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G.A No 101016906

Project Number: 101016906
Start Date of Project: 2021/01/01
Duration: 48 months

Type of document D1.2. – V1.0

KoM Report

Dissemination level	PUBLIC
Submission Date	2021-02-28
Work Package	WP1
Task	T1.2
Type	Report
Version	1.0
Author	RSA
Approved by	UNIROMA3

This project is funded by the European Union
G.A No 101016906

Executive Summary

Deliverable D1.2 includes the presentations offered by project's beneficiaries during the Kickoff meeting held remotely on the 11th and 12th of February 2021 and also recap the main topics examined.

The above-mentioned presentations summarize the key technical and managing relating issues as discussed and approved during the meeting.

Table of Content

Abbreviations and Acronyms

CA	Consortium Agreement
CO	Coordinator
DoA	Description of Action
EC	European Commission
FS	Financial Statement
GA	Grant Agreement
KoM	Kick-off Meeting
MS	Management Staff
PM	Project Manager
PMC	Project Management Committee
PO	Project Officer
PR	Periodic Report
SyGMa	H2020 System for Grant Management
TS	Technical Staff
UoR	Use of Resources
WP	Work Package
WPL	Work Package Leader
PA	Precision Agriculture

1 Introduction

The KoM was held remotely due to the active health and travel restrictions tied to the COVID-19 emergency.

The meeting was attended by the representatives of all CANOPIES beneficiaries, totaling 47 participants. During the two sessions all issues related to the commencement, management, finance and technicalities of CANOPIES project have been presented and thoroughly discussed.

The participants engaged in technical discussions during the two days and proved to be fully committed in the project tasks, as described in the Annex I to the Grant Agreement.

The table contains the names of the participants:

Beneficiary	Name	Last Name
UNIROMA3	Andrea	GASPARRI
UNIROMA3	Federica	PASCUCCI
UNIROMA3	Martina	LIPPI
UNIROMA3	Stefano	PANZIERI
UNIROMA3	Matteo	SANTILLI
UNIROMA3	Renzo Fabrizio	CARPIO
UNIROMA3	Antonio	FURCHÌ
KTH	Dimos	DIMAROGONAS
KTH	Danica	KRAGIC
KTH	Hang	YIN
KTH	Ali	GHADIRZADEH
KTH	Alfredo	REICHLIN
KTH	Wenceslao	SHAW-CORTEZ
KTH	Pushpak	JAGTAP
KTH	Carlos	Rodríguez DE COS
UNIROMA 1	Daniele	NARDI
UNIROMA 1	Thomas A.	CIARFUGLIA
UNIROMA 1	Sara	KASZUBA
UNIROMA1	Mulham	FAWAKHERJI
UPC	Alberto	SANFELIU
UPC	Ana	PUIG – PEY CLAVER
UPC	Juan	ANDRADE-CETTO
UNICLAM	Alessandro	MARINO
UNICLAM	Gianluca	ANTONELLI
UNICLAM	Filippo	ARRICHIELLO
UNICLAM	Giuseppe	GILLINI
UNICLAM	Paolo Augusto	DI LILLO
UNICLAM	Daniele	DI VITO
UNICLAM	Giacomo	GOLLUCCIO
DTI	Tsampikos	KOUNALAKIS

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DTI	Lars	DAALGARD
DTI	Kasper	CAMILLUS JEPPESEN
DTI	Jonas	BÆCH
PALEBLUE	Felix	GORBATSEVICH
PALEBLUE	Juan	CORREA
PALEBLUE	Pascal	SERRARENS
PALROBOTICS	Francesco	FERRO
PALROBOTICS	Carlos	VIVAS
PALROBOTICS	Sarah	TERRERI
PALROBOTICS	Jordi	PAGES
PALROBOTICS	Alessandro	DI FAVA
PALROBOTICS	Alex	SANCHO
PALROBOTICS	Lorna	MCKINLAY
PALROBOTICS	Delia	GARCIA
AGRIMESSINA	Francesco	MESSINA
AGRIMESSINA	Giuseppe	VALENZANO
RSA	Alessandro	ALBINO FREZZA

