D4.1 Pilot 1 objectives, requirements and design

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List of Acronyms

Abbreviation / acronym	Description
AB	Advisory Board
AEMET	State Meteorological Agency of Spain
CA	Consortium Agreement
CFS	Certificate on the Financial Statements
CSIC	Spanish National Research Council
CSV	Comma-separated values File
DL	Deliverable Leader
DoA	Description of Action
DOI	Digital Object Identifiers
DSS	Decision Support System
DT	Deliverable Team
Dx.y	Deliverable number y, belonging to WP number x
EC	European Commission
FSIGN	Financial Signatory
GA	Grant Agreement
GDPR	General Data Protection Regulation
GeoJSON	Geographic JavaScript Object Notation
IAR	Interim Activity Report
IEC	Standards of the International Electrotechnical Commission
JPG	Joint Photographic Experts Group file
JSON	JavaScript Object Notation
K8s	Kubernetes
KPI	Key Performance Indicator
MCC	Mission Control Centre
NDVI	Normalized Difference Vegetation Index
PC	Project Coordinator
PEDM	Project Ethics and Data Manager
PIM	Project Impact Manager

Abbreviation / acronym	Description
PM	Person-month
PMO	Project Management Office
PR	Peer Reviewer
QA	Quality Assurance
QM	Quality Manager
RAM	Risk Assessment Matrix
RASCI	Responsible/Accountable/Supportive/Consulted/Informed
RP	Reporting Period
SC	Steering Committee
SER	Seresco S.A.
TER	Terras Gauda
CSIC	Consejo Superior de Investigaciones Científicas
TIF	Tagged Image File
TL	Task Leader
TM	Technical Manager
UAV	Unmanned Aerial Vehicle
UC	Use Case
UGV	Unmanned Ground Vehicle
WP	Work Package
WPL	Work Package Leader
WU	Wageningen University

Executive Summary

This document is a deliverable of the FLEXIGROBOTS project, funded by the European Commission under its Horizon 2020 Framework Programme (H2020).

This document presents the works carried out in Pilot 1 in the first year of the project, referring to task ***T4.1 Pilot objectives, requirements and design***. The objectives are set out, the scenarios and use cases are detailed, as well as the functional and non-functional requirements, the KPIs to be achieved, and the data sets to be used and generated according to the case. The robotic elements and UAVs, as well as the different devices involved in the development of the pilot, are also described. The technical design of the pilot and the requirements of the FlexiGroBots platform are detailed, in order to ensure the coordinated development of the common platform. Also, the results of the first works and field tests are presented, as well as the next steps in the works of the task. The deliverable ends with a section of conclusions.

Until the moment, the first round of datasets has been collected during the harvesting campaign of 2021. There, all the partners of Pilot 1 met and executed UAV flights and UGV surveys of the field. Positive results regarding the harvest assistance provided by the UGV were obtained. Finally, during that meeting, many dissemination activities were carried out to foster the visibility of the FlexiGroBots project.

1 Introduction

1.1 Purpose of the document

The present document is the summary of the development plan of the pilot. This document also includes all the requirements of the pilot, both functional and non-functional, for all the components, not only software components but also hardware components, like UGVs and UAVs. The architecture of the solution and the design of all the components that will be developed for the system is also a part of this document reflected in the specification of four identified use cases, along with the specification of datasets to be generated, needed hardware and devices specifications.

1.2 Structure of the document

This document is structured in 6 major sections:

- Section 1: this section, is the introduction.
- Section 2: presents the objectives of the pilot.
- Section 3: describes the specification of the use cases of the pilot, to be developed.
- Section 4: describes the identified datasets that will be shared in the scope of the FlexiGroBots project.
- Section 5: describes the involved robots, devices and platforms.
- Section 6: includes conclusions related to this deliverable.

2 Objectives

This pilot has the ambitious goal of taking advantage of some of the state-of-the-art digital emerging technologies to demonstrate how they can be a real help to the farmers, being at the same time environmentally sustainable and economically affordable.

The objective is to demonstrate the high capacity and versatility of robots to carry out different tasks in vineyards, as well as their economic profitability.

A fleet of heterogeneous robots, that will work in a coordinated way, will be used to carry out different agricultural activities: On land, small autonomous mobile robots (AMR) will be used to inspect and actuate on the ground; in the air, semi-autonomous unmanned air vehicles (i.e. UAV or UAVs) will be responsible to gather data to plan and monitor autonomous ground vehicles.

The UAV platforms will be dedicated to the inspection, both for the early detection of pests and for obtaining data that allow defining the architecture of the vineyard and thus have information of interest such as, for example, water stress, degree of maturation, etc. Multiple UAVs will coordinate to accomplish a monitoring mission following a predefined plan (path planning) with the autonomy to skip certain check points (observation data collection) when they consider it will give no new data and evidences to update ground operations. Thus, the objective will be the total coverage of the vineyard minimizing costs which, in the use of UAVs, are directly proportional to the total flight time and the number of flight missions to accomplish.

Specifically, the UAV (aka. UAVs) will be used for early detection of Botrytis cinerea, a necrotrophic fungus that affects many plant species, most notably wine grapes. The observation of the presence of this disease will be based on multispectral images. Visible and near-infrared reflectance spectroscopy can be applied to the early detection of Botrytis cinerea before symptoms appeared. Apart from their responsibility as mobile actuators, the ground robots will be in charge of close observation of grapes on the ground, to complement the initial data captured from the air and thus complete a more accurate diagnosis of the grapevine condition.

3 Description of the Use Cases

3.1 High-level description

From the initial objectives, a high-level description of the use cases is obtained.

Exploration of the vineyard

- **Aerial exploration**

UAVs (unmanned aerial vehicles) will be used to obtain detailed aerial images of the vineyard.

The system must process the images obtained by identifying the affected or potential risk areas to develop the botrytis infestation, it must create a map of risk areas and offer proposals for a detailed exploration using ground vehicles.

- **Ground exploration**

UGVs (unmanned ground vehicles) will be used to carry out detailed explorations of the risk zones identified by the system.

The UGVs will try to confirm the existence of the pest in addition to taking photos and videos of the farm for the end-user.

Treatment application

Once the botrytis pest or the potential risk of existence has been confirmed UGVs will be used to apply a treatment in a localized way.

Focusing on the plants/grapes where the pest existence has been detected and saving costs of wide, recursive and unlocalized treatment application.

Helping during the harvest

The UGVs will assist in the harvesting work, following the grape harvester who will load the grapes directly into the robot basket. Bringing the grapes to the winery or to the nearest transport tractor as soon as possible, reduces the usual times and increases the quality of the grapes used for winemaking.

3.2 Use case descriptions

WP4 – Pilot 1 proposes the use of a **fleet of heterogeneous robots that will be used to carry out different agricultural activities, divided into 4 global defined use cases:**

- **Aerial Exploration:** UAV platforms equipped with a high accuracy Real Time Kinematics (RTK) GPS, multispectral camera, and other measuring precision systems will be dedicated to vineyard inspection, to achieve early detection of Botrytis cinerea, a necrotrophic fungus that affects many plant species, most notably wine grapes, and to obtain data of interest related to the vineyard such as, for example, water stress, NDVI, degree of maturation indices, etc. generating georeferenced maps of possibly Botrytis affected zones to be explored by the UGV platforms in a second phase.

- **Ground exploration:** The ground robots, with the geolocated reference based on the information obtained from the UAVs, will approach the areas where the disease is most likely to have developed, to verify if this is the case, sending images to the data centre to confirm it.
- **Phytosanitary treatment application:** The ground robots will carry a spray tool to apply phytosanitary treatments in a localized way. They will approach the areas where it has been confirmed the existence of the disease and will apply the phytosanitary treatment in the specific area and plant.
- **Grape transport:** Ground robots will be responsible for transporting, autonomously, the grapes collected in the vineyard to an unloading point. They will be small mobile robots capable of safely following the operators who are harvesting. UGVs will have sensors that will allow us to know the filling status of the basket, as well as the weight of the grapes. That information, together with the geolocation, is of great interest to precisely know the production of each specific area of the vineyard, allowing to generate a harvest map of the vineyard.

Each one of the use cases is detailed below following the standard *IEC 62559 use-cases methodology* [13] template format, as in the rest of the deliverables of WP5 and WP6, following the guidelines of D2.7 [14].

3.2.1 WP4-UC-1. Aerial exploration

3.2.1.1 Name of use case

Use case identification		
ID	Area / Domain (s) / Zone (s)	Name of use case
WP4-UC-1	WP4 - Pilot 1 Artificial Intelligence applied to Botrytis detection	Aerial exploration

Table 1. WPA-UC-1 Use case identification

3.2.1.2 Scope and objectives of use case

Scope and objectives of use case	
Scope	WP4 – Pilot 1
Objective (s)	• Generate UAV exploration image products (Orthophotos, NDVI maps, etc.).

Scope and objectives of use case	
	• Generate a map of potentially affected zones by Botrytis disease in the explored vineyard's parcels.
Related business case (s)	Ground Exploration use case will start from Botrytis risky map resulting from this UC.

Table 2. WPA-UC-1 Scope and objectives of use case

3.2.1.3 Narrative of use case

Narrative of use case
Short description
Aerial exploration of the vineyard with the aim of early botrytis disease detection.
Complete description
With the aim of early Botrytis detection. A flight will be scheduled by the farmer to explore the vineyard on a specific date. On this date, a fleet of Unmanned Aerial Vehicles (UAV) will explore the vineyard parcels obtaining multispectral high-resolution images to be processed by the system generating a map of potentially affected zones.

Table 3. WPA-UC-1 Narrative of use case

3.2.1.4 Key Performance Indicators (KPIs)

Key performance indicators			
ID	Name	Description	Reference to mentioned use case objectives
1	Number of generated botrytis maps by campaign	The flights should be carried at least twice a year. Minimum 2 flying days a year.	1, 2
2	UAV image product spatial accuracy	The images collected by the UAV will be processed and UAV image products generated. A top 25% of features matching the ground truth should be verified (e.g., markers on the vineyard canopy/ground).	1
3	Botrytis detection accuracy	Botrytis detected from UAV images products match with the ground truth locations in the vineyard. A top 25% matching with ground truth should be verified. (e.g., Grapes with Botrytis symptoms).	2

Table 4. WPA-UC-1 Key performance indicators

3.2.1.5 Use case conditions

Use case conditions
Assumptions
1) It is assumed that the weather forecast will be good enough to enable the minimum number of flights proposed every year.
2) It is assumed that there will be enough Botrytis cases in the following 3 years to enable to collect enough data to design a disease detection approach.
3) It is assumed that the Botrytis symptoms will be noticed on the ground with visual inspection before each flight.
Prerequisites
1) Information from the fields (e.g., shapefiles).
2) Botrytis locations (ground truth).

Table 5. WPA-UC-1 Use case conditions

3.2.1.6 Further information to the use case for classification / mapping

Classification information
Relation to other use cases
N/A
Level of depth
Kite
Prioritisation
High
Generic, regional or national relation
N/A
Nature of the use case
N/A

Table 6. WPA-UC-1 Classification information

3.2.1.7 Diagrams of use case

Diagram(s) of use case

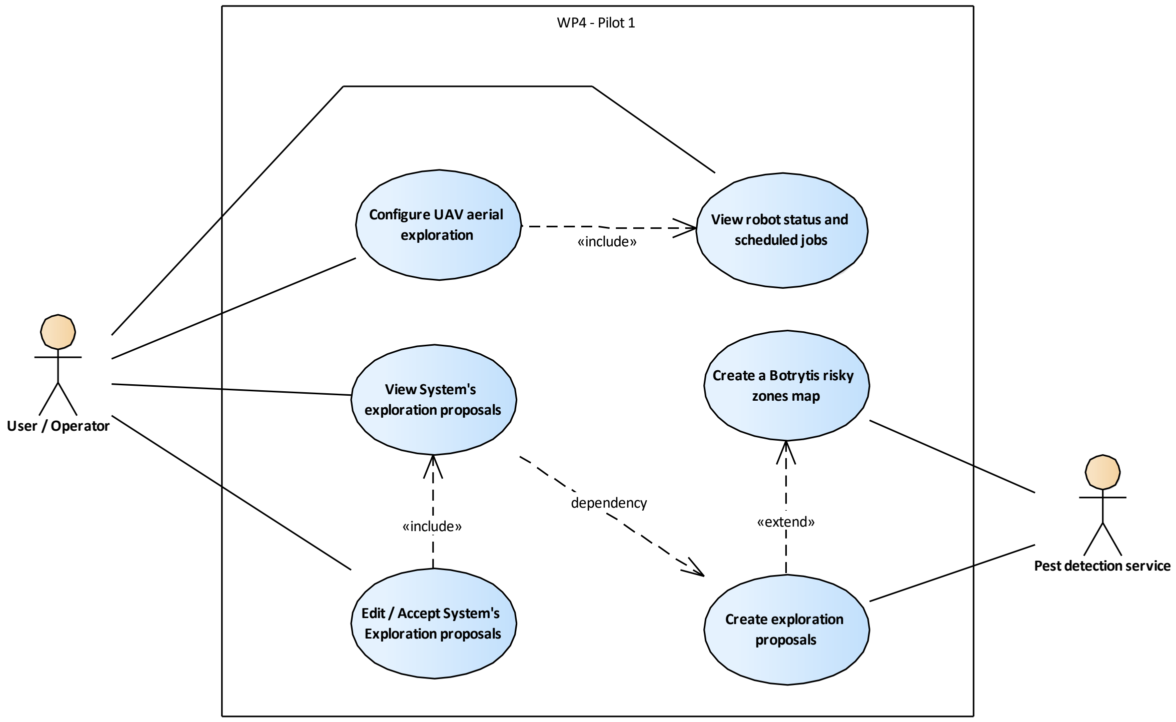


Figure 1. WPA-UC-1 Diagrams of use case

3.2.1.8 Technical details

3.2.1.8.1 Actors

Actors			
Grouping		Group description	
N/A		N/A	
Actor name	Actor type	Actor description	Further information specific to this use case
User	Primary	Farmer	N/A
Pest detection service	Secondary	Botrytis detection service	N/A

Table 7. WPA-UC-1 Actors

3.2.1.9 Step by step analysis of use case

3.2.1.9.1 Overview of scenarios

Scenario conditions						
No.	Scenario name	Scenario description	Primary actor	Triggering event	Pre-condition	Post-condition
1	Main	UAV Aerial exploration	User	User/operator configures a UAV exploration	N/A	N/A

Table 8. WPA-UC-1 Scenario conditions

3.2.1.9.2 Steps - Scenarios

Scenario								
Scenario name:	No. 1 - Main							
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requirement, R-IDs
1			The user/operator defines the vineyard fields to map and communicates that to the UAV operators (pilot and observer/assistant).		User	UAV fleet control system	1	
2			Pilot (and/or observer) calibrates multispectral camera, executes the flight over the		UAV fleet control system	Geospatial processing service	2	

Scenario								
			parcels and uploads RAW images to the data lake.					
3			Images are processed to generate high-resolution images (orthophotos and NDVI) with a geospatial processing routine.		Geospatial processing service	Pest detection service	3	
4			Image products are processed with an AI algorithm to generate a waypoint list with potentially infected patches.		Pest detection service	User	4	

Table 9. WPA-UC-1 Scenario

3.2.1.10 Information exchanged

Information exchanged			
Information exchanged, ID	Name of information	Description of information exchanged	Requirement, R-IDs
1	UAV scheduling data	Geometries of parcels to explore, date, etc.	
2	RAW Images	RAW images captured by UAVs without processing	
3	Image products	Image products obtained after geospatial processing	
4	Botrytis map	Botrytis zones map obtained after AI processing	

Table 10. WPA-UC-1 Information exchanged

3.2.1.11 Common terms and definitions

Common terms and definitions	
Term	Definition
UAV	Unmanned Aerial Vehicle
Botrytis	Vine's disease affecting grapes
NDVI	Normalized Difference Vegetation Index

Table 11. WPA-UC-1 Common terms and definitions

3.2.2 WP4-UC-2. Ground Exploration

3.2.2.1 Name of use case

Use case identification		
ID	Area / Domain (s) / Zone (s)	Name of use case
WP4-UC-2	WP4 - Pilot 1 Artificial Intelligence applied to Botrytis detection	Ground Exploration

Table 12. WP4-UC-2 Scope and objectives of use case

3.2.2.2 Scope and objectives of use case

Scope and objectives of use case	
Scope	WP4 – Pilot 1
Objective (s)	1) Autonomous exploration of a vineyard, fully covering the Botrytis affected zones detected by the aerial exploration. 2) Acquisition of grapevine imagery for farmer assessment or automatic Botrytis detection.
Related business case (s)	Will start with UC 1 risky maps and will be previous of the treatment application UC 3.

Table 13. WP4-UC-2 Scope and objectives of use case

3.2.2.3 Narrative of use case

Narrative of use case
Short description
Autonomous exploration from the ground of a vineyard for early Botrytis detection.
Complete description
Close recognition of areas possibly infected with Botrytis. The robots, with the geolocated reference based on the information obtained from the UAVs, will approach the areas where the disease is most likely to have developed, to verify if this is the case, sending images to the data centre.

