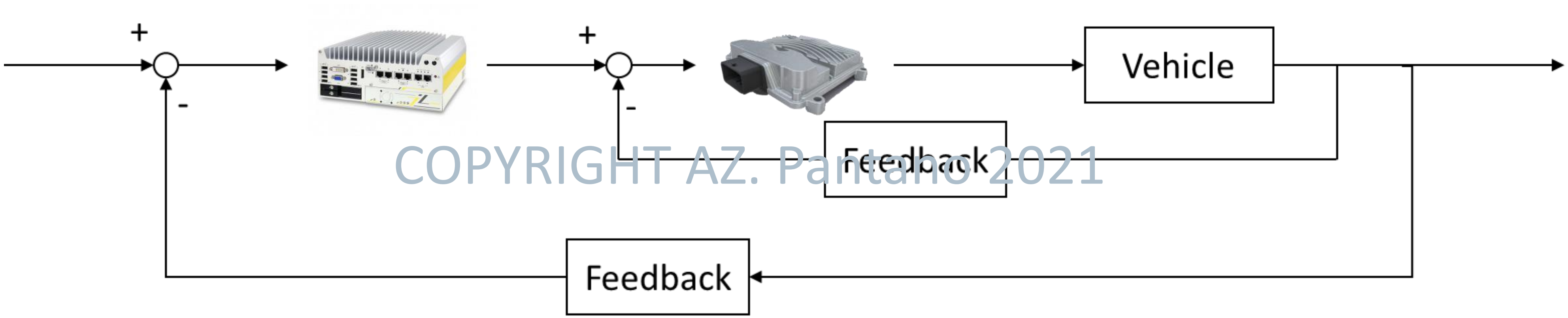


Figure 1: The cascade control present in the Rovitis robot

PANTANO

What should I do at the target location?

The Rovitis robot must drive in highly vegetation areas and the software system must cope with them. The ensemble of the four autonomous components enables the driving also in high vegetation areas.

Placeholder for video, for further information see link below

Video 1: Robot operation with high vegetation through the usage of the lidar

Placeholder for video, for further information see link below

Video 2: Robot operation with management of rows with one or two sides

Sources: https://youtu.be/_2R5TlfcC4I , https://youtu.be/Ka7NG7kK-RU

Robot teaching

Giving a good user experience to operators

The Rovitis robot gets the information on the field directly from the user through the teach&repeat methodology. This is achieved through a **highly customizable app** and an **open-source** platform for farming robotic applications. The user drives around the robot for the first time and the robot records all the information for the management of that particular lot.

Figure 1: The user interface of the Rovitis robot app

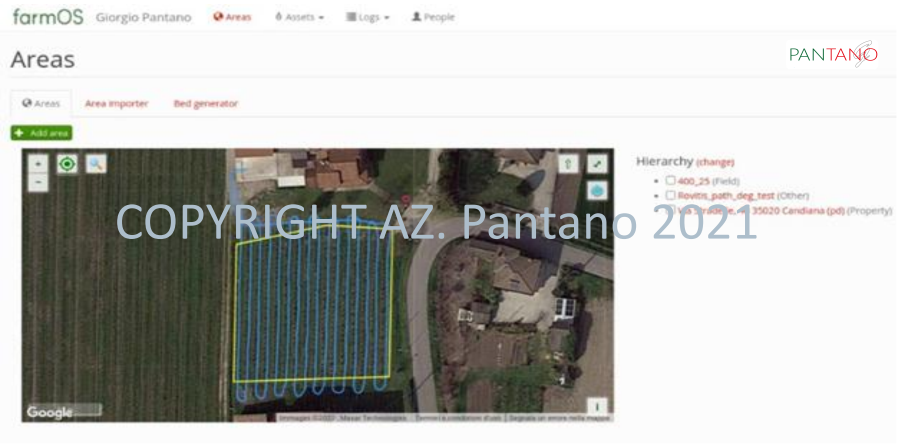


Figure 2: The global path of the vineyard field represented in blue on the opensource software farmOS

Rovitis and Dodich in operation

Boring videos but trustful robots

Placeholder for videos, for further information see link below

Sources:
https://youtu.be/lQaKmxqgfRw
https://www.youtube.com/watch?v=2hK7Tz2j-co&feature=youtu.be
https://www.youtube.com/watch?v=yls_-odmj2Y&feature=youtu.be

Thorvald autonomous platform
Thorvald light treatment

Placeholder for videos, for further information see link below

Sources:
https://youtu.be/Y-3GdbrH1MM
https://youtu.be/tL6DM6KqpM4

Sources:
www.sagarobotics.com

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