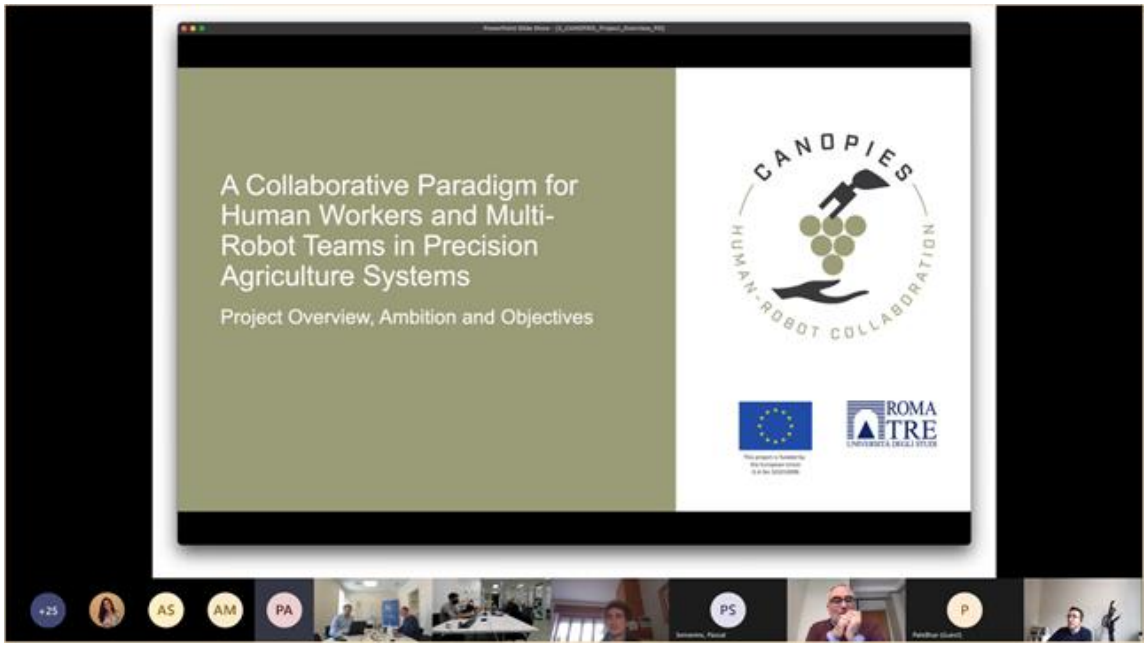

Figure 1 - Screenshot during the Coordinator's presentation on the first day of the KoM

Figure 2 – Screenshot during the second day of the KoM

2 EC Participation

2.1 Briefing from the CANOPIES Project Officer

The Project Officer Antonio PUENTE RODERO (DG CNET-A) attended the meeting on the 12th of February. Antonio briefed the Consortium on his role and on the main managing relating issues to be attentively considered by the CANOPIES Consortium, in order to ensure a smooth implementation of the project.

The following key-items have been focused by the PO:

- Pre-financing and interim payments.
- Reporting to the EC.
- Ownership of the results generated in CANOPIES.

All beneficiaries introduced themselves describing their organization and the role they will be playing in CANOPIES.

3 CANOPIES – Workplan and technical discussions

3.1 Work Package 1 – Aim and scope

WP1 is dedicated to the technical and managing coordination of CANOPIES, the management of the communication among the project's partners and with the EC, the overall legal, contractual, financial and administrative management of the Consortium, and the coordination, the update and management of the CA together with the implementation of all actions necessary to fulfill the obligations of the GA. The CO (UNIROMA TRE) will be responsible for the technical and scientific coordination of the project, while beneficiary # 10 (RSA) will act as Project Manager being in charge of all typical reporting and management task required by the H2020 standard procedures,

3.2 Work package 2 – Aim and scope

WP2 focuses on defining all the requirements and specifications for the design of the integrated system. These comprise the agronomic specifications, the functional requirements of all the components of the integrated system, the dimensioning of the table-grape scenario that will be used for validation purposes. Ethical, legal and societal issues will be also taken into account.

3.3 Work Package 3 – Aim and Scope

WP3 is devoted to developing, integrating and testing the robotic platforms. Two farming and two logistic prototypes will be developed along with their localization and autonomous navigation capabilities. All the required robotic, system and simulation components, such as the perception system, the Box-Exchange Mechanism, the dual arm setup, and end-effectors, will be designed and developed. The networking communication infrastructure will also be designed. Continuous acceptance testing and integration phases will be carried out for the entire duration of the project.