Table 14. WP4-UC-2 Narrative of use case

3.2.2.4 Key Performance Indicators (KPIs)

Key performance indicators			
ID	Name	Description	Reference to mentioned use case objectives
1	Inspection Cost	Cost savings per season. Exploration needed for early disease detection.	1 & 2
2	Botrytis detection accuracy	On the visible bunches of grapes, Botrytis detected from UGV images must match with the ground truth at least 80%.	2

Table 15. WP4-UC-2 Key performance indicators

3.2.2.5 Use case conditions

Use case conditions
Assumptions
It is assumed that we will have a good mobile phone signal to monitor the autonomous robots.
It is assumed that it will have enough images of Botrytis to properly train the detection systems.
Prerequisites
Existence of areas in the vineyard affected by Botrytis.
Botrytis locations (ground truth).

Table 16. WP4-UC-2 Use case conditions

3.2.2.6 Further information to the use case for classification / mapping

Classification information
Relation to other use cases
Relation to WP4-UC-1
Level of depth
Kite
Prioritisation
High
Generic, regional or national relation
N/A
Nature of the use case
N/A

Table 17. WP4-UC-2 Classification information

3.2.2.7 Diagrams of use case

Diagram(s) of use case

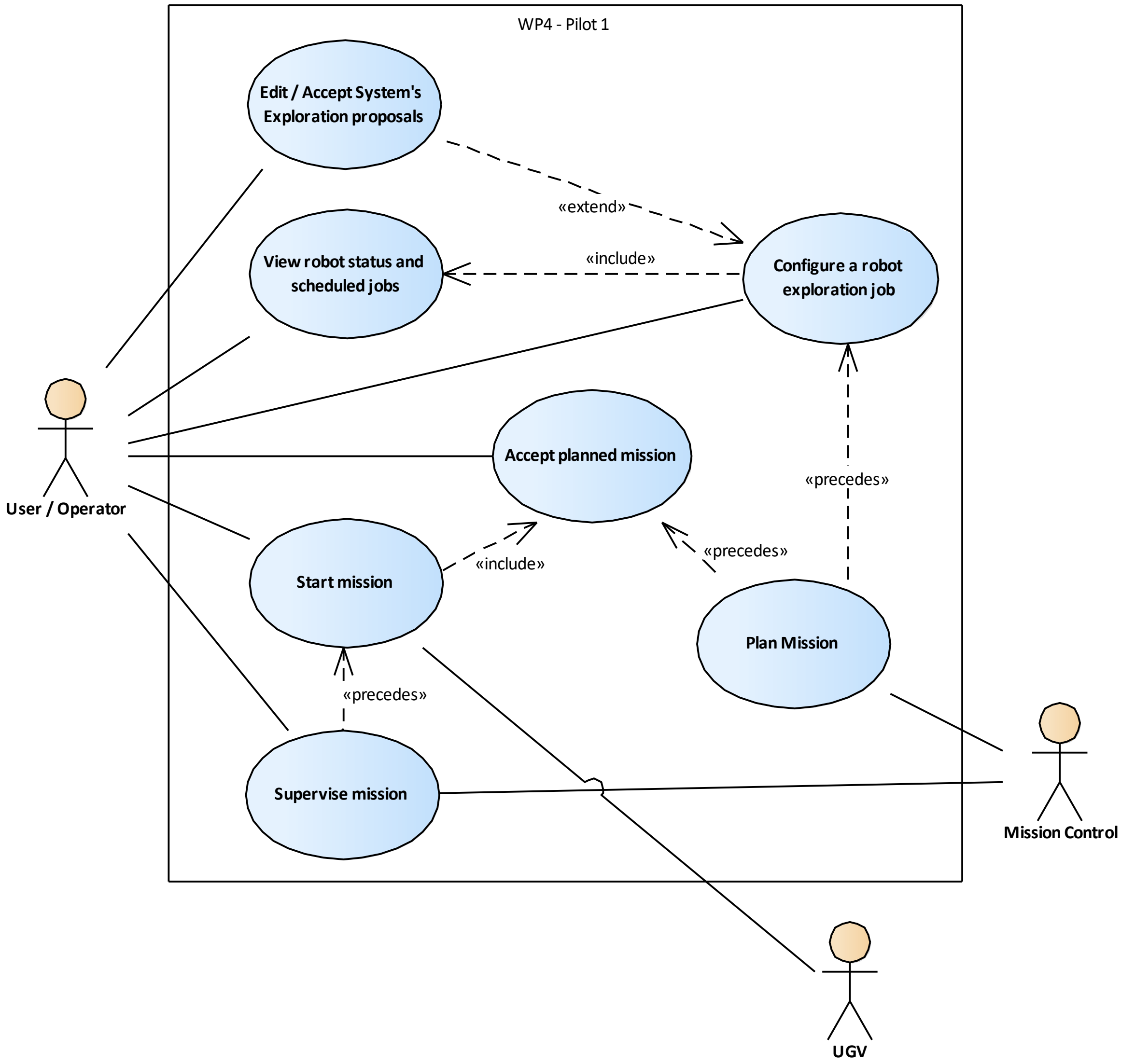


Figure 2. WP4-UC-2 Diagrams of use case

3.2.2.8 Technical details

3.2.2.8.1 Actors

Actors			
Grouping		Group description	
N/A		N/A	
Actor name	Actor type	Actor description	Further information specific to this use case
User	Primary	Farmer	N/A
UGV	Primary	Autonomous robot	N/A
Mission Control/ Supervisor	Secondary	Monitoring/Supervising system	N/A

Table 18. WP4-UC-2 Actors

3.2.2.9 Step by step analysis of use case

3.2.2.9.1 Overview of scenarios

Scenario conditions						
No.	Scenario name	Scenario description	Primary actor	Triggering event	Pre-condition	Post-condition
1	Main	UGV exploration	User	User/operator configures a UGV Exploration	-	-
2	Secondary	Some problem arises	UGV	Mission Control (Supervisor) detects some problem	-	-

Table 19. WP4-UC-2 Scenario conditions

3.2.2.9.2 Steps – Scenarios

Scenario								
Scenario name:	No. 1 - Main							
Step No.	Event	Name of process /	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requirement, R-IDs

Scenario								
		activity						
1			Operator starts UGV Exploration, defining the Mission configuration.		User	Mission Planner	1	
2			Mission Planner generates a plan for robots.		Mission Planner	User	2	
3			Operator approves the plan and orders to start the mission.		User	Mission Control	3	
4			Plans are sent to robots.		Mission Control	UGV	4	
5			Robots execute the mission.		UGV	Mission Control, User	5, 6	
6			Mission Control supervises the mission and shares the robot's telemetry.		Mission Control	User	5	
Scenario name:	No. 2 - Secondary							
Step No.	Event	Name of process /	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requirement, R-IDs

Scenario								
		activit y						
5.1			UGV or Mission Control detect a problem.					
5.2			The Fault Recovery Module searches for a solution.		Mission Control	UGV	7	
5.3			The Alarm Notification Manager decides if reporting or not the problem		Mission Control	User	8	
5.4			If reported, the user selects a solution and the mission continues		User	Mission Control	9	

Table 20. WP4-UC-2 Scenario

3.2.2.10 Information exchanged

Information exchanged			
Information exchanged, ID	Name of information	Description of information exchanged	Requirement, R-IDs
1	MissionConfiguration	Selected plots, the robot fleet configuration, potential Botrytis map, etc.	-
2	MissionPlan	Plans for robots. Set of the plans for all the robots in the fleet	-
3	StartMission	MissionPlan, Id of MissionType	-

Information exchanged			
Information exchanged, ID	Name of information	Description of information exchanged	Requirement, R-IDs
4	StartRobot	The plan for a robot. Set of waypoints	-
5	RobotState	Telemetry of the robot	-
6	ImageRobot	Images	-
7	RecoveringPlan	New plan for the robot. It can include an emergency stop.	-
8	Alarm	Explanation of the problem detected, related data and potential solution	-
9	Solution	Selected solution	-

Table 21. WP4-UC-2 Information exchanged

3.2.2.11 Common terms and definitions

Common terms and definitions	
Term	Definition
UGV	unmanned ground vehicle
Botrytis	Vine's disease affecting grapes

Table 22. WP4-UC-2 Common terms and definitions

3.2.3 WP4-UC-3. Treatment

3.2.3.1 Name of use case

Use case identification		
ID	Area / Domain (s) / Zone (s)	Name of use case
WP4-UC-3	WP4 - Pilot 1 Artificial Intelligence is applied to a bunch of grapes detection and treatment.	Treatment

Table 23. WP4-UC-2 Use case identification

3.2.3.2 Scope and objectives of use case

Scope and objectives of use case	
Scope	WP4 – Pilot 1

Objective (s)	1) Apply treatment in affect zones, using a prescription map 2) Apply treatment after a real-time Botrytis detection (exploratory objective).
Related business case (s)	It will start from the results of the ground exploration UC 2.

Table 24. WP4-UC-2 Scope and objectives of use case

3.2.3.3 Narrative of use case

Narrative of use case
Short description
Autonomous treatment of Botrytis in a vineyard
Complete description
The treatment robots roam the areas affected by Botrytis, applying phytosanitary products according to a prescription map or when Botrytis is detected in real time.

Table 25. WP4-UC-2 Narrative of use case

3.2.3.4 Key Performance Indicators (KPIs)

Key performance indicators			
ID	Name	Description	Reference to mentioned use case objectives
1	Treatment Cost	Reduce at least 9% the use of the phytosanitary product, minimizing costs and environmental damages.	1 & 2
2	Botrytis detection accuracy	On the visible grape bunches, Botrytis detected from UGV images must match with the ground truth at least 80%.	2
3	Botrytis Treatment accuracy	It will be treated 100% of the grape bunches with detected Botrytis.	1 & 2

Table 26. WP4-UC-2 Key performance indicators

3.2.3.5 Use case conditions

Use case conditions
Assumptions

It is assumed that we will have a good mobile phone signal to monitor the autonomous robots.
It is assumed that it will have enough images of Botrytis to properly train the detection systems.
Prerequisites
Existence of areas in the vineyard affected by Botrytis.
Botrytis locations (ground truth).

Table 27. WP4-UC-2 Use case conditions

3.2.3.6 Further information to the use case for classification / mapping

Classification information
Relation to other use cases
Relation to WP4-UC-1 and WP4-UC-2
Level of depth
Kite
Prioritisation
High
Generic, regional or national relation
N/A
Nature of the use case
N/A

Table 28. WP4-UC-2 Classification information

3.2.3.7 Diagrams of use case

Diagram(s) of use case

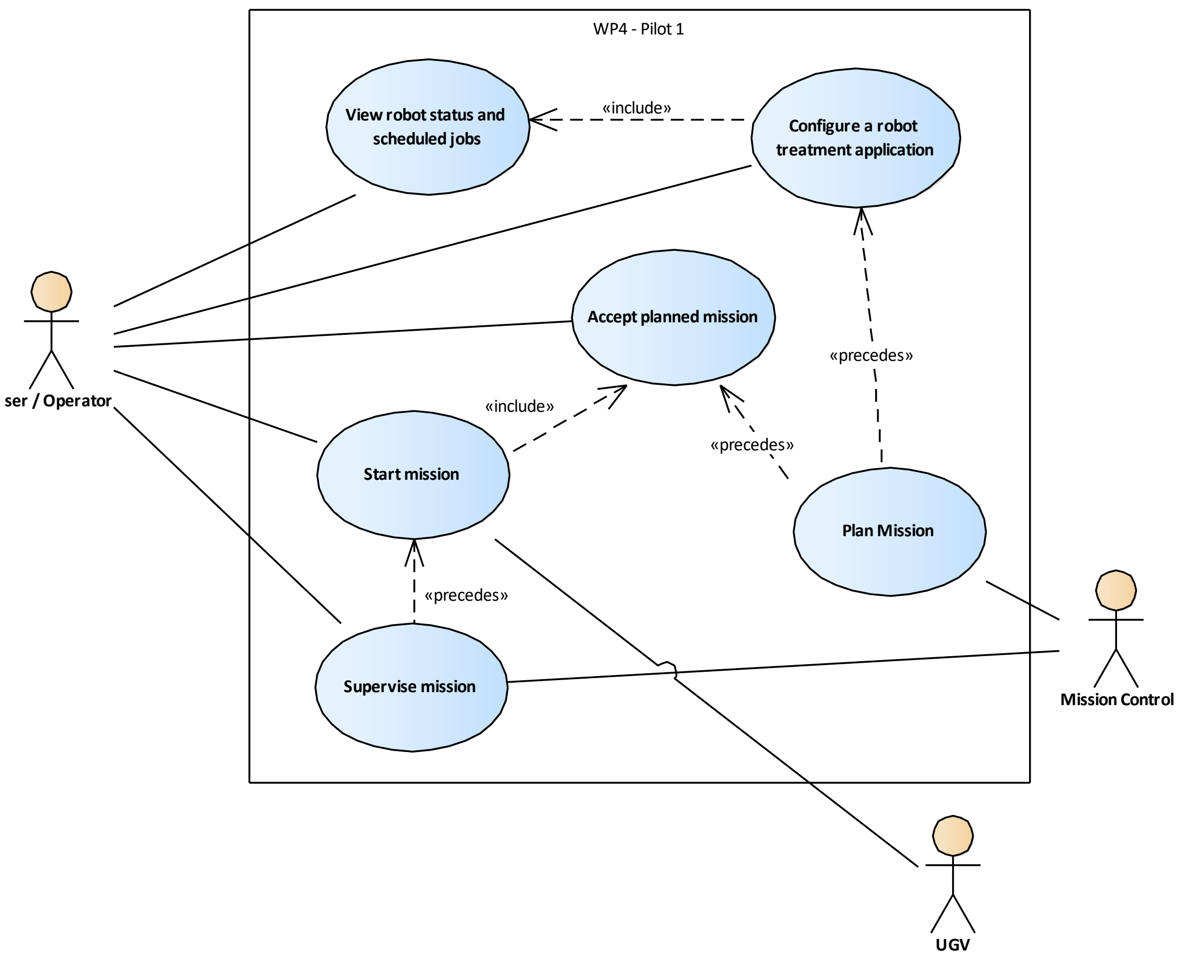


Figure 3. WP4-UC-2 Diagrams of use case

3.2.3.8 Technical details

3.2.3.8.1 Actors

Actors			
Grouping		Group description	
N/A		N/A	
Actor name	Actor type	Actor description	Further information specific to this use case
User	Primary	Farmer	N/A

Actors			
UGV	Primary	Autonomous robot	N/A
Mission Control/ Supervisor	Secondary	Monitoring/Supervising system	N/A

Table 29. WP4-UC-2 Actors

3.2.3.9 Step by step analysis of use case

3.2.3.9.1 Overview of scenarios

Scenario conditions						
No.	Scenario name	Scenario description	Primary actor	Triggering event	Pre-condition	Post-condition
1	Main	UGV Treatment	User	User/operator defines and prescription map	N/A	N/A
2	MainAlter	UGV treatment	User	User/operator start treatment task with UAV map of the potentially affected areas	N/A	N/A
3	Secondary	Some problem arises	UGV	Mission Control (Supervisor) detects some problem	N/A	N/A

Table 30. WP4-UC-2 Scenario conditions

3.2.3.9.2 Steps – Scenarios

Scenario								
Scenario name:	No. 1 - Main							
Step No.	Event	Name of proces	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requirement, R-IDs

Scenario									
		s / activity							
1			Operator starts UGV Exploration, defining the Mission configuratio n.		User	Mission Planner	1	-	
2			Mission Planner generates a plan for robots		Mission Planner	User	2	-	
3			Operator approves plans and orders to start the mission.		User	Mission Control	3	-	
4			Plans are sent to robots.		Mission Control	UGV	4	-	
5			Robots execute the mission.		UGV	Mission Control, User	5,6	-	
6			Mission Control supervises the mission and shares the robot's telemetry.		Mission Control	User	5	-	
7			Robots apply treatment following the prescription map guideline.					-	

Scenario								
Scenario name:	No. 2 - MainAlter							
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requirement, R-IDs
1			Mission Planner generates a plan for robots.		Mission Planner	User	2	Exploration is proposed by the system after a UAV aerial exploration
3-6 from scenario: 1-Main								
7			Robots send images.		UGV	Pest detection service	6	Detection and communication must be in real-time
8			When a pest is detected, the robot applies treatment.		Pest Detection Service	UGV	7	Detection and communication must be in real-time
Scenario name:	No. 3 - Secondary							
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requirement, R-IDs

Scenario								
5.1			UGV or Mission Control detect a problem.					-
5.2			The Fault Recovery Module searches for a solution.		Mission Control	UGV	8	-
5.3			The Alarm Notification Manager decides if reporting or not the problem.		Mission Control	User	9	-
5.4			If reported, the user selects a solution and the mission continues.		User	Mission Control	10	-

Table 31. WP4-UC-2 Scenario

3.2.3.10 Information exchanged

Information exchanged			
Information exchanged, ID	Name of information	Description of information exchanged	Requirement, R-IDs
1	MissionConfiguration	He selects plots selected, the robot fleet configuration, potential Botrytis map, etc.	-
2	MissionPlan	Plans for robots. Set of the plans for all the robots in the fleet	-
3	StartMission	MissionPlan, Id of MissionType	-
4	StartRobot	The plan for a robot. Set of waypoints	-
5	RobotState	Telemetry of the robot	-

Information exchanged			
Information exchanged, ID	Name of information	Description of information exchanged	Requirement, R-IDs
6	ImageRobot	Image	-
7	DetectionData	Position of the grape bunch affected by Botrytis	Response in real-time
8	RecoveringPlan	New plan for the robot. It can include an emergency stop.	-
9	Alarm	Explanation of the problem detected related data and potential solution	-
10	Solution	Selected solution	-

Table 32. WP4-UC-2 Information exchanged

3.2.3.11 Common terms and definitions

Common terms and definitions	
Term	Definition
UGV	unmanned ground vehicle
Botrytis	Vine’s disease affecting grapes

Table 33. WP4-UC-2 Common terms and definitions

3.2.4 WP4-UC-4. Harvest

3.2.4.1 Name of use case

Use case identification		
ID	Area / Domain (s) / Zone (s)	Name of use case
WP4-UC-4	WP4 - Pilot 1 Artificial Intelligence applied to operators assistance	Harvesting assistance

Table 34. WP4-UC-4 Use case identification

3.2.4.2 Scope and objectives of use case

Scope and objectives of use case	
Scope	WP4 – Pilot 1
Objective (s)	1) Follow the operator without hindering his/her work.