3.4 Work Package 4 – Aim and scope

WP 4 aims to design new perception methods for modelling and detection of grapes, vineyard tree branches and other obstacles. Ripe grapes will be localized (position and orientation) in the 3D world by exploiting different types of vision sensors such as video cameras, stereovision cameras, event cameras, Lidar. Next, access paths will be planned for the robot arms to perform agronomic operations, for example pick a grape bunch or do a branch pruning. Finally, the agronomic quality assessment will be designed.

3.5 Work Package 5 – Aim and scope

WP5 is dedicated to design and develop all manipulation functionalities of the mobile manipulator system composed by the mobile base and the dual-arm system. These functionalities will form the basis for the implementation of all the PA tasks addressed in CANOPIES. Both coordinated and uncoordinated motions will be enabled, and force control algorithms will be devised to achieve physical interaction with the farmers and the environment. Low-level procedures for ensuring human safety will be implemented.

3.6 Work Package 6 - Aim and scope

WP6 aims to develop a novel approach for human-robot interaction combining predictive models of human motion, planning of joint actions, multi-modal interaction, and shared mental state. Both

implicit and explicit communication will be considered where implicit communication will be inferred from the human motion and prediction, while explicit communication will be achieved through a specific language. A virtual reality system will be developed to validate the devised methods. The interaction with the environment and with the human will be modelled in this system.

3.7 Work Package 7 – Aim and scope

WP7 is devoted to design of the methodologies for the coordination of the multi-robot system in a PA context. In the considered scenario, some agricultural robots are filling in their boxes while other logistic robots are moving around to support them by replacing their full boxes with empty ones. We will design coordinate control strategies involving both the agricultural robots and the logistic ones to optimally carry out the requested agronomic activities.

3.8 Work Package 8 – Aim and Scope

WP8 is dedicated to design task planning strategies for human-multi-robot systems in which humans may aid the multi-robot system during an agronomic task. Learning-by-demonstration methods will be considered to allow the robots to mimic human motion to appropriately execute complex tasks. Safe human intervention will be then guaranteed. A multi-robot, online re-planning approach will ensure the multi-robot system never enters a region occupied by a human, while adhering to the agronomic task specifications. Next, human intervention will be considered via human-in-the-loop commands for multi-robot task planning. When a human operator must adjust a high-level plan online in the event of unforeseen circumstances, the task planner must re-plan, while always respecting safety conditions. Finally, a virtual reality (VR) 3D environment will be created for human operators to interact with the robots in the field and implement the safe task planning methods.

3.9 Work Package 9 – Aim and Scope

WP9 focuses on the experimental validation on a table-grape vineyard of the integrated system capabilities. Incremental objectives will be considered for the validation: i) Field Validation of the Robot Navigation Functionalities; ii) Field Validation of the Robot Manipulation Functionalities; iii) Field Validation of the Agronomic Perception Functionalities; iv) Field Validation of the Multi-Robot Cooperation; v) Field Validation of the Multi-Robot Cooperation; vi) Field Validation of the Human-Multi-Robot Task Planning; and vii) Final Demo of the Integrated System. The field validation of the system capabilities has been organized according to the seasonal arrangement of the agricultural practices (December-January for pruning and July-September for harvesting) starting from year 2.

3.10 Work Package 10 – Aim and scope

WP10 aims at guaranteeing dissemination and promotion of the exploitation of CANOPIES. Dissemination will be conducted throughout the entire project: first, methods, concepts and ideas will be promoted, then as soon as some results will be available, these will be presented using the available platforms. The exploitation will be done in conjunction with the procurers and the companies. A web platform for communication will be developed. This site and connections to social media will be the basis for disseminating and sharing knowledge between as well as among project partners and external participants.

4 Main topics discussed during the KoM

The following is the listing of the main topics that have been discussed by the Consortium during the meeting. These can be categorized distinguishing among Technical, Logistic and management-related matters.

4.1 Technical

As far as the technical matters are concerned, the followings were the main topics discussed:

i) Navigational sensors/equipment requirements and specifications; ii) Agronomic perception sensors/equipment requirements and specifications; iii) HW-related integration aspects; iv) reshaping of the provisional GANTT chart of the project and, v) Discussion about dissemination actions, i.e., setting disseminations channels through Linkedin, creation of a common press release, creation of banners.

4.2 Management

Concerning the management of CANOPIES, the following items were thoroughly discussed and approved:

i) Project Management guidelines (D.1.1), including a) Distribution of the pre-financing; b) Governance of CANOPIES; c) Reporting to the EC; d) Standards applicable to internal documents and deliverables; and e) Internal scheduling to carry our final review of the deliverables, prior to submission; ii) Composition of the Project Management Committee.

4.3 Logistics

The discussions mainly focused on the impact of the COVID-19 emergency in the shorth term. In particular the main items addressed were: i) travel restrictions applicable per each Beneficiary; ii) additional costs related to COVID-19 travelling restriction to be included in the project's eligible travel costs (such as mandatory PCRs tests).

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5 Annexes

- Agenda of the KoM
- Presentations (Beneficiaries)
- Presentations (Work Packages)

KoM Agenda

Day 1 – 11 February 2021

Morning session 9:45 – 13:00 (Technical Discussion)

09:45 Opening of KoM [A. Gasparri – A. Benedetto] (15 min)

10:00 Consortium Introduction (10 min each / short ppts are welcome)

11:40 Coffee Break

12:00 Project Overview, Ambition and Objectives [A. Gasparri] (30 min)

12:30 WP1 – Project Management [UNIROMA3+RSA – A. Gasparri + A. Frezza] (30 min)

- WP Objective, Tasks Description, Deliverables and Milestones
- Technical discussion (all tasks)
- Coordination and planning of activities

13:00 Lunch Break

Afternoon session 14:00 – 17:30 (Technical Discussion)

14:00 WP2 – Functional Specifications [AGRIMESSINA – TBA] (30 min)

- WP Objective, Tasks Description, Deliverables and Milestones
- Technical discussion (all tasks)
- Coordination and planning of activities

14:30 WP3 – Robot Development, Integration and Testing [DTI – TBA] (30 min)

- WP Objective, Tasks Description, Deliverables and Milestones
- Technical discussion (all tasks)
- Coordination and planning of activities

15:00 WP4 – Agronomic-Oriented Perception [UPC – TBA] (30 min)

- WP Objective, Tasks Description, Deliverables and Milestones
- Technical discussion (all tasks)
- Coordination and planning of activities

15:30 Coffee Break

15:45 WP5 – Single Robot Functionalities [UNICLAM – TBA] (30 min)

- WP Objective, Tasks Description, Deliverables and Milestones
- Technical discussion (all tasks)
- Coordination and planning of activities

16:15 WP6 – Human-Robot Interaction [UNIROMA1 – TBA] (30 min)

- WP Objective, Tasks Description, Deliverables and Milestones
- Technical discussion (all tasks)
- Coordination and planning of activities

16:45 WP7 – Multi-Robot Coordination [UNIROMA3 – TBA] (30 min)

- WP Objective, Tasks Description, Deliverables and Milestones
- Technical discussion (all tasks)
- Coordination and planning of activities

17:15 Closing discussion

17:30 End of Day 1

Day 2 – 12 February 2021

Morning session 09:45 – 11:15 (with PO)

09:45 Opening of KoM [A. Gasparri]

09:50 Consortium Introduction (5 min each / short ppts are welcome)

10:40 Project Overview [A. Gasparri] (15 min)

10:55 Forewords by ICT Project Officer [A. PUENTE RODERO] (15 min)

11:15 Coffee Break

Morning session 11:30 – 13:30 (Technical Discussion)

11:30 WP8 – Task Planning for Human-Multi-Robot Systems [KTH – TBA] (30 min)

- WP Objective, Tasks Description, Deliverables and Milestones
- Technical discussion (all tasks)
- Coordination and planning of activities

12:00 WP9 – Architecture Field Validation [UNIROMA1 – TBA] (30 min)

- WP Objective, Tasks Description, Deliverables and Milestones
- Technical discussion (all tasks)
- Coordination and planning of activities

12:30 WP10 – Dissemination and Promotion of Exploitation [UPC – TBA] (30 min)

- WP Objective, Tasks Description, Deliverables and Milestones
- Technical discussion (all tasks)
- Coordination and planning of activities

13:00 Closing discussion

13:30 End of the Meeting

KoM Day 1

A Collaborative Paradigm for Human Workers and Multi-Robot Teams in Precision Agriculture Systems