	2) Move autonomously from a specific location in the field to the unloading point of the grapes, and from the unloading point to a precise point in the field.
Related business case (s)	N/A

Table 35. WP4-UC-4 Scope and objectives of use case

3.2.4.3 Narrative of use case

Narrative of use case
Short description
An AGV fleet assist operator in the manual grape harvesting.
Complete description
A collaborative working environment between robot basket carriers and operators during manual grape harvesting will be created. Each robot, pottering a basket, will follow an operator. When the basket is full, a robot with an empty basket will replace the robot with the full basket that will go autonomously to the grape unloading point.

Table 36. WP4-UC-4 Narrative of use case

3.2.4.4 Key Performance Indicators (KPIs)

Key performance indicators			
ID	Name	Description	Reference to mentioned use case objectives
1	Cost of grape transport	Reducing costs of grape transport by at least 11%.	1 & 2
2	Time of grape transport	Improving the efficiency by reducing at least 30% of the required time.	1 & 2
3	Additional benefit	The volume of production can be known on the go. So, it can be elaborated a harvesting map.	1 & 2

Table 37. WP4-UC-4 Key performance indicators

3.2.4.5 Use case conditions

Use case conditions

Assumptions
It is assumed that we will have a good mobile phone signal to monitor the autonomous robots.
Prerequisites
-

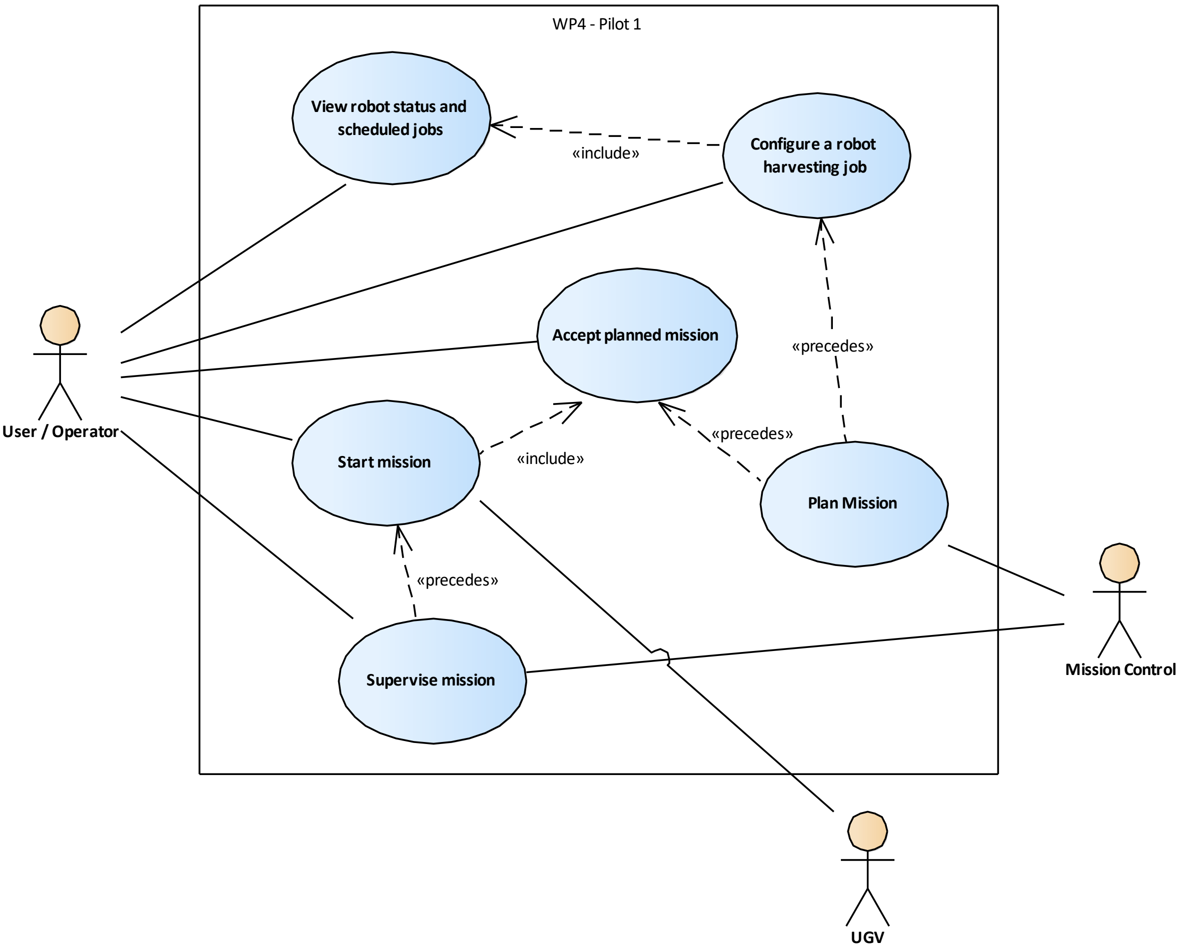
Table 38. WP4-UC-4 Use case conditions

3.2.4.6 Further information to the use case for classification / mapping

Classification information
Relation to other use cases
-
Level of depth
Kite
Prioritisation
High
Generic, regional or national relation
-
Nature of the use case
Application

Table 39. WP4-UC-4 Classification information

3.2.4.7 Diagrams of use case

Diagram(s) of use case
 Figure 4. WP4-UC-4 Diagrams of use case

3.2.4.8 Technical details

3.2.4.8.1 Actors

Actors			
Grouping		Group description	
N/A		N/A	
Actor name	Actor type	Actor description	Further information specific to this use case
User	Primary	Farmer	N/A
UGV	Primary	Autonomous robot	N/A

Actors			
Mission Control/ Supervisor	Secondary	Monitoring/Supervising system	N/A

Table 40. WP4-UC-4 Actors

3.2.4.9 Step by step analysis of use case

3.2.4.9.1 Overview of scenarios

Scenario conditions						
No.	Scenario name	Scenario description	Primary actor	Triggering event	Pre-condition	Post-condition
1	Main	Harvesting assistance	User	User/operator configures a harvesting assistance mission	N/A	N/A
2	Secondary	Some problem arises	UGV	Mission Control (Supervisor) detects some problem	N/A	N/A

Table 41. WP4-UC-4 Scenario conditions

3.2.4.9.2 Steps – Scenarios

Scenario								
Scenario name:	No. 1 - Main							
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requirement, R-IDs
1			Operator starts UGV Mission, defining the Mission configuration.		User	Mission Planner	1	-

Scenario								
2			Mission Planner generates a plan for robots.		Mission Planner	User	2	-
3			Operator approves the plan and orders to start the mission.		User	Mission Control	3	-
4			Plans are sent to robots.		Mission Control	UGV	4	-
5			Robots autonomously reach the start points.		UGV	Mission Control, User	5	-
6			Robots move forward following the operator.		UGV	Mission Control, User	5, 10	-
7			Robots autonomously reach the unloading point.		UGV	Mission Control, User	5	-
8			Mission Control supervises mission and shares robot info.		Mission Control	User	5, 10	-
Scenario name:	No. 2 - Secondary							

Scenario								
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requirement, R-IDs
5.1/7.1			UGV or Mission Control detect a problem.					-
5.2/7.2			The Fault Recovery Module searches for a solution.		Mission Control	UGV	7	-
5.3/7.3			The Alarm Notification Manager decides if reporting or not the problem.		Mission Control	User	8	-
5.4/7.4			If reported, the user selects a solution and the mission continues.		User	Mission Control	9	-

Table 42. WP4-UC-4 Scenario

3.2.4.10 Information exchanged

Information exchanged			
Information exchanged, ID	Name of information	Description of information exchanged	Requirement, R-IDs
1	MissionConfiguration	Selected plots, the robot fleet configuration, potential Botrytis map, etc.	-
2	MissionPlan	Plans for robots. Set of the plans for all the robots in the fleet	-
3	StartMission	MissionPlan, Id of MissionType	-
4	StartRobot	The plan for a robot. Set of waypoints	-
5	RobotState	Telemetry of the robot	-
6	ImageRobot	Images	-
7	RecoveringPlan	New plan for the robot. It can include an emergency stop.	-
8	Alarm	Explanation of the problem detected related data and potential solution	-
9	Solution	Selected solution	-
10	Weight	The weight of the basket	-

Table 43. WP4-UC-4 Information exchanged

3.2.4.11 Common terms and definitions

Common terms and definitions	
Term	Definition
UGV	unmanned ground vehicle

Table 44. WP4-UC-4 Common terms and definitions

4 Description of datasets

WP4 – Pilot 1 will use **robots (UAVs and UGVs)** that will be used to carry out different agricultural activities on the field. During the execution of these activities, robots will gather different types of data, that combined with the data collected by the **meteorological stations and sensors** present in the vineyard, will be used to implement the already explained use cases of the pilot.

4.1 Data summary

WP4 has identified four independent datasets:

- Sensor and meteorology data.
- TG Images.
- UAV Image products.
- UGV Images and telemetry.

WP4 has worked on documenting each one of the identified datasets as a contribution to other work packages. Below is the information about each dataset structured as a questionnaire format contributed by the WP4.

4.2 Data acquisition

Describe what the purpose of the data collection/generation is and its relation to the objectives of the Task (i.e., what this data is required for)?

Sensor and meteorological data:

The purpose is to offer a dataset with current and historic information collected by on-field sensors and weather stations along with meteorological services to enable the development, training and/or testing of AI algorithms or processes focused on different agricultural tasks e.g.: Disease detection and/or prediction (like botrytis), treatment application and irrigation optimization, decision making, etc.

TG Images:

Provide data relating to images of affected Botrytis vineyards and those that are healthy, so learning methods close to aerial and ground robots can be trained to identify the disease. The geo-positioning of the sensitive areas and the bunches in the canopy, as well as the images that show the body position and movements of the operators who pick the grapes.

UAV Image products:

The purpose of the UAV image products datasets is to design an approach that will enable detect Botrytis in the vineyard and generate a list of coordinates where the disease symptoms were detected.

UGV Images and Telemetry:

On the one hand, the unmanned ground vehicles (UGVs) will collect images of vineyard suffering Botrytis during the mission. Afterwards, they will be manually labelled to help in the training of neural networks for Botrytis prediction in vineyards.

On the other hand, the plan generated for the mission of the UGVs, and all information exchanged between them and the base station (position, status, possible incidences, and solutions, etc.) will be collected. This dataset will be useful to reproduce the mission, analyse it, and to study future improvements that would have an impact on the better performance of the task.

Describe what types of data the Task will generate/collect (e.g., bibliographic data, modelling data, survey replies, etc.)?

Sensor and meteorological data:

- Meteorological data time series (Observations) captured by sensors and weather stations on the ground in Terras Gauda’s vineyard and around.
- Aggregated meteorological data time series related to Terras Gauda’s vineyard parcels captured by sensors and weather stations on the ground.

TG Images:

- 1. Photos of Botrytis in its different stages of development and virulence, depending on the phenological stages of the vine.
- 2. Photos of the usual position of the bunches in the canopy. Height, outside, inside, etc.
- 3. Data on the usual position of the grape pickers, type of movements they make, movement of the grape boxes, etc.
- 4. Data on the process carried out by the operators who drive the tractor and fill the trailer once the boxes of grapes are taken to the head of the vine lines.

UAV Image products:

- UAV Single images.
- UAV true colour orthophotos.
- UAV false colour orthophotos.
- UAV NVDI maps.
- Botrytis detection map coordinates.

UGV Images and Telemetry:

- Images collected by the cameras on-board the UGVs, subsequently labelled.

- Plan for the mission and all information exchanged between the UGVs and the Base Station (position, status, possible incidences and solutions, etc.).

4.2.1 Format and structure of the data

Describe what formats of data the Task will generate/collect (e.g., pdf, xlsx, SQL, etc.)?

Sensor and meteorological data:

- JSON.
- CSV.

TG Images:

- Images in jpg.
- Explanation for labelling in docx.
- Geo-referenced information in GeoJSON files.

UAV Image products:

- JPG's.
- TIF's.
- CSV.

UGV Images and Telemetry:

- JPG.
- BAG.

4.2.2 Existing data

Will the task re-use any existing data and how? (See also Chapter 7 of the CESSDA guide)

Sensor and meteorological data:

No. Developed task will use only generated/captured info during the project development.

TG Images:

Yes. The data necessary for the recognition of Botrytis are repetitive. In fact, a large number of images is needed to adequately train the developed detection procedures.

UAV Image products:

No. Developed task will use only generated/captured info during the project development.

UGV Images and Telemetry:

No.

4.2.3 Origin of the existing data (if any)?

What is the origin of the data?

<u>Sensor and meteorological data:</u> • Motes and stations, developed by Envira manufacturer, placed in Terras Gauda's vineyard. • AEMET's (Spain's meteorological agency) weather stations placed near Terras Gauda's vineyard. • MeteoGalicia (Galicia's meteorological agency) weather stations placed near Terras Gauda's vineyard. **<u>TG Images:</u>** • Stored images of Botrytis in the different phenological stages of the vineyard. • Botrytis detection records. • Historical data on the rate of harvest by plots, and the number of boxes completed per day and operator. Historical data will come from Terras' repository. **<u>UAV Image products:</u>** • Images of vineyards suffering botrytis were collected by the UAVs. • The information generated for and in the mission. **<u>UGV Images and Telemetry:</u>** • Images of vineyards suffering botrytis were collected by the UGVs. • The information generated for and in the mission.

4.2.4 Size of the data

What is the expected size of the data? (in Gb)

<u>Sensor and meteorological data:</u> Not expected more than 1 GB (Not verified statement) **<u>TG Images:</u>** • 50 GB (images). • 0.5 GB (other data). **<u>UAV Image products:</u>** • 500 GB – 1 TB. **<u>UGV Images and Telemetry:</u>** • 50 GB. • 1 GB.

4.2.5 Usage of the data

To whom it might be useful ("data utility")?

Sensor and meteorological data:

Considering FlexiGroBots project scope, it will be useful mainly for WP4 development, as it is focused on the botrytis detection on vineyards, but it could be useful for any other partner or 3rd party looking for meteorological information on a specific zone.

TG Images:

CSIC, WU, SERESCO.

UAV Image products:

To all the partners participating in WP2, 3, and 4.

UGV Images and Telemetry:

For researchers working on deep learning, for farmer or UGVs.

4.2.6 Where and how are the data stored?

Sensor and meteorological data:

Currently on-premises under Seresco's control:

- Time series collected data is currently being stored in an InfluxDB database instance (A time-series data specialized database).
- Geo-position of weather stations and sensor is currently being stored in a PostgreSQL database instance.

Datasets will be made available on FlexiGroBots storage and open-access repository.

TG Images:

- Terras' repository, CSIC repository (DIGITAL.CSIC.ES)
- CSIC repository is open access.

UAV Image products:

- All the datasets will be stored in FlexiGroBots storage, an open-access repository.
- The own institutional storage is deposited in an open-access repository.

UGV Images and Telemetry:

- All the datasets will be stored in their own institutional storage and deposited in an open-access repository.

4.2.7 What are the risks for the data?

Sensor and meteorological data:

There is no identified risk associated with data.

TG Images:

There is no risk associated with the data.

UAV Image products:

That there is not enough – physical or virtual - space to store/backup it.