Kickoff Meeting Opening

This project is funded by the European Union
G.A No 101016906

1

Agenda – Day 1 (Morning)

Morning session 09:45 – 13:00

09:45 Opening of KoM [A. Gasparri – A. Benedetto]

10:00 Consortium Introduction (10 min each Partner)

11:40 Coffee Break

12:00 Project Overview, Ambition and Objectives [A. Gasparri]

12:30 WP1 – Project Management [UNIROMA3+RSA – A. Gasparri + A. Frezza]

13:00 Lunch Break

2

Agenda – Day 1 (Afternoon)

Afternoon session 14:00 – 15:30 (Technical Discussion – Part I)

14:00 WP2 – Functional Specifications [AGRIMESSINA – TBA]

- WP Objective, Tasks Description, Deliverables and Milestones
- Technical discussion (all tasks)
- Coordination and planning of activities

14:30 WP3 – Robot Development, Integration and Testing [DTI – TBA]

15:00 WP4 – Agronomic-Oriented Perception [UPC – TBA]

15:30 Coffee Break

Agenda – Day 1 (Afternoon)

Afternoon session 15:45 – 17:30 (Technical Discussion – Part II)

15:45 WP5 – Single Robot Functionalities [UNICLAM – TBA]

- WP Objective, Tasks Description, Deliverables and Milestones
- Technical discussion (all tasks)
- Coordination and planning of activities

16:15 WP6 – Human-Robot Interaction [UNIROMA1 – TBA]

16:45 WP7 – Multi-Robot Coordination [UNIROMA3 – TBA]

17:15 Closing discussion

17:30 End of Day 1

Agenda – Day 2 (Morning)

Morning session 09:45 – 11:15 (with PO)

09:45 Opening of KoM [A. Gasparri]

09:50 Consortium Introduction (5 min each Partner)

10:40 Project Overview [A. Gasparri]

10:55 Forewords by ICT Project Officer [Antonio PUENTE-RODERO]

11:15 Coffee Break

Agenda – Day 2 (Morning)

Morning session 11:30 – 13:30 (Technical Discussion)

11:30 WP8 – Task Planning for Human-Multi-Robot Systems [KTH – TBA]

- WP Objective, Tasks Description, Deliverables and Milestones
- Technical discussion (all tasks)
- Coordination and planning of activities

12:00 WP9 – Architecture Field Validation [UNIROMA1 – TBA]

12:30 WP10 – Dissemination and Promotion of Exploitation [UPC – TBA]

13:00 Closing discussion

13:30 Lunch Break

Welcome from UNIROMA3

Prof. Andrea Benedetto

- Full Professor of Civil Engineering
- Head of the Engineering Department

A Collaborative Paradigm for Human Workers and Multi-Robot Teams in Precision Agriculture Systems

Consortium Introduction

This project is funded by the European Union
G.A No 101016906

1

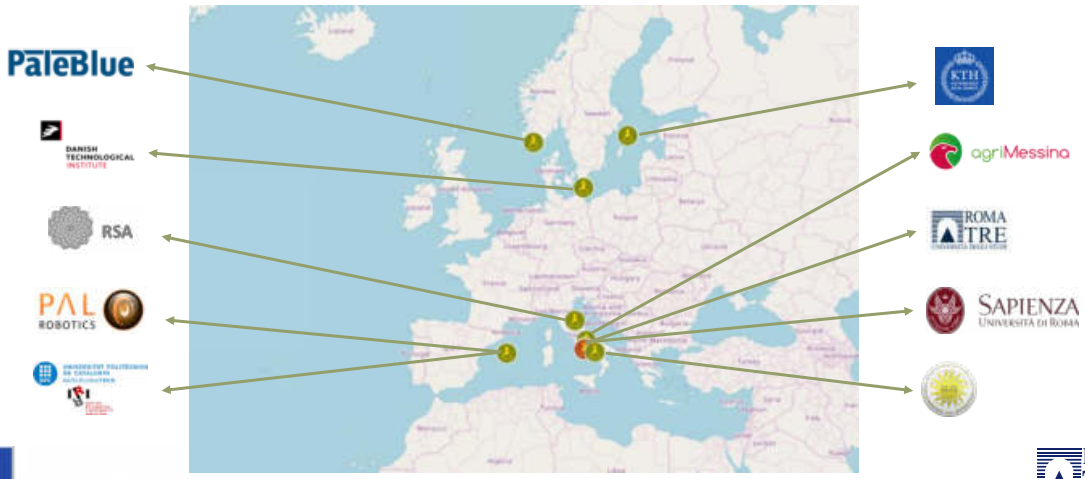
Canopies Project

Consortium

- 5 Countries
- 5 Universities
- 1 Research Center
- 4 SMEs

2

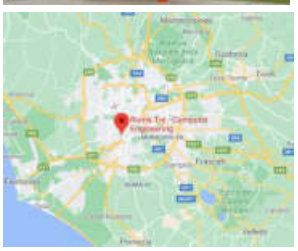
Canopies: where do we come from?



Università degli Studi Roma Tre (UNIROMA3)

Description

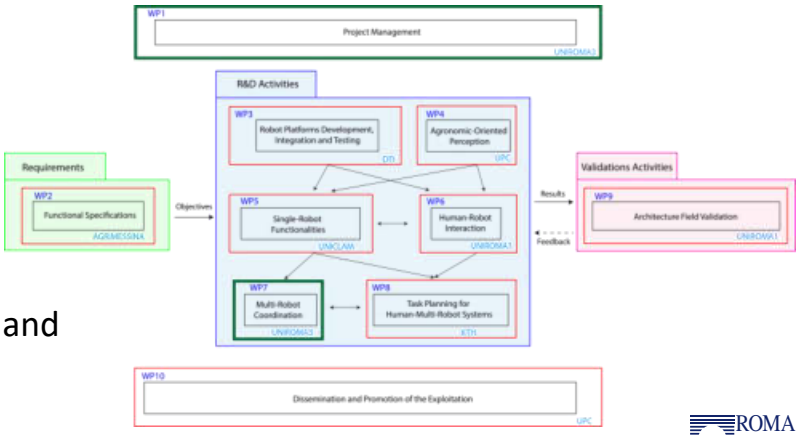
- Young **public research university** founded by the Italian Ministry of Education, University and Research in **1992**.
- Roma Tre University is organized in **12 Departments** enrolling about **35.000** students and having about **1.400** academic and professional staff.
- Our **Engineering Department** was selected by the Italian Ministry of Public Education as one of the 180 **Departments of Excellence** in 2018.



Università degli Studi Roma Tre (UNIROMA3)

Role in the Project

- Project Coordination
- Leadership of WP1 (technical and scientific project coordination)
- Leadership of WP7 (Design of distributed estimation, coordination and field coverage protocols)



Università degli Studi Roma Tre (UNIROMA3)

Role in the Project

- Leadership of Task T3.5 in WP3 (design of the autonomous navigating functionalities of the mobile robotic platform)
- Leadership of Task T9.5 in WP9 (field validation of the multi-robot coordination capabilities)
- Leadership of Task T9.7 in WP9 (final demonstration of the integrated system within a real-world (1:1 scale) table- grape vineyard)

Università degli Studi Roma Tre (UNIROMA3)

Team

Andrea Gasparri
Associate Professor

Stefano Panzieri
Full Professor

Giovanni Ulivi
Full Professor

Federica Pascucci
Associate Professor

Martina Lippi
Research Affiliate

Antonio Furchì
Ph.D Student

Matteo Santilli
Research Affiliate

Renzo Carpio
Ph.D Student

Università degli Studi Roma Tre (UNIROMA3)

Expertise

- Field Robotics
- Autonomous Navigation
- SLAM
- Multi-Robot Coordination
- Distributed Estimation
- Distributed Control

Autonomous Navigation in Dynamic Environment

Large-Scale Simultaneous Mapping and Localization

Multi-Robot Coordination with limited FOV

Multi-Robot Collaboration

Università degli Studi Roma Tre (UNIROMA3)

Projects

PANTHEON – PRECISION FARMING OF HAZELNUT ORCHARDS
(H2020-SFS-2017-1)
[2017 – 2021]

PARADISE – PRECISION FARMING FOR SUSTAINABLE PRODUCTION IN SUBURBAN AREAS
(POR-FESR 2014-2020 REGIONE LAZIO)
[2020 – 2022]

RESISTO – RESILIENCE ENHANCEMENT AND RISK CONTROL PLATFORM FOR COMMUNICATION INFRASTRUCTURE OPERATORS
(H2020-CIP-2016-2017)
[2018 – 2021]