UGV Images and Telemetry:

There is no risk associated with the data, although it is possible that the images do not show Botrytis and, in that case, there will be no labels associated with each image or there will be a NULL label.

4.3 Data management

4.3.1 FAIR Data (Findability, Accessibility, Interoperability, Reusability)

4.3.1.1 Making data FINDABLE

(Chapter 2 of CESSDA Guide)

4.3.1.2 Metadata provision

Are the data produced and/or used in the Task discoverable with metadata?

Sensor and meteorological data:

Not yet. Metadata will be generated.

TG Images:

Yes, metadata will be included for each dataset.

UAG Image products:

Not yet. Metadata will be generated.

UGV Images and Telemetry:

Yes, metadata will be included for each dataset.

4.3.1.3 Identification of data

Does the task make use of persistent and unique identifiers such as Digital Object Identifiers?

Sensor and meteorological data:

The datasets will be deposited in a repository with DOI.

TG Images:

The datasets will be deposited in a repository with DOI (CSIC repository).

UAG Image products:

The datasets will be deposited in a repository with DOI.

UGV Images and Telemetry:

The datasets will be deposited in a repository with DOI.

4.3.1.4 Naming conventions

What naming conventions do you follow? (*Folders and files conventions*)

Naming conventions are not currently defined.

4.3.1.5 Search keywords

Will search keywords be provided that optimize possibilities for re-use?

e.g., Tagging items (i.e., datasets, documents, codes, etc.) with relevant keywords that are automatically indexed by the search

Sensor and meteorological data:

To be defined.

TG Images:

If necessary, relevant keywords will be provided.

UAG Image products:

To be defined.

UGV Images and Telemetry:

Yes, relevant keywords will be provided.

4.3.1.6 Versioning

Do you provide clear version numbers?

e.g., Might be taken in charge by a tool, might only upload one version of each dataset

Only one version of each dataset will be uploaded.

4.3.1.7 Standards for metadata creation

What metadata will be created? In case metadata standards do not exist in your specific discipline, please outline what type of metadata will be created and how.

e.g. Description, ownership, date etc.

e.g. Standard e.g. Dublin Core metadata standard

e.g., readme.txt file

A readme.txt file will be created for each dataset.

4.3.1.8 Making data ACCESSIBLE

See Chapter 4 and Chapter 6 of CESSDA Guide

4.3.1.8.1 Open available datasets

Which data produced and/or used in the Task will be made openly available as the default?

Follow the principle "as open as possible, as closed as necessary".

All data can be openly available.

4.3.1.8.2 Closed datasets

If certain or parts of datasets cannot be shared (or need to be shared under restrictions), explain why, clearly separating legal and contractual reasons from voluntary restrictions (e.g. ethical, rules of personal data, intellectual property, commercial, privacy-related, security-related, etc.).

Sensor and meteorological data:

To be defined.

TG Images:

Data shared under restrictions: Rules of personal data.

Private company data, etc.

UAG Image products:

To be defined.

UGV Images and Telemetry:

Labelled images will be IPR protected and shared openly but users will have to reference the CSIC group.

4.3.1.8.3 Repository

How will the data be made accessible (e.g., by deposition in a repository)?

Can you provide us with the link and D.O.I. (digital object identifier)?

e.g., Deposited in open access repository (e.g., OSF, Zenodo)

DOI for datasets differs from DOI for publications. You might find some useful information under: https://academia.stackexchange.com/questions/52032/how-do-i-get-a-doi-for-a-dataset

If you do not have/or will obtain a DOI, just mention that here.

Sensor and meteorological data:

Currently produced data is being stored in influxDB and PostgreSQL Database instances on-premises.

Open access repository providing a D.O.I will be used to deposit the data during project development.

TG Images:

There will be available by deposition in a repository with DOI.

UAG Image products:

All the data will be released in a public repository with DOI.

UGV Images and Telemetry:

There will be available by deposition in a repository with DOI.

4.3.1.8.4 Software tools for access

What methods or software tools are needed to access the data?

Sensor and meteorological data:

To be defined. Depends on the final used repository.

TG Images:

A web browser, it is not mandatory to use another tool. GIS for geo-referenced data.

UAG Image products:

Web browser.

UGV Images and Telemetry:

A web browser, it is not mandatory to use another tool.

Is documentation about the software needed to access the data included?

Sensor and meteorological data:

To be defined.

TG Images:

No.

UAG Image products:

No.

UGV Images and Telemetry:

No.

Is it possible to include the relevant software (e.g., in open-source code)?

Sensor and meteorological data:

To be defined.

TG Images:

Yes.

UAG Image products:

N/A. **UGV Images and Telemetry:** As explained above, any web browser can be used to access the datasets.

4.3.1.8.5 Data depository

Where will the data and associated metadata, documentation and code be deposited? Preference should be given to certified repositories which that open access where possible.

e.g. Deposited in open access repository (e.g., OSF, Zenodo)

Sensor and meteorological data: Open access repository providing a D.O.I will be used to deposit the data during project development. **TG Images:** The datasets will be deposited in an open-access repository (CSIC repository). **UAG Image products:** All the data will be released in a public repository with DOI (e.g., Zenodo). **UGV Images and Telemetry:** The datasets will be deposited in an open-access repository (CSIC repository, www.digital.csic.es).

Have you explored appropriate arrangements with the identified repository?

Sensor and meteorological data: No. **TG Images:** Yes. **UAG Image products:** No. **UGV Images and Telemetry:** Yes.

If there are restrictions on use, how will access be provided?

No, it is an open-access repository.

Is there a need for a data access committee[1]?

No, it is not necessary.

[1] A committee that reviews and authorizes requests for data access and use.

4.3.1.9 Making data INTEROPERABLE[2]

See Chapter 3 and Chapter 6 of the CESSDA Guide

4.3.1.9.1 Interoperability of the data produced in the Task

Is the Task allowing data exchange and re-use between researchers, institutions, organizations, countries, etc. (i.e., adhering to standards for formats, as much as possible compliant with available (open) software applications, and in particular facilitating re-combinations with different datasets from different origins)?

Yes.

What data and metadata vocabularies, standards or methodologies will the Task follow to make the data interoperable?

e.g., metadata format is compliant with standard formats (MARCXML, Dublin Core, and DataCite Metadata Schema)

A *readme.txt* file will be attached to each dataset, explaining how the data can be re-use for other researchers.

4.3.1.9.2 Vocabulary

Will your task use standard vocabularies for the data types present in the datasets to allow inter-disciplinary interoperability?

Yes.

If not, will you provide mapping to more commonly used ontologies?

N/A.

4.3.1.10 Making data RE-USABLE

See Chapter 3 of the CESSDA Guide

4.3.1.10.1 License

How will the data be licensed to permit the widest re-use possible?

e.g., Creative Commons license CC-BY or CC-0 (according to the H2020 guidelines)

Be aware there are different licenses for research data (in comparison with publications), depending on the nature of these data (origin).

[2] Due to the versatility of the pilots, a number of standards should be used to ensure interoperability and proper communication, protection, and reusability of the generated data. These include standards such as ROS, ISOXML (ISO 11783), ISO 50001, ISOBUS (ISO 11783), ISO 22000, DIN EN 1672-2:2009-07, Machinery Directive 2006/42/EC, FDA 21CFR 174-178, EHEDG Doc. 8 / 13 (+ more depending on the application), ISO 22166, ISO 18497, ISO 17757, ISO 25119, ISO 62443.

Sensor and meteorological data: To be defined. **TG Images:** Creative Commons license CC-BY will be used for the datasets. **UAG Image products:** To be defined. **UGV Images and Telemetry:** Creative Commons license CC-BY will be used for the datasets.

4.3.1.11 Availability

When will the data be made available for re-use?

e.g., after upload

After upload.

If applicable, specify why and for what period a data embargo is needed.

N/A.

How long is it intended that the data remains re-usable?

e.g., at least 15 years, for the lifetime of the repository

For the lifetime of the repository.

4.3.1.11.1 Third parties

Are the data produced and/or used in the Task useable by third parties, in particular after the end of the pilot/project? If the re-use of some data is restricted, explain why.

Sensor and meteorological data: It's expected to be open and useable by third parties. **TG Images:** No. **UAG Image products:** It's expected to be opened a useable by third parties. **UGV Images and Telemetry:** Yes, the datasets produced will be useable by third parties after the end of the project and as long as Terras Gauda agrees with it.

4.3.1.11.2 Data quality

How is the data quality assured? Are data quality assurance processes described?

<u>Sensor and meteorological data:</u> Data will be made available as it was originally collected, apart from the possible validations and assurance processes are done on data origin, is not expected for the task to run any other validation or assurance processes. **<u>TG Images:</u>** The procedure to collect the data will be explained. **<u>UAG Image products:</u>** Data will be made available as it was originally collected, apart from the possible validations and assurance processes are done on data origin, is not expected for the task to run any other validation or assurance processes. **<u>UGV Images and Telemetry:</u>** The procedure to collect the data will be explained.

<u>Note</u>: Please note that making data accessible should be the standard/default. When for some data this is not possible, then it should be clearly explained, i.e., examples of restricted data could be personal information or consortium confidential data – the latter might be accessible to all the partners but kept within the project for exploitation during some time; this one, when published, normally is made available.

4.3.2 Allocation of resources

See Chapter 1 of the CESSDA Guide

4.3.2.1 Costs

What are the costs for making data FAIR in your project? And how will these be covered?

e.g., Long term storage, journal open access costs etc.

e.g. project's budget

None, a free platform is going to be used for preserving and sharing data.

4.3.2.2 Responsibility for data management

Who will be responsible for data management in the Task?

<u>Sensor and meteorological data:</u> Sergio Álvarez from Seresco **<u>UAG Image products:</u>** João Valente from Wageningen University **<u>UGV Images and Telemetry:</u>**

The head of the CSIC group, Angela Ribeiro

4.3.2.3 Costs and potential value of long-term preservation

What are the costs of long-term preservation? And who decides and how what data will be kept and for how long?

None

4.3.3 Data security

Datasets must be preserved/stored during and beyond the lifetime of the Task. This means that each Task must provide a clear description of procedures for short-term and long-term preservation of the datasets.

See Chapter 4 of CESSDA Guide

4.3.3.1 Data security

What provisions are in place for data security (including data recovery as well as secure storage and transfer of sensitive data)?

e.g., data stored in the partners' networks with backups, firewall; in the project's SharePoint accessible with credentials; Basecamp; OwnCloud etc.

Sensor and meteorological data: Currently it is stored on-premises under security provisions: Backups, geo-replication, firewall. **TG Images:** Data will be stored in the CSIC institutional storage (https://digital.csic.es/) protected with a firewall, and with automatic backups. **UAG Image products:** Data stored in the partners' networks with backups, firewall; in the project's OwnCloud accessible with credentials, WU OneDrive accessible with credentials. **UGV Images and Telemetry:** Data will be stored in the own institutional storage (https://digital.csic.es/) protected with a firewall, and with automatic backups.

4.3.3.2 Data storage

Is the data safely stored in certified repositories for long term preservation and curation?

Yes

4.3.4 Ethical and legal aspects

In those cases where personal data (GDPR) is involved, detailed information is planned to be provided:

- On what personal data is collected, stored and processed;
- On the recruitment process, inclusion/exclusion criteria for participation;
- On privacy/confidentiality and the procedures that are implemented for data collection, storage, access, sharing policies, protection, retention and destruction during and after the project;
- On how informed consent is pursued;
- if application/is needed to be filed with a local/institutional ethics review body (if personal data is being collected) and if yes, which bodies / where / when.

See Chapter 5 of CESSDA Guide

4.3.4.1 Ethical or legal issues

Are there any ethical or legal issues that can have an impact on data sharing?

e.g., data from 3rd-party that didn't give an explicit consent, data that need to comply with the GDPR etc.

In a project like FlexiGroBots, the following ethical issues might arise:

• privacy and surveillance

• data ownership or the right to access data

• responsibility for decisions and their consequences (including accidents)

Sensor and meteorological data:

Part of the Data will be collected from public agencies requesting to be mentioned on data distribution or use.

TG Images:

No.

UAG Image products:

Data will be collected from public agencies requesting to be mentioned on data distribution or use.

UGV Images and Telemetry:

No.

4.3.4.2 Data collection in non-EU countries

Does your task involve data collection in non-EU countries[3]?

No

In case it does, please specify: Which data are collected in non-EU countries?

N/A

Is the research conducted legally in at least one EU Member State[4]?

Yes

4.3.4.3 Data transfer to non-EU countries

Does your task involve a data transfer to non-EU countries[5]?

No

In case it does, please specify which data are transferred to non-EU countries.

N/A

4.3.4.4 Personal data

Does your data collection involve the collection of personal data or data that can be traced back to whom it is about? In case not, the remainder of section 5 can be skipped.

No

4.3.4.5 Personal data: Information provisions and access

Do you comply with the GDPR concerning information provisions and access to personal data (right to be informed, right to access and informed consent[6] for data sharing and long-term preservation included in questionnaires is given by data providers)?

N/A

[3] EU's ethics requirements apply to all EU-funded research, irrespective of where it takes place. Similarly, the GDPR applies to all data-processing operations conducted by data controllers based in the EU, irrespective of where the processing takes place. This means that, even if you are collecting personal data outside the EU, you must still ensure and be able to demonstrate compliance with EU law.
[4] For activities carried out outside the EU, it is not enough for that the activity to be accepted and comply with the legal obligations of a non-EU country; the activities must ALSO be allowed in at least one Member State.
[5] In case personal data is transferred from the EU to an organization located in a non-EU country, then such transfer must comply with Chapter V of the GDPR and must be submitted as a deliverable (https://gdpr-info.eu/chapter-5/)
[6] A template for informed consent can be found on the Website/OwnCloud…

4.3.4.6 Personal data: Rectification and erasure

Do you comply with the GDPR concerning rectification and erasure of personal data (rights to rectification, erasure, restriction of processing, to be notified and data portability)?

N/A

4.3.4.7 Personal data: Right to object and automated individual decision-making

Do you comply with the GDPR concerning right to object and automated individual decision-making?

N/A

4.3.4.8 Personal data: Data controllers and processors

Do you comply with the GDPR responsibilities for data controllers and processors (the controller and the processor have implemented appropriate technical and organizational measures to ensure a level of security appropriate to the risk and keep records of its processing activities)?

See Chapter 4 of CESSDA Guide.

N/A

4.3.5 Other issues

4.3.5.1 Other procedures for data management

Do you make use of other national/funder/sectorial/departmental procedures for data management? If yes, which ones?

See also https://www.cessda.eu/Training/Training-Resources/Library/Data-Management-Expert-Guide/5.-Protect/Processing-personal-data/Diversity-in-data-protection

No

4.3.5.2 Dissemination of research results

Indicate how the 'research results' of the Task are communicated/disseminated to relevant European and global channels such as OpenAIRE, CIARD, GODAN and Big Data Europe.

The datasets resulting from the research will be communicated to some of these platforms. They will also be communicated through scientific publications citing open data sources.

4.4 Dataset catalogue

General	
WP	4
Task	4.2-4
Title dataset	Sensor and meteorology data
DMP version	1.0
Date	2021/05/13
Main contact person	Sergio Álvarez (SER)

Table 45. Sensor and meteorology data

4.4.1 TG Images

General	
WP	4
Task	Pilot 1
Title dataset	TG Images
DMP version	1.0
Date	07/05/2021
Main contact person	Emilio Rodríguez (TER)

Table 46. TG Images

4.4.2 UAV Image products

General	
WP	4
Task	4.2-4
Title dataset	UAV image products
DMP version	1.0
Date	2021/05/13
Main contact person	João Valente (WU)

Table 47. UAV Image products

4.4.3 UVG Images and Telemetry

General	
WP	4
Task	4.2-4
Title dataset	UGV Images and Telemetry
DMP version	1.0
Date	2021/05/13
Main contact person	Angela Ribeiro (CSIC)

Table 48. UVG Images and telemetry

5 Description of robots, devices & platforms

WP4 – Pilot 1 proposes the use of a **fleet of heterogeneous robots (UAVs and UGVs)** that will be used to carry out different agricultural activities on the field [1] [2] combined with the use of **meteorological stations and sensors** installed inside the parcels or in the near around.

Below is a description of the UAVs, UGVs and meteorological stations used by the pilot together with its specifications and technical information of the components and/or hardware used to build them.

5.1 Pilot Implementation Architecture

The high-level design (HLD) explains the proposed architecture for use in the development of Pilot 1. The architecture diagram provides an overview of a complete system, identifying the main components that would be developed for the system and their interfaces.