COCKPITCI – CYBERSECURITY ON SCADA: RISK PREDICTION, ANALYSIS AND REACTION TOOLS FOR CRITICAL INFRASTRUCTURES
(FP7-SEC-2011-1)
[2012 – 2014]

ATENA – ADVANCED TOOLS TO ASSESS AND MITIGATE THE CRITICALITY OF ICT COMPONENTS AND THEIR DEPENDENCIES OVER CRITICAL INFRASTRUCTURES
(H2020-DS-2015-1)
[2016 – 2019]

NECTAR – NETWORKED COOPERATIVE TEAMS OF AUTONOMOUS ROBOTS
(FIRB FUTURO IN RICERCA 2008)
[2010 – 2014]

Kungliga Tekniska Högskolan (KTH)

Description

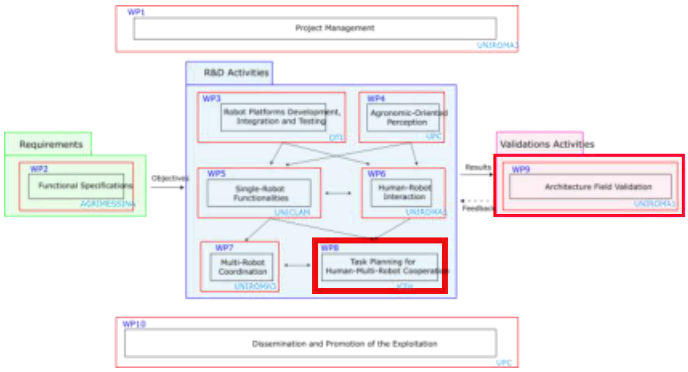
- Largest technical university in Sweden (1/3 of Sweden's capacity for engineering and technical research at post-secondary level)
- Part of WASP and KTH Digital Future environments

- Expertise & perspectives from the private and public sectors provided in collaborations & knowledge exchange with external partners and other universities

Kungliga Tekniska Högskolan (KTH)

Role in the Project

- Leadership of WP8 (Task Planning for Human-Multi-Robot Systems)
- Leadership of Task T9.6 in WP9 (Field Validation of the Task Planning for Human-Multi-Robot Systems)



Kungliga Tekniska Högskolan (KTH)

Unit Members:

Decision and Control Systems (DCS) Lab




Dimos Dimarogonas | Wenceslao Shaw Cortez | Pushpak Jagtap | Carlos Rodríguez de Cos

Expertise:

Task planning, Control of multi-robot systems

Kungliga Tekniska Högskolan (KTH)

Unit Members:

Robotics, Perception, and Learning (RPL) Lab

Danica Kragic

Hang Yin

Ali Ghadirzadeh

Expertise:

- Vision for robotics
- Learning

Kungliga Tekniska Högskolan (KTH)

Projects:

- Horizon 2020 Areoworks (2015-2018)
- H2020 Co4Robots (2017-2020)
- ERC StG BUCOPHSYS (2015-2020)
- SSF FACT (2016-2020)
- H2020 socSMCs (2015-2019)

Sapienza Università di Roma (UNIROMA1)

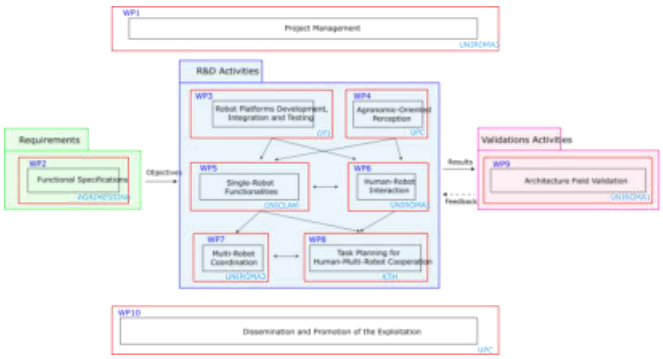
Description

- One of the oldest (1303) and largest Universities, the largest in Eu.
- Sapienza University is organized in 68 Departments, 12 Faculties enrolling about 115.000 students with about 5500 academic and professional staff.
- Our Department was selected by the Italian Ministry of Public Education among the 180 Departments of Excellence focused on Cyber Security, 2018.