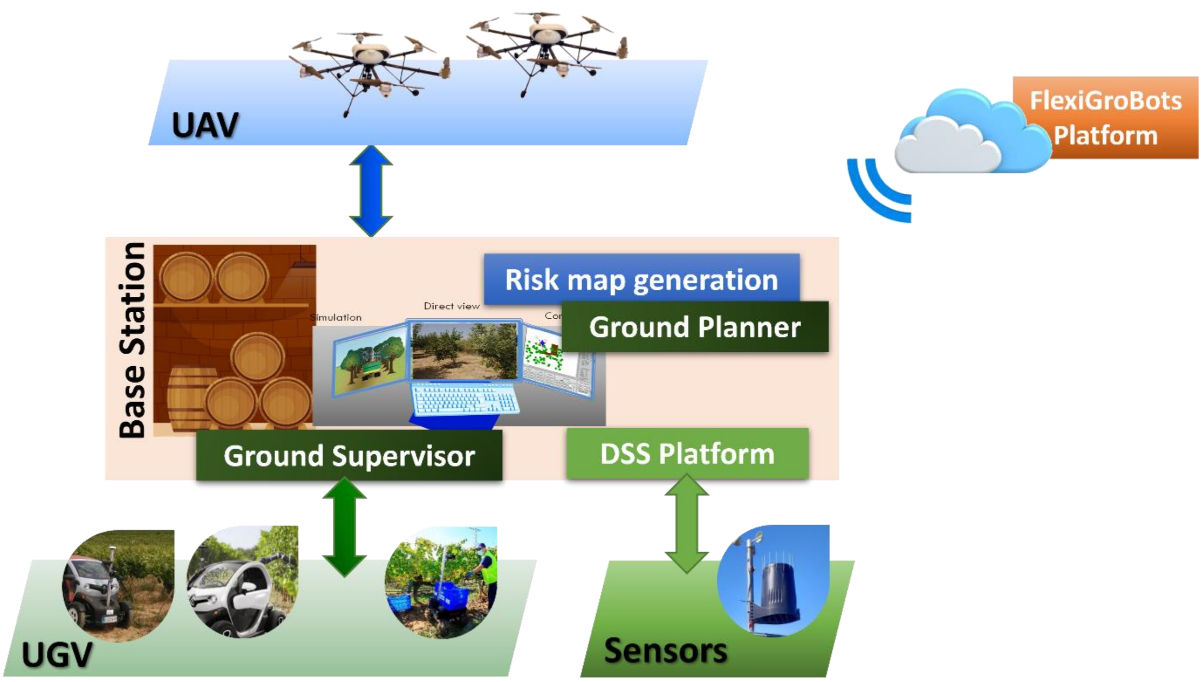


Figure 5 The high-level design (HLD) architecture proposed for Pilot 1: UAV, Ground supervisor, DSS platform, UGV, Sensors, and FlexiGroBots platform.

UAV fleet

A general functioning is developed for the UAV fleet, meaning that it can be applied to any vineyard without major modifications. It consists of a unique sector: the UAV sector. The main control modules on the UAV sector are 1) the Mission planning and 2) the Inspection task. The mission planning will be performed by a certified pilot using the UAV remote controller. The Mission planner oversees generating a flight plan that is subject to some parameters such as the cameras and sensors specifications, geographical information from the field, and mapping requisites. The geographical information about the field will be provided by the farm or winery (in this case Terras Gauda). The fleet should fly safely over the whole parcel of the vineyard which needs to be inspected. The inspection task is responsible for the UAV data acquisition, which will evolve into the detection of Botrytis. The detection stage is developed in Python and runs under Linux operating system. Botrytis detection cannot be performed in real-time since the algorithm takes several hours to run.

UGV fleet

The ground robot fleet is developed to operate in a general way in any vineyard. Ground robotics has different modules distributed in two sectors: a) Base Station sector and b) Robot sector. The base station applications are developed in Python and run under the Windows operating system. In order to achieve a real-time performance, the modules are executed in a computer hosted in the farm or winery (in this case Terras Gauda). At the base station level, we have a planning module (Planner), which is previously executed in the cases of scouting and treatment tasks, and a supervision module (Supervisor), which is executed whenever there is an active mission (scouting, treatment, and harvest assistance). In the robot sector, different control modules are running, able to generate in the robots the autonomous behaviours of scouting, treatment, and harvest assistance. The robot sector modules are developed in Python and run on the ROS operating system [3].

In the Base Station sector, the Planner is in charge of generating the optimal routes [4] for the robots to go through the areas defined by the UAVs. To do so, it uses the information found in the risk map. The Supervisor performs four types of functions: 1) Start-up a mission, 2) Supervise a mission, 3) Generate alarms in case of malfunction and 4) Detect the end of the mission for one or more robots, sending the stop order to the robots.

Each of the above functions can be briefly described as follows:

1) There are two start-up modes: A) start-up for the inspection and treatment missions; and b) start-up for the harvesting assistance mission. In the case of the first type of missions, the robots are sent the assigned routes and the type of mission they must perform. B) In the case of harvest assistance, the robots are sent the identifier of the assigned operator and the starting point (the head of a vineyard line).
2) There are two types of mission supervision: a) in the case of inspection and treatment the supervisor receives the telemetry and status of the robot, making this information available to other modules of the architecture such as the DSS platform or the FlexiGroBots platform. B) In the case of harvesting assistance, it receives the telemetry data of the robot as well as the weight of the box that the robot is transporting. It makes the telemetry information available to other modules of the architecture such as the DSS platform or the FlexiGroBots platform and stores the information about the weight of the box as well as the position. When the weight of the box approaches 20kg, the Supervisor sends a mission start command (operator ID and start-up point) to a

waiting robot with an empty box, i.e., replacement robot. When the replacement robot arrives at the starting point, the Supervisor sends a stop order to the robot with the full box that will navigate autonomously to the winery. It is important to note that the Supervisor, who knows the route and receives the telemetry of the robot, always supervises the navigation of the robots from the winery to the field, and vice versa.

3) The Supervisor generates alarms whenever it determines, from the information it receives, that there is some kind of problem. The alarms are published to reach the operator as soon as possible, both through the DSS platform and the FlexiGroBots platform. In cases where there is an obvious risk, the Supervisor sends a stop command to the robot(s) involved in the problem.
4) The Supervisor in different circumstances, including the end of the mission for one or more robots or a risk situation, generates the stop command.

In the robot sector, different modules are executed whose objective is to generate the different robot's behaviours, such as safe navigation, Botrytis detection, Botrytis treatment and monitoring of an assigned operator, stopping in different situations, risk detection, etc.

DSS platform

DSS platform is the part of the system that offers the information to the final user. It collects information from different sources: robots, meteorological stations, GIS… process it and offers it to the farmer.

It is based on an API REST, which expose the agricultural information, consumed by a web client. At the same time, there is a hub that integrates and collects the information from external sources to allow the platform to process this information and offer a decision support to the farmer.

The next diagram represents how the DSS platform will be deployed, and how the different external agents will interact with it. There are two main external systems, ground robots, and UAVs.

The platform will be deployed into Azure Cloud, within a Kubernetes cluster. This Kubernetes architecture allows the developers to abstract from the infrastructure issues and focus on the development itself. It also allows for automation and scaling of deployments of changes and new versions.

Along with the artefacts that compose the platform, there are other Azure services that supports the operation of this: the PostgreSQL service, the Azure Monitor, the Container Registry, and the Blob storage. Lastly, it is represented the JavaScript Web App, which is basically a representation of the user or the computer who consumes the platform services.

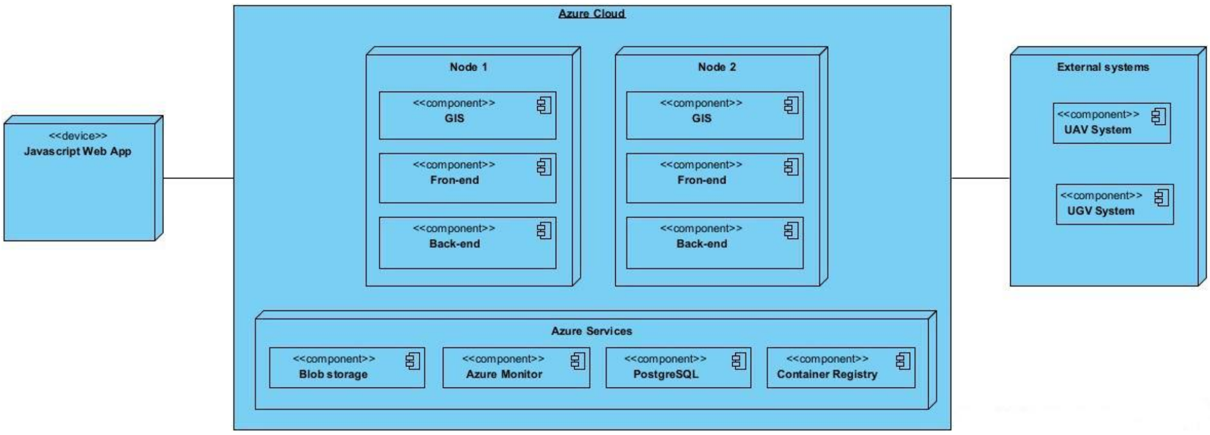


Figure 6 - DSS Deployment Diagram

5.2 Sensors and weather stations specifications

5.2.1 AEMET

AEMET [5] is the National Meteorological Agency of Spain whose objective is the provision of meteorological services that fall within the competence of the State. It was created in 2008 replacing the National Institute of Meteorology and is attached to the Ministry for the Ecological Transition and the Demographic Challenge.

The AEMET observation network has more than 820 meteorological stations distributed throughout the Spanish territory. This observation network is divided into different networks, depending on the characteristics of the sensors of these stations.

For the scope of the WP4 pilot, the data collection will be focused on a specific weather station of the National Surface Observation Network and the automated Ordinary Climatological Network, "O Rosal" station:

O Rosal:

- Latitude: 41.9438889 WGS84 (EPSG:4326).
- Longitude: -8.8475 WGS84 (EPSG:4326).
- Altitude: 55 m.
- Data collection period: 1 hour.

AEMET does not facilitate on the web information about components and sensors used in the stations. The available measurements for the station are:

- Temperature (ºC).
- Wind speed (km/h).
- Wind direction.
- Gust (Km/h).
- Gust direction.
- Precipitation (mm).
- Pressure (hPa).

- Pressure tendency (hPa).
- Humidity (%).

5.2.2 MeteoGalicia

MeteoGalicia [6], also known as the Galician Meteorological Observation and Prediction Unit, is an organism created in 2000 as the result of an agreement between the University of Santiago de Compostela and the Xunta of Galicia. Its main objectives are to carry out a meteorological forecast of Galicia as well as the operation and maintenance of the meteorological and climatological observation network of the Xunta of Galicia:

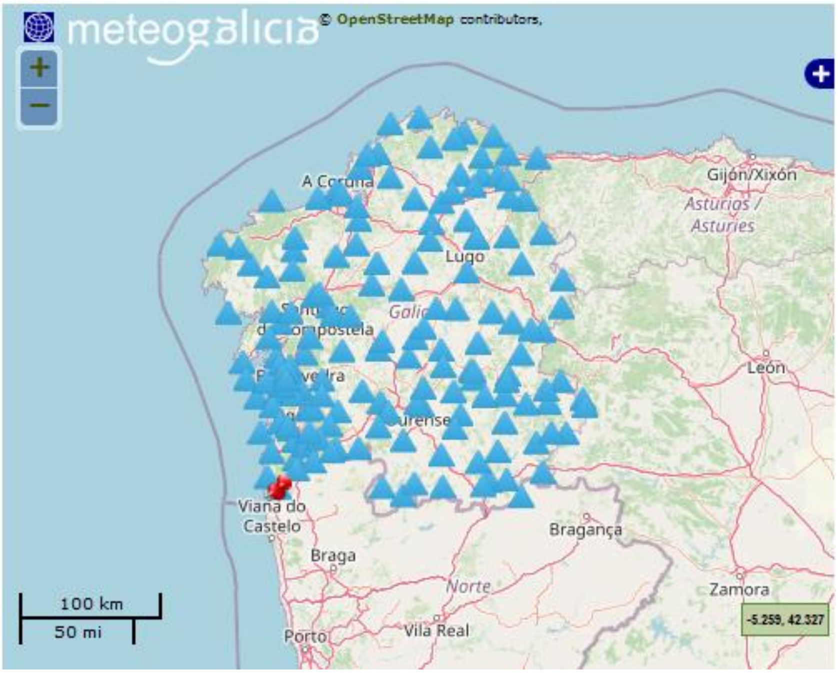


Figure 7. Meteorological and climatological observation network of the Xunta of Galicia

For the scope of the WP4 pilot, the data collection will be focused on a specific weather station installed very close to Terras Gauda vineyard (between the plots), "As Eiras" station:

As Eiras

- Latitude: 41.938732 WGS84 (EPSG:4326).
- Longitude: -8.789739 WGS84 (EPSG:4326).
- Altitude: 47 m.
- Data collection period: 10 minutes.

Figure 8. Weather station

5.2.2.1 Weather station components

Meteogalicia publishes on its website information about the components and devices installed in each one of its meteorological stations. Below is a list of the components used in the aforementioned "As Eiras" meteorological station of interest for the pilot:

5.2.2.1.1 Anemometer-Vane

MANUFACTURER: R. M. Young

MODEL: 05106-5 MA

SPECIFICATIONS:

- Wind speed, uncertainty: ± 0.3 m/s
- Wind direction, uncertainty: ±3 º

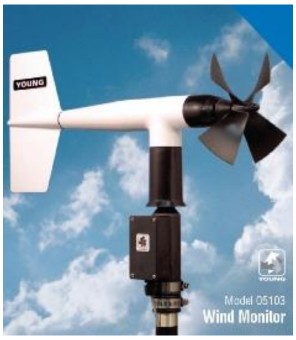


Figure 9. Anemometer-Vane

5.2.2.1.2 Pressure probe

MANUFACTURER: Vaisala
MODEL: PTB110
SPECIFICATIONS:

- Atmospheric pressure, uncertainty: ±0.3 hPa at +20°C

Figure 10. Pressure probe

5.2.2.1.3 Temperature and Humidity probe

MANUFACTURER: Vaisala
MODEL: HMP155
SPECIFICATIONS:

- Air temperature, uncertainty: ± 0.25 ºC
- Relative humidity, uncertainty: ± 1.8 %

Figure 11. Temperature and humidity probe

5.2.2.1.4 Pyranometer

MANUFACTURER: Kipp&Zonen
MODEL: CMP-3
SPECIFICATIONS:

- Global solar radiation

Figure 12. Pyranometer

5.2.2.1.5 Surface/soil temperature probe

MANUFACTURER: Campbell
MODEL: T-107
SPECIFICATIONS:

- Surface temperature

Figure 13. Surface/soil temperature probe

5.2.2.1.6 Pluviometer

MANUFACTURER: Campbell
MODEL: ARG100

Figure 14. Pluviometer

5.2.2.1.7 Leaf wetness sensor

MANUFACTURER: Campbell
MODEL: 237

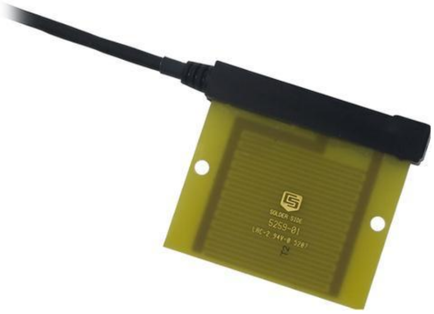


Figure 15. Leaf wetness sensor

5.2.2.1.8 Datalogger

MANUFACTURER: Campbell
MODEL: CR1000

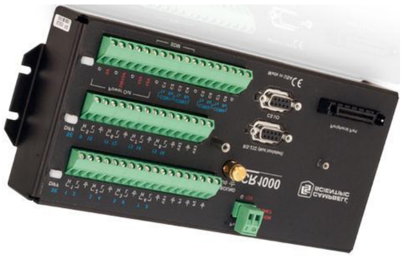


Figure 16. Datalogger

5.2.2.1.9 Soil humidity probe

MANUFACTURER: Campbell
MODEL: CS616

Figure 17. Soil humidity probe

5.2.2.1.10 Night sky brightness sensor

MANUFACTURER: knightware
MODEL: SQM-LR

Figure 18. Night sky brightness sensor

5.2.3 Envira

The WP4 – Pilot will use several motes and weather stations designed and developed by Envira Sostenible [7]:

Figure 19. Weather station designed by Envira Sostenible

The nanoenvi mote is a self-contained system for the capture, processing, and communication of agroclimatic parameters like leaf wetness, leaf temperature, soil temperature and ambient temperature and humidity.

The system is solar-powered and has an internal battery with a 6600 mAh capacity.

To reduce power requirements, the microprocessor is in sleep mode and wake up after a configurable period to take a measurement. If the communication is not possible, the data is stored locally to be transmitted in the next communication.

Communications are made with a M2M modem (3G) using JSON files.

5.2.3.1 Specifications

Microcontroller	XMEGA256
Frequency	2-32 MHz
SRAM	16 KB
EEPROM	4 KB
FLASH	16 MB
Clock	RTC (32 KHz)
Nº of sockets for probes	6
Protection	IP66 EN 60529
Impact resistance	ISO 2039-1
Ambient temperature (min.)	-10 ° C
Ambient temperature (max.)	50 ° C
Approx. Weight	350 g

5.2.3.2 Weather station components

Envira facilitates information about some of the components and sensors installed in each one of its meteorological stations. Below is a list of some of the components that are being used in Terras Gauda's available Envira stations of interest for the pilot:

5.2.3.2.1 LEAF WETNESS SENSOR

Measurement Speed: 10 ms

Sensor Type: Frequency domain

Output: 320 - 1000 mV @ 3 V excitation

Operating Environment: -40 ºC to 60 ºC

Power: 2.5 VDC @ 2 mA, to 5 VDC @ 7 rnA

Sensor Dimensions: 11.2 cm x 5.8 cm x .075 cm

Figure 20. Leaf wetness sensor

5.2.3.2.2 TEMPERATURE SENSORS (AIR & LEAF)

Resolution: 0.01 ºC

Accuracy: 0.3 ºC

Repeatability: 0.1 ºC

Operating range: -40 to 123.8 ºC

Response Time: 5 to 30 seconds

Long term drift: <0.04 OC/y

5.2.3.2.3 RELATIVE HUMIDITY SENSORS (AIR & LEAF)

Resolution: 0.05 %RH

Accuracy:1.8

Repeatability: 0.1 %RH

Non linearity: +

Operating range: 0 to 100 %RH

Response Time: 5 to 30 seconds

Long term drift: <0.5 %RH/y

Figure 21. Relative humidity sensor

5.2.3.2.4 SOIL TEMPERATURE SENSOR

Power consumption: < 3mA

Supply Voltage: 3.6V to 20 VDC.

Power on to Output stable: 2 seconds

Output Impedance: 10K ohms

Operational Temperature: -40 ºC to 85 ºC

Accuracy: 5 ºC

Resolution: 0.1250C

Output Voltage Range: 0V to 3V linear to temperature

Figure 22. Soil temperature sensor

5.2.3.2.5 MODEM

Manufacturer: Quectel

Model: M95

5.2.3.2.6 PLUVIOMETER

Manufacturer: Davis instruments

Model: 7852M/7857M

Figure 23. Pluviometer

5.3 Aerial fleet

5.3.1 DJI Matrice 210 RTK

Figure 24. DJI Matrice 210 RTK [8]

- Specifications:
  - Dimensions (unfolded), 887×880×408 mm
  - Weight, approx. 4.8 kg
  - Max. angular velocity, Pitch: 300°/s, Yaw: 150°/s
  - Max ascends speed, 5m/s
  - Max descendent, 3 m/s
  - Max wind resistance, 12 m/s
  - Max flight time, 24 min (with payload)
  - Operating temperature (-20° to 45° C)

- Features:
  - Gimbal

- Infrared obstacles detection, sensing range (0-5m)
- Remote controller (2.4GHz)
- Drive mode, flight planning/manual

Figure 25. Gimbal

- Sensors:
  - Multispectral camera – Micasense Rededge [9]
    - Spectral, Blue, Green, Red, Red Edge, Near Infrared
    - Bands EO, (NIR)
    - Wavelengths
      - Blue (475 nm centre, 20 nm bandwidth)
      - Green (560 nm centre, 20 nm bandwidth)
      - Red (668 nm centre, 10 nm bandwidth)
      - Red Edge (717 nm centre, 10 nm bandwidth)
      - Near-IR (840 nm centre, 40 nm bandwidth)
    - Sensor resolution, 1280 x 960 (1.2 MP per EO band)
    - GSD, 8 cm/pixel (per EO band) at 120 m AGL
    - Frames/second, 1 fps (all bands 12-bit, RAW/TIFF)
    - Focal length, 5.5 mm
    - Field of view, 47.2°

Figure 26. Multispectral camera - Micasense Rededge

5.3.2 DJI Matrice 300 RTK

Figure 27. DJI Matrice 300 RTK [8]

- Specifications:
  - Dimensions (unfolded), 810×670×430 mm
  - Weight, approx. 5 kg
  - Max. angular velocity, Pitch: 300°/s, Yaw: 100°/s
  - Max ascends speed, 6m/s
  - Max descendent, 5 m/s
  - Max wind resistance, 15 m/s
  - Max flight time, 55 min (with payload)
  - Operating temperature (-20° to 50° C)

- Features:
  - Gimbal
  - Infrared obstacles detection, sensing range (0.1-8m)
  - Remote controller (2.4GHz)
  - Drive mode, flight planning/manual
- Sensor:
  - RGB and LiDAR camera – DJI Zenmuse L1 [8]
    - RGB
      - Photo size: 5472x3078 (16:9); 4864x3648 (4:3); 5472x3648 (3:2)
      - Focal length, 24 mm
      - Video resolution H.264, 4K: 3840x2160 30p
    - LiDAR
      - Lidar ranging accuracy 3cm @ 100 m
      - Maximum returns supported: 3

Figure 28. RGB and LiDAR camera - DJI Zenmuse L1

5.3.2.3 Receptor Trimble R2 GNSS + Controller TSC3

- Specifications:
  - Range of frequencies: L1/L2
  - Coverage: range of operation in the constellations GPS, GLONASS, Galileo and Beidou
  - Precision in RTK fixed:
    - Horizontal 10 mm + 1 ppm RMS
    - Vertical 20 mm + 1 ppm RMS

Figure 29. Receptor trimble R2 GNSS + Controller TSC3

5.4 Ground fleet

5.4.1 Inspection and treatment robots

Ground Autonomous Platform based in a Renault Twizy (Urban 80 model) [10]

- Platform Features:
  - Electric vehicle.
  - Zero-emissions.
  - Dimensions: 2,338 m length, 1,234 m width, 1,454 m height.
  - Motor torque: 57 Nm.
  - Maximum motor power: 13 kW (17cv).
  - No vibrations.
  - Easier to control than a combustion engine.
  - Very low speeds (< 1 km/h).
  - 80 km after a 3.5 hour charge.

Figure 30. Renault Twizy

- Integrated devices for vehicle automation:
  - 3 Nucleo-F446RE boards (STMicroelectronics).
  - Steering column with power steering (Ref. 6700000301).
  - Steering wheel angle sensor (LWS – Bosch).
  - Servo High-Voltage-Brushless HBS 880 BB MG (Graupner).
  - Communication protocol: ISOBUS [11].
  - Off-road wheels.

- Sensors
  - Digital single-lens reflex camera (Canon EOS 7D).
    - 18MP - APS-C CMOS Sensor.
    - ISO 100 – 6400 (expands to 12800).
    - Dimension: 148 x 111 x 74 mm.
    - Weight: 860g.
    - Weather sealed body.
    - Resolution: 2584x1938 pixels.
    - 2 frames/s.

Figure 31. Canon EOS 7D

Figure 32. Photograph taken with a reflex camera

  - RGB-D Camera (Kinect v2 - Microsoft)
    - Dimensions: 66 x 249 x 67 mm.
    - Weight: 1.4 kg.
    - Colour: 1920×1080 pixels.
    - Depth: 512×424 pixels.
    - 30 frames/s.
    - TOF => Outdoors.

Figure 33. Kinect v2 - Microsoft

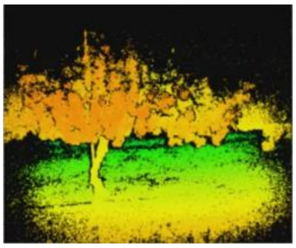


Figure 34. Photograph taken with an RGB-D camera

  - RTK-GPS receiver (Hemisphere R220 or similar)
    - RTK correction (error < 2 cm).
    - 10 Hz.

- Processor and OS
  - Nvidia Jetson Nano
    - GPU: 128-core Maxwell.
    - CPU: Quad-core ARM A57 @ 1.43 GHz.
    - Memory: 4 GB 64-bit LPDDR4 25.6 GB/s.
    - Dimensions: 85 x 110 x 39 mm.
  - On-board computer
    - Intel Core i7-4771@3.5GHz.
    - 16GB RAM.
    - NVIDIA GeForce GTX 660.
  - Operating system: ROS on Linux
- Treatment equipment: TBA.

5.4.2 Harvesting assistance robots

- Ground autonomous platform based in a RB-VOGUI by Robotnik [12]
  - Dimensions: 1.040 x 650 x 530 mm.
  - Weight: 165 Kg.
  - Speed: 2.5 m/s.
  - Environment: Indoor/Outdoor.
  - Autonomy: Up to 8h.
  - Batteries: LiFePO4 30Ah@48V.
  - Traction motors: 4 x 500 W.
  - Swerve motors: 2 x 100 W Ackermann/4 x 100 W OMNI 4.
  - Temperature range: -10°C a +45°C.
  - Payload: Up to 150 Kg.
  - Maximum slope: 47%.

Figure 35. RB-VOGUI

- Sensors
  - RGB-D Camera (Kinect v2 - Microsoft)
    - Colour: 1920×1080 pixels.
    - Depth: 512×424 pixels.
    - 30 frames/s.
    - TOF => Outdoors.
  - RTK-GPS receiver (Hemisphere R220 or similar)
    - RTK correction (error < 2 cm).
    - 10 Hz.
  - Other sensors: TBA
- Control
  - Controller: Open architecture ROS/PC with Linux integrated.
  - Communication: Wi-Fi 802.11n.
  - Connectivity: Internal: USB, RS232, RJ45 / External: 2x USB, 2x RJ45, 1X HDMI + USD, 5, 12 VDC and 48v power supplies.

5.5 Detailed planning

The high-level planning for the pilot components is detailed in D2.7. Detailed planning of the tasks carried out during the first steps of design, integration and testing of robots, devices and platforms is included in Robots, devices & platforms. Detailed planning of this document.

6 Conclusions

WP4 partners have been actively working in the development of Pilot 1 in terms of analysis, objectives definition, requirements gathering, and design as specified for task 4.1.

Functional and non-functional requirements had been identified and established, together with the identification of technical limitations and solutions to implement the desired functionalities of Pilot 1. All this work has been used to create a high-level definition of use cases for the pilot, and the identification of datasets that are expected to be generated and used during the development of the pilot. In addition, initial work on the development and deployment of some pilot needed components have been started. As the different platform components have been identified and designed, the platform architecture has been refined. The state-of-the-art technologies used have made it possible to build or at least plan an orchestrated system of artefacts that will be able to meet the needs of the project.

Integrating the information from the different datasets so that it can be correctly consulted and exploited by the farmer is the main task to be tackled in the following months, as far as the development of the software platform is concerned. New needs and opportunities will surely arise during this work, which will be exploited for the optimization of the system.

As part of the in-field test, in September 2021, all the partners from Pilot 1 met in the vineyard. During this meeting, aerial and ground data collection was performed by robots and UAVs to generate information to feed and train the different detection algorithms. Until now, many datasets have been collected and the pre-processing of them has started. The upcoming steps are to analyse the data and train algorithms for Botrytis detection.

Regarding the trial to support the grape pickers, it can be said that in the first trial carried out during the current harvest, the results have been positive, at least in the coexistence of the ground robot and the grape picker. The robot at no time hindered the work of collecting the grapes, making it easier for the grape picker to place the bunches in the case without having to bend down and without having to load the box to move it between the vines, which demonstrated, in this first test, that the grape harvester can focus exclusively on cutting the bunches, in addition to making his work less hard, which can mean an improvement not only in his attitude towards this work, but also in the speed of the grape harvest In parallel to the development of the ground robots test and drone flights, dissemination activities were performed through interviews with members of the different partners, which have subsequently been published in local and national media, both in the press and on television and online sites.

To sum up, WP4 partners have managed to successfully achieve objectives and milestones established for the development of Task 4.1.

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[14]FlexiGroBots D2.7 Pilot alignment and joint assessment report

Annexes

The following annexes are presented below for reference. Please be aware that the content of these annexes is subject to change during the project lifetime.

1 Robots, devices & platforms. Detailed planning

Below is the initial planning (from M1: January 2021 to M12: December 2021) for the requirements specification of the pilot, both functional and non-functional, for all components, not only software components but also hardware components such as UGV and UAV. The architecture of the solution and the design of all the components that will be developed for the system is also part of the objectives of task 4.1, in addition to the specification of data sets to be generated, necessary hardware and device specifications.

WP	WP/Tasks	Leader	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12
WP4	**Pilot 1 setup and assessment**	**SER**												
T4.1	Pilot objectives, methodology, requirements and design	SER												
T4.2	Development of demonstrator-specific components	CSIC												
T4.3	Demonstrator integration, testing and deployment	SER												
T4.4	Pilot assessment	SER												
			MS1				**MS2**							**MS3**
	Milestones	**Number**												
	Project kick-off, start of activities	**MS1**	M1											
	Initial platform release	**MS2**					M5							
	Release of demostrator components	**MS3**												M12

Figure 36. Gantt diagram M1-M12

1.1 Initial design

To design a system capable of managing the work of different robots and coordinating information between them, the work to be carried out in the framework of the pilot will focus on three main elements.

1.1.1 Aerial fleet

The first element is the aerial fleet, which will acquire imagery to detect Botrytis and send the coordinates of the potential areas to the ground robots. Figure 37 and Figure 3838 represents how the workflow of the data acquisition is distributed, together with a visual representation of how it would look in the field.

Figure 37. Representation of the process that ranges from data acquisition (from both UAV and UGV), to the detection of Botrytis and the consequent communication to the farmer

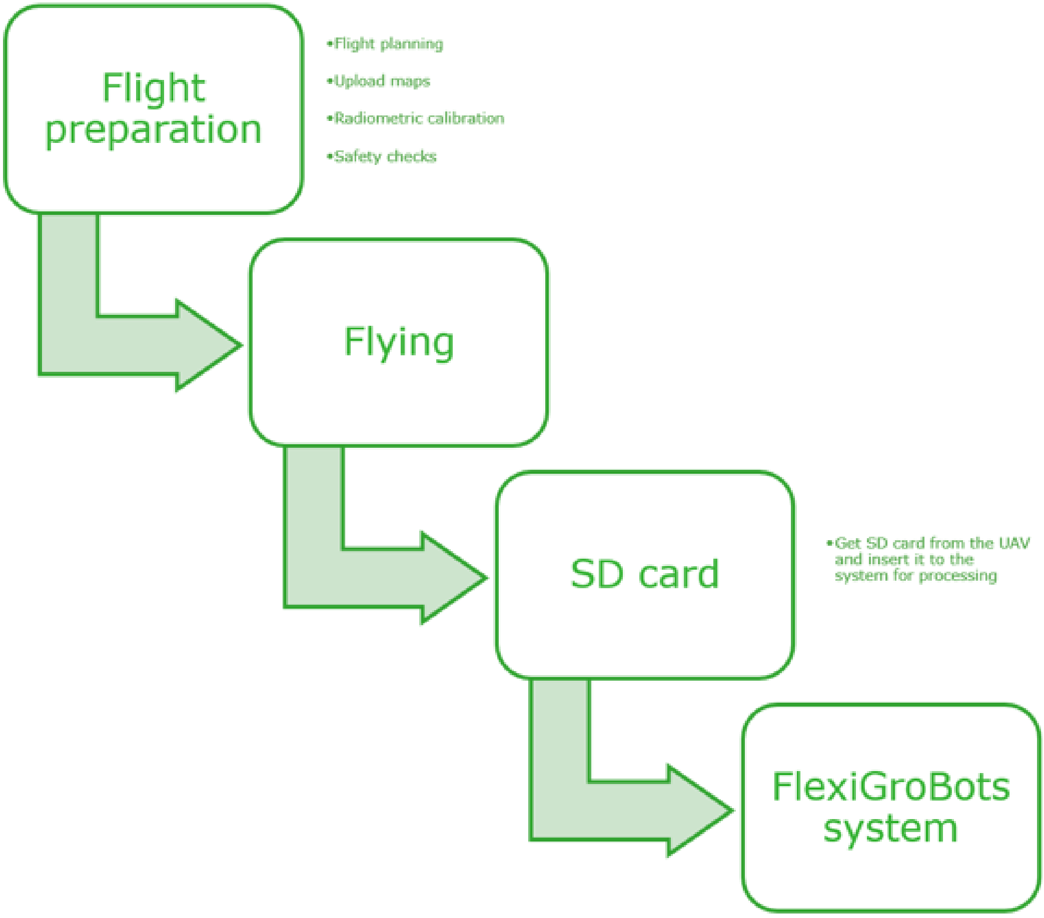

Figure 38. Flowchart of the aerial imagery acquisition from prior to the flight execution to the extraction of data from the UAV to the DSS Platform

1.1.2 Ground fleet

1.1.2.1 Autonomous inspection robot

In order to achieve the autonomous navigation of the platform, a previous stage is necessary: the automation of the vehicle. To get this, different actions on the vehicle were required (Figure 3939 and Figure 40), always taking into account that the manual driving mode of the vehicle wanted to be kept.

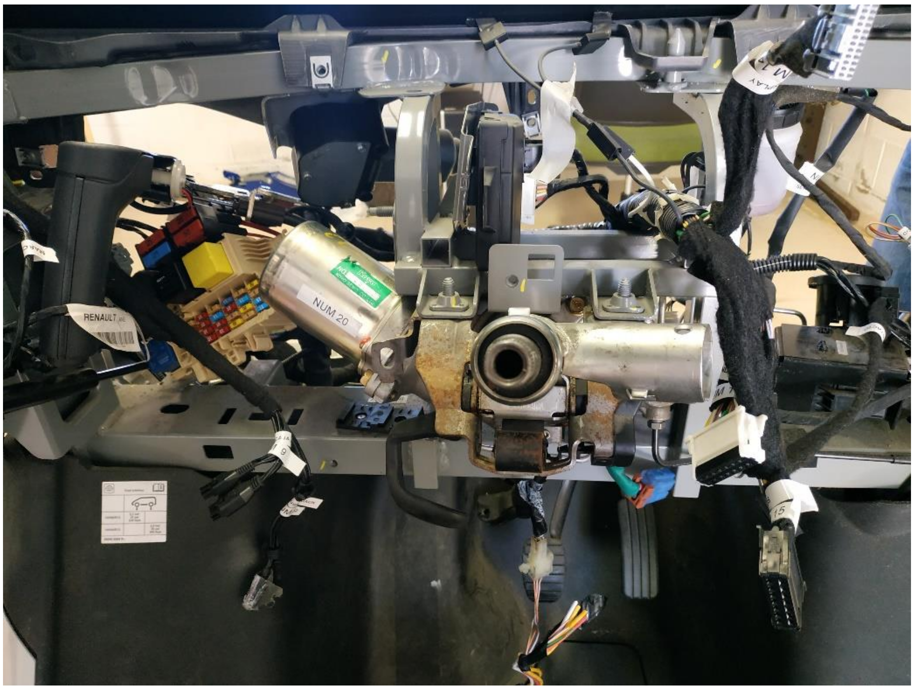

Figure 39. Image of some of the actions on the vehicle for its automation (a)

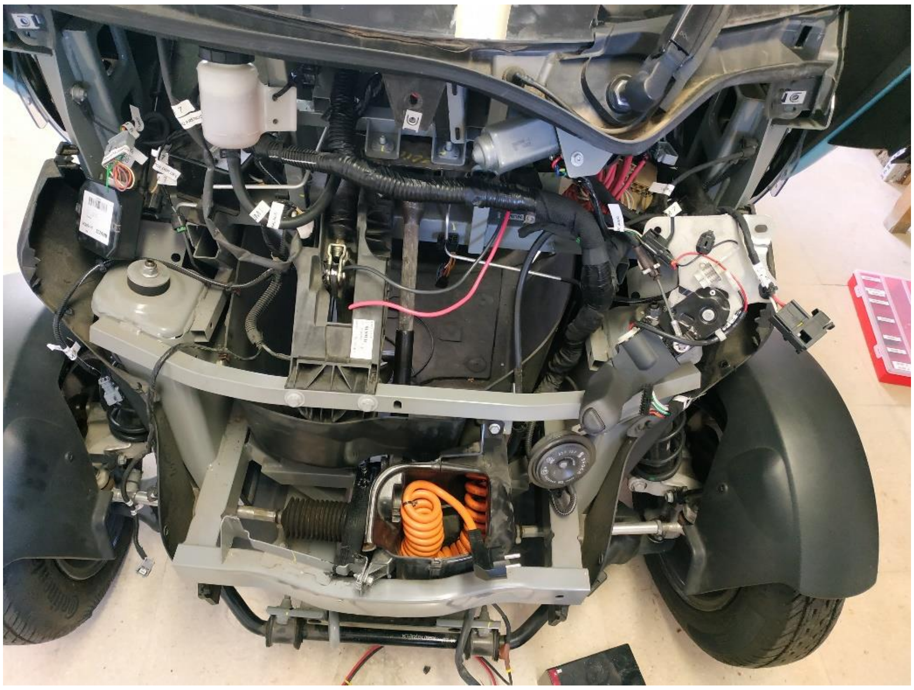

Figure 40. Image of some of the actions on the vehicle for its automation (b)

Renault Twizy does not have any power steering system, so it was decided to replace the steering column with one that had this system. Thus, after the replacement, when turning the direction of the vehicle is required, a microcontroller sends the proper signals to the power steering system, turning the steering column to the desired vehicle orientation.

The throttle pedal on Renault Twizy works generating signals proportional to the pressure applied on it to its own internal controller. Taking advantage of this operating mode, equivalent signals are produced by a microcontroller, and connected to this internal controller, simulating that the throttle pedal has been pressed, and therefore, changing the vehicle speed.

Unlike the throttle pedal, the braking pedal on Renault Twizy is mechanical, not digital, for security reasons, so it required an actuator element to press the brake pedal. The actuation over this pedal is only necessary for emergency cases that need sudden braking, i.e., detection of an obstacle in the way of the vehicle; for conventional navigation, in which the vehicle moves slowly, it can be decelerated to a smooth stop by simply ceasing to act on the throttle.

An on-board computer running on ROS (Robot Operating System) sends the necessary commands to the microcontrollers in order to control all aforementioned systems.

1.1.2.2 Harvest assistance robot

Operator detection system

The detection of the operator is carried out by localisation of a fluorescent yellow reflective vest in RGB images together with depth images. Both RGB and depth images are obtained by the RGB-D device mounted on the robot. The detection of the reflective vest is carried out by means of a colour segmentation in the RGB image previously adjusted to the colours present in the reflective vest.

Once the vest is located in the image, the depth image is searched in the same region to obtain the distance from the camera to the reflective vest and, therefore, the distance from the robot to the operator.

The development of the operator detection was carried out using Python and ROS.

Figure 41. Operator detection system (RGB-D images)

Keep distance from the operator system

Once the distance from the robot to the operator is known, tracking must be carried out. To do this, the robot must change its linear velocity as well as its angular velocity in order to stay at a given distance.

The linear velocity is controlled according to the distance of the operator. If the operator is more than 1.2m away from the camera, the robot will move forward until it reaches a distance of 1.2m or less. As soon as the robot is below the set distance, it will remain completely stationary until the target is further than 1.2m away again.

The angular velocity is controlled according to the position of the operator in the image. If the operator is in the centre of the image, the angular velocity will be zero. If the operator is at the sides of the image, the robot will modify its angular velocity until the operator is back in the centre of the image.

The control of the linear speed and the angular speed is carried out simultaneously.

The development of the robot control was carried out using Python and ROS.

1.1.3 DSS Platform

The architecture of the platform must allow the user to track the fleet of ground robots and aerial UAVs. To do this, a web architecture design has been carried out, based on a Kubernetes cluster, hosted in the Azure cloud. This technology allows us to abstract from the configuration of the machines and servers necessary for the operation of the system and focuses on the modularisation and programming of the appropriate solution.

Within the Kubernetes universe, there are concepts such as nodes, PODs, or containers, which are used to define the granularity of these components within the architecture. The Kubernetes philosophy is that the system itself manages the creation, replication, or elimination of these resources, depending on its usage needs and following certain premises or instructions defined by the programmer.

Below is an outline of the system's architecture, where we can distinguish three large groups of components:

- The web client, also called the user interface. It is the window to the system, a web page that allows users to interact with the application.
- Azure Cloud. The Azure cloud, where the Kubernetes cluster is hosted, as well as other services such as the database server, or support services for the cluster, such as a monitoring service or an image storage service for the containers.
- External systems. In this case we refer to ground robots and UAVs, which will send their telemetry to the cluster, in charge of processing this data.

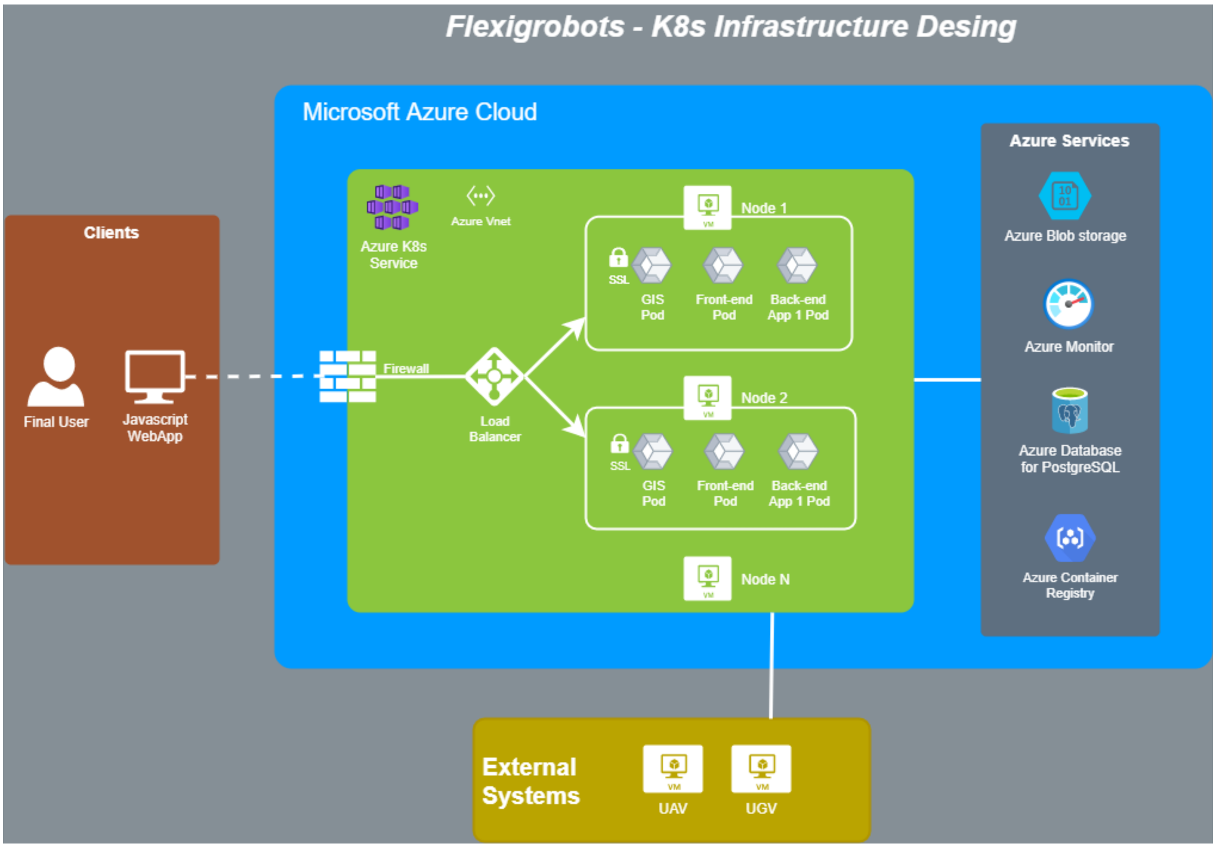

Figure 42. K8s Infrastructure design

1.1.4 FlexiGroBots Platform requirements identified

In addition, the following interactions or needs regarding the global FlexiGroBots platform should be considered:

AI Platform

The Artificial Intelligence platform must have a workspace with Python. The working environment will be used to develop the algorithms and processes required when detecting Botrytis disease in vineyards. The algorithms will be executed when making use of the Botrytis detection services.

Common data enablers

Azure cloud will be used to deploy the pilot components leveraging available services. Some of the services that will be used are virtual machines, storage accounts and messaging brokers among others.

The data will be stored in a PostgreSQL database and PostGIS will be used to store relational data and vector spatial information related to the farms and their fields, as well as any other type of information.

In addition, the IDSA (*International Data Spaces Association*) connector will be used, whose objective is to allow data sharing, governance of the stored information and guarantee a secure data exchange.

Geospatial services

OGC (*Open Geospatial Consortium*) services and data interfaces will allow us to access geographic information in order to obtain and store detailed and accurate data. Geospatial services will provide us with precise information about the fields, such as the geometry of the areas (using UTM coordinates), distance between rows and plants in the crops, etc. They will also provide us with raster information associated with the fields, obtained through satellites, UAV's (*Unmanned Aerial Vehicles*), robots or other mechanisms to obtain raster data. These services will provide us with UAV imagery, ground control points (e.g., geo-referenced coordinates), ground truth data (e.g., geo-referenced coordinates with field observations of the disease), shapefiles, etc.

In addition, they will provide us with the ability to perform geospatial queries ("near", "geometries intersection", etc.).

A geospatial processing module will be included to process RGB and multispectral images to generate an orthophoto automatically. An orthophoto is a high-resolution image of the terrain that has been transformed into an orthogonal projection without perspective effects, which will allow us to make accurate measurements of the terrain. This module will generate the orthophoto by means of a set of images applying photogrammetry techniques.

Mission Control Centre

The mission control centre will be composed of the mission planner, mission supervisor, fault recovery module, alarm notification manager and adaptive mission planning.

The mission planner shall consist of strategies that plan the execution of an agricultural task or mission. The mission supervisor will be in charge of monitoring the individual and collective behaviour of the robots. It will also have to monitor the equipment used during a task or mission. The fault recovery module will have to detect faults and generate fault recovery plans. The alarm notification manager will notify of the faults detected in the previous module.

1.2 Pilot field tests

In mid-September, during this season's harvest period, the first field tests were carried out in the Terras Gauda vineyards.

It has been possible to develop data acquisition tasks by performing different drone flights with different types of cameras and at different angles of inclination. More than 200 points on the ground have been taken with exact GPS markers that indicate different problems in the vineyard, not only botrytis, but also downy mildew, tinder, and horse bites (in the area there are wild horses, which access the plots and bite the clusters of ripe grapes because they are sweet).

In this way, datasets of information have been obtained to work for months on the correlation between different layers and points of affectation.

The first tests have also been carried out to support the harvest working together with real grape pickers. The tests have been a success because the robots did not disturb or put the worker at risk and they achieved to follow him perfectly, thanks to the visual identification of the vest.

1.2.1 Scope

The Terras Gauda vineyard, located in the northwest of Spain, in Galicia and within the D.O. Rías Baixas, is planted with three grape varieties: Albariño, Loureiro and Caiño blanco, varieties perfectly adapted to the soil and climate of the region.

For the Pilot 1 trials we have selected two parts of two differentiated plots.

The plot chosen for the early disease detection test, specifically the disease caused by the Botrytis Cinerea fungus, is made up of three vine rows, each approximately 130 m long, to enable efficient drone flights to locate the disease in the bunches, as well as the subsequent verification work of the ground robots.

For this, we have chosen the Loureiro grape variety, the one with the thinnest skin and therefore the most sensitive to this fungus.

The plot has hardly any slope. It is found in sandy loam soil formed by schist and due to the trellis system, a large part of the bunches are exposed and visible. The separation between the vine rows is approximately 3 m and between plants, 2.5 m

On the other hand, the plot selected for the test to support the grape pickers using ground robots is made up of rows of vines of about 150 m in length. With this type of row, we can have a reliable vision of the support work that robots can carry out during the harvest, in a plot with representative characteristics of the Terras Gauda vineyard.

In the same way as the plot to test the detection of Botrytis, it has gentle slopes and the trellis system is similar.

The main difference is that in this case, the grape variety chosen is the Albariño, the majority in our vineyard.

1.2.2 Harvest assistance robot

Tests were carried out on 16th September 2021 to evaluate both the behaviour of the robot and the response of the operator in charge of the harvest.

Two lines of the vineyard were selected by Terras Gauda staff to carry out the tests, as well as two operators to carry out the harvest. One of the operators was given the vest so that he would be the target of the robot's tracking.

The instructions given to the operator were to carry out his tasks as normally as possible by depositing the grapes in the case transported by the robot. In the pictures you can see the development of the test.

The robot tracked the operator during the entire test, maintaining the distance configured for the task, thus fulfilling the objectives regarding the behaviour of the robot with the operator. The operator started the test by trying to adapt to the robot. Later, when she realised that the robot was responding appropriately, she started to perform his tasks in a more natural way. Seeing that she could harvest in a completely normal way without carrying the box, the operator was very satisfied with the task performed by the robot. By not having to carry the box, the speed at which the operator harvested the grapes seemed to increase, but this data is pending further tests to prove it.

Figure 43: Worker harvesting with the robot.

1.2.3 Acquisition of preliminary Botrytis detection dataset

Image acquisition tasks have been carried out from the mobile platform to generate a preliminary set of data that allows working on Botrytis detection algorithms.

The images were taken in vineyards owned by Bodegas Terras Gauda on September 16th, 2021. Specifically, in two rows of these vineyards (Row 1: from 41º57'16.4402''N, 8º47'42.4669''W to 41º57'20.0903''N, 8º47'39.9467''W; Row2: from 41º57'16.4115''N, 8º47'42.3051''W to 41º57'20.0685''N, 8º47'39.7967''W), as it can be seen in Figure 44.

Figure 44. The red rectangle contains the rows of vineyards sampled during the tests

The camera used was a digital single-lens reflex camera, Canon EOS 7D. The camera was placed on-board a wheeled robot, on a support at 90 cm height Figure 4545. The robot was teleoperated to move at a distance of 1.5 m from the vineyards, trying to simulate the conditions when the camera is on-board the ground inspection platform. Images were automatically taken at a speed of almost 1 fps, during the movement of the robot at very low speed (0.5 km/h). The weather conditions when the images were collected were sunny, but the sun was not at its zenith, so some images were collected at backlight.

Figure 45. Localization of the camera and the robot during the tests

1007 images were collected, with a resolution of 3456x2304 pixels. An example of one of them can be seen in Figure 4646.

Figure 46. Image collected by the camera during the tests

1.2.4 UAV flights

Several flights were performed on September 16th, 2021 on the fields of Terras Gauda (41°57’18’’ N, 8°47’41’’ W). The flights that were executed with the UAV DJI Matrice 210 RTK carried the RedEdge Micasense camera. There were four flights at 30 meters with different angles (nadir or 0°, 30° and 45°). The nadir flight was repeated because the weather conditions were not the most appropriate for the first attempt.

Regarding the second UAV technology, DJI Matrice 300 RTK was flown while carrying the DJI Zenmuse L1 camera. This technology acquires images, video and pointclouds simultaneously. This drone was flown with four different specifications: 50 m height, 30 m height during a sunny moment, 30 m height at sunset, and a static flight with manual mode.

All flights were planned to be executed with the best weather conditions, as it can be seen in Figure 47.

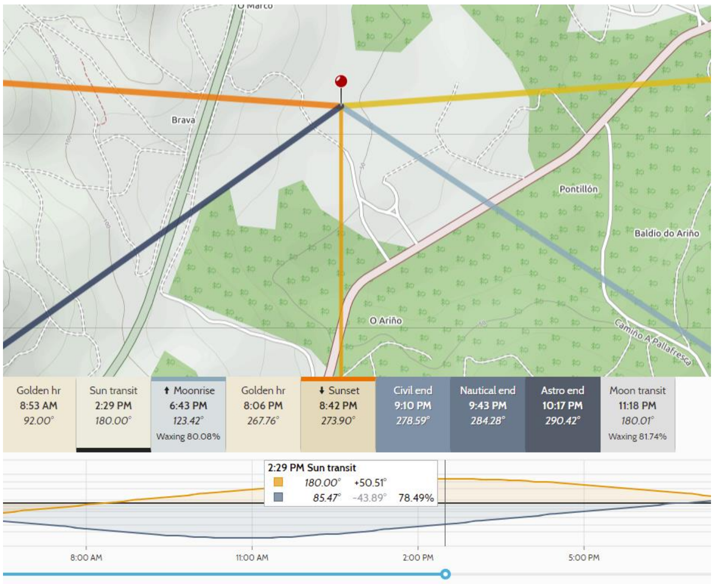

Figure 47. Flight planification to fly when the best atmospheric conditions are present.

To acquire the ground truth data, the receptor Trimble R2 + Controller TSC3 were needed. A total of 214 ground truth points were collected. The categorization of the data was done visually. Most of the points were identified as *Botrytis* or *Mildew*, but there are other categories such as bite or foliar problem.

1.3 Next steps

The WP4 workflow is orchestrated around 4 Tasks, as indicated in the following table:

WP	WP/Tasks	Leader	M13	M14	M15	M16	M17	M18	M19	M20	M21	M22	M23	M24
WP4	**Pilot 1 setup and assessment**	**SER**												
T4.1	Pilot objectives, methodology, requirements and design	SER												
T4.2	Development of demonstrator-specific components	CSIC												
T4.3	Demonstrator integration, testing and deployment	SER												
T4.4	Pilot assessment	SER												

Milestones	Number	
Mid-project platform release	**MS4**	M18
Release of demonstrator subsystems	**MS5**	M24

Figure 48. Gantt diagram M13-M24

WP	WP/Tasks	Leader	M25	M26	M27	M28	M29	M30	M31	M32	M33	M34	M35	M36
WP4	**Pilot 1 setup and assessment**	**SER**												
T4.1	Pilot objectives, methodology, requirements and design	SER												
T4.2	Development of demonstrator-specific components	CSIC												
T4.3	Demonstrator integration, testing and deployment	SER												
T4.4	Pilot assessment	SER												

Milestones	Number	
Final platform release	**MS6**	M30
Final assessment of pilots	**MS7**	M36

Figure 49. Gantt diagram M25-M36

Regarding T4.1, it is planned to deepen on integration specifications, especially in the integrations with the MCC component and other possibly available global components offered by the FlexiGroBots platform, allowing to update the documentation about *Pilot objectives, methodology, requirements and design*, including new requirements and new designs that address new objectives arising from developments, deployments and tests of the successive versions of the demonstrator.

The work plan to follow during the next 2 years includes the following integration task windows (T4.3. M16-M22 & M27-M34). This task will integrate the new version of software components and services developed within the pilot (T4.2. M13-M34) to be able to deploy new demonstrator versions.

Therefore, it is expected to invest most of the effort on this task 4.2 to develop, integrate and test needed components, specifically, Pilot 1 components testing intensification is expected around the ripening and grapes harvesting periods (M20-M22 & M32-M34).

It will include in-field deployment of the UGVs, UAVs, and the deployment of other software components including first versions of end-user applications. All WP4 partners will be involved in testing the developed components according to use cases defined in T4.1.

The next period also includes task 4.4 where assessment work is scheduled to progress. Specific tasks related to ELSE factors will be carried out:

- Research on the applicability of the EU's guidelines for trustworthy AI in the agricultural sector and the specific pilot.
- Applying the EU guidelines for trustworthy AI (especially the operationalised assessment list) to the specific pilot, resulting in tailored recommendations.

1.3.1 Upcoming field tests

After these first trials and based on the partial results obtained, it is considered that some changes could be proposed for the trials of the next growing season, in order to complete and obtain more information about them.

In relation to the plot to carry out the Botrytis detection tests, we consider that we should keep the same grape variety, the Loureiro, since it is the most sensitive to the attacks of the fungus, but we can consider in the next growing season, use a plot with more variable slopes to check the effectiveness of drone flights in more difficult conditions, or combine this with the plot of the first trials.

Regarding the trial to support the grape pickers, for the next growing season and although we will use the same Albariño plot again, I think we could discuss the possibility of doing a trial under more difficult conditions for the ground robot. For example, selecting a plot with a steeper slope to observe the possible difficulties that the robot may encounter in transporting the grape case. In a trial in a plot of this type, the work of the robot will further favour the hard work of a grape picker in sloping areas, where loading and moving the cases from one vine to another becomes harder and more difficult.

1.3.2 DSS Platform

The next task will be the integration with external systems. We must allow the end-user to track the fleets, for which we must manage the information generated by the robots in real-time.

The ground robots generate a series of telemetric data that the platform must process so that the farmer always knows the location of the robot, its trajectory, the movements made, etc. To integrate this data into the platform, a messaging broker will be used to enable real-time management of the telemetry. The performance of the messaging broker is crucial for the farmer, its integrity must be guaranteed, and it must be able to display robot information in real-time on the web interface.

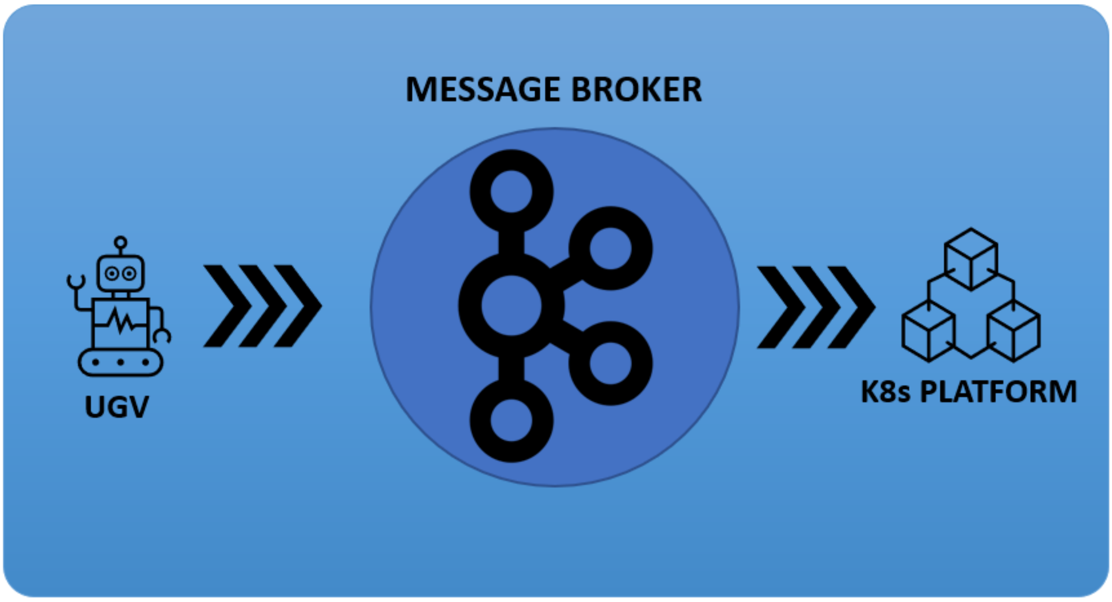

Figure 50. DSS platform

In the case of drone flights, images of the crops must be integrated so that they are easy for the farmer to consult. For this, FlexiGroBots Platform will offer a GIS server capable of storing geospatial information dedicated to the pilots.

In this case, the next step would be to analyse and design a flow of information from the GIS server to the web platform, so that the users' information requirements on images of the state of the plots, presence of diseases and yield estimation can be met.

The analysis must also be done to be able to show the results of the disease prediction models to the user. One of the objectives of the platform is the prediction of Botrytis, so it will be necessary to integrate the process of calculating the disease within the platform, so that the farmer can obtain this information well in advance.

1.3.3 Ground fleet

1.3.3.1 Autonomous inspection robot

Navigation system integration

Once achieved the automation of the vehicle, the next step is to integrate fuzzy controllers for the autonomous navigation of the platform based on GPS-RTK signal Figure 51. Human behaviour regarding speed and steering control of a vehicle can be approached using artificial intelligence techniques. Among them, fuzzy control has proven that it can perfectly mimic human driving behaviour while driving and route tracking. Furthermore, once a fuzzy controller is properly working, it can be used in other different kinds of vehicles making suitable adjustments.

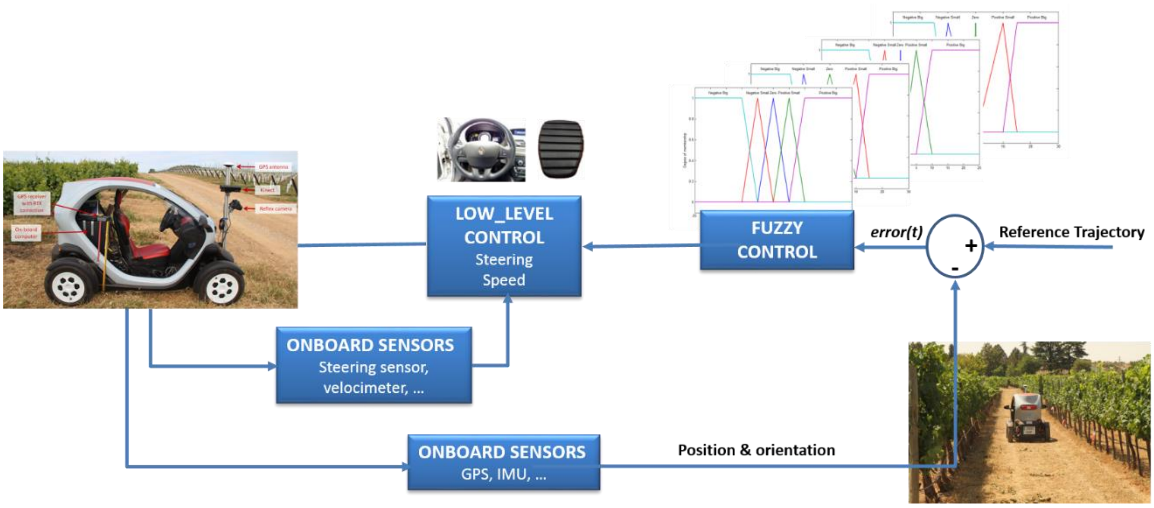

Figure 51. Navigation system integration

Botrytis detection system

For the detection of botrytis, we have started by labelling 1000+ images obtained during sampling in Terras Gauda. Once the images have been labelled, a Deep Learning algorithm will be trained to detect bunches of grapes. Subsequently, the problem of identifying Botrytis in bunches of grapes will be addressed. Expert-supervised labelling will be needed in order to properly identify bunches affected by the disease.

The following images (Figure 52 and Figure 53) show examples of the labelling process. The yellow rectangles show areas where there are bunches of grapes, and the red rectangle shows an area affected by Botrytis.

Figure 52. Example of the dataset labelling process. The yellow rectangles (show areas labelled as "bunch of grapes") (a)

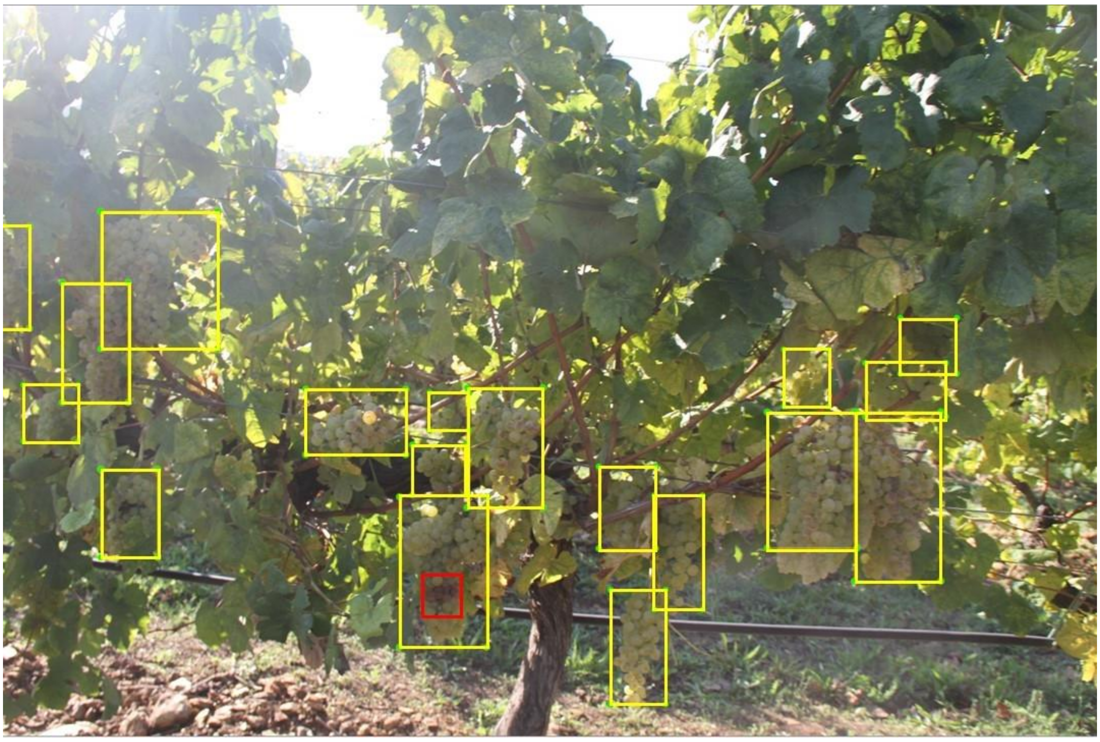

Figure 53. Example of the dataset labelling process. The yellow rectangles (show areas labelled as "bunch of grapes" and the red rectangle shows an area labelled as "grapes with Botrytis") (b)

1.3.3.2 Harvest assistance robot

In the coming months, a set of devices will be designed and properly integrated into the new platform (a mobile robot RB-VOGUI from Robotnik) with the aim of having the first prototype of this robot available in early February. The devices are as follows

- A GPS-RTK receiver
- A tray for continuous weighing of the grapes in the box transported by the robot. At the moment there is a preliminary design of the tray.
- A robust and easy to use anchoring system to fix the boxes of fruit to the base of the robot.
- The communications system will be integrated to send, with the latency defined at each moment, the weight of the box, which will provide a harvest map in real-time.

1.3.4 Aerial fleet

After having collected and pre-processed the datasets, the coming steps to be taken for the FlexiGroBots projects are the followings:

- For the multispectral images:
  - Analyse the changes of NDVI where there is presence of *Botrytis* (and if possible, also *Mildew*).
  - Analyse the changes of NDVI where there were foliar problems.
  - Train, validate and test an algorithm to predict the presence of *Botrytis* (and if possible, also *Mildew*) with Botrytis maps.

- For the video shots:
  - Annotate the videos with the presence of grape clusters.
  - Train, validate and test the PointTrack algorithm as a backup strategy for disease detection.

- For the point clouds:
  - Processing and analysing the point clouds as a backup strategy for *Botrytis* detection.