Sapienza Università di Roma (UNIROMA1)

Role in the Project

- Leadership of WP6 (Human Robot Interaction)
- Leadership of WP9 (Field Validation)



Sapienza Università di Roma (UNIROMA1)

Role in the Project

- Leadership of Task T4.3 in WP4 (Grape Quality Estimation)
- Leadership of Task T6.3 in WP6 (Human Robot Communication)
- Leadership of Task T6.3 in WP6 (Human Robot Awareness)
- Leadership of Task T9.4 in WP9 (Field validation of the hri capabilities)

Sapienza Università di Roma (UNIROMA1)

Lab RoCoCo http://www.diag.uniroma1.it/~labrococo

Daniele Nardi

Luca Iocchi

Giorgio Grisetti

Mulham Fawakerij WP4

Thomas Ciarfuglia WP4

Sara Kaszuba WP6

Sapienza Università di Roma (UNIROMA1)

Team Expertise

- Artificial Intelligence
- Human Robot Interaction
- SLAM
- Action Planning
- Robot Perception
- AI and Robotics for Precision Farming

Projects

SciRoc — European Robotics League plus Smart Cities Robot Competitions
CA H2020 2019-2021

BUBBLES — BUBBLES: Defining the **BU**ilding **B**asic **Bl**ocks for a U-Space S**E**paration Management **S**ervice
FP7 2013-2016

AI4EU — A European AI on demand platform and Ecosystem
H2020 2019-2021

Flourish — European Robotics League plus Smart Cities Robot Competitions
H2020 2015-2018

AIPlan4EU — Bringing AI Planning to the European AI On-Demand Platform
Bringing AI Planning to the European AI On-Demand Platform
H2020 2021-2023

Rovina — Robots for Exploration, Digital Preservation and Visualization of Archeological Sites
FP7 2013-2016

Universitat Politècnica de Catalunya (UPC)

Description

- The Universitat Politècnica de Catalunya (UPC) (www.upc.edu) is a public institution dedicated to research and higher education and it is one of the biggest universities in Spain, with over 32.000 students, 33 departments and 205 research groups. UPC participates in this project with IRI and UMA.
- The Institut de Robòtica i Informàtica Industrial (IRI, www.iri.upc.edu) is a Joint Research Institute that hosts researchers both from the Universitat Politècnica de Catalunya (UPC) and from the Spanish Scientific Research Council (CSIC), and participate in this project as a Joint Research Unit (JRU), with UPC leading the participation, and CSIC acting as 3rd party.
- Unit of Agricultural Machinery (http://www.uma.deab.upc.edu) is a recognized research group bellowing to UPC. Main activities of UMA are focused in research, education and extension activities related with agricultural machinery.

EXCELENCIA MARÍA DE MAEZTU

Universitat Politècnica de Catalunya (UPC)

Role in the Project

- Leadership of WP4 (Agronomic-oriented perception)
- Leadership of WP10 (Dissemination and Promotion of the Exploitation)

Universitat Politècnica de Catalunya (UPC)

Role in the Project

- Leadership of Task T4.1 in WP4 (Agronomic Target Detection and Modelling)
- Leadership of Task T4.2 in WP4 (Agronomic Target Localization)
- Leadership of Task T6.1 in WP6 (Human-Body Prediction)
- Leadership of Task T6.2 in WP6 (Human-Robot Motion Planning)
- Leadership of Task T10.1 in WP10 (Website Construction and Updates)
- Leadership of Task T10.2 in WP10 (Dissemination)
- Leadership of Task T10.4 in WP10 (Communication Activities and Event)

Universitat Politècnica de Catalunya (UPC)

UNIT Members

- Alberto Sanfeliu (UPC-IRI)
- Emilio Gil (UPC-UMA)
- Juan Andrade-Cetto (CSIC-IRI)
- Antonio Grau (UPC-IRI)
- Yolanda Bolea (UPC-IRI)
- Rene Alquezar (UPC-IRI)
- Ana Puig-Pey (UPC-IRI)
- Joan Vallvé (UPC-IRI)
- Francesc Moreno-Noguer (CSIC-IRI)
- Anais Garrell (CSIC-IRI)
- Joan Solà (CSIC-IRI)

Universitat Politècnica de Catalunya (UPC)

Expertise

IRI focuses its activity in human-centered robotics research with expertise in various areas of robotics, such as computational kinematics and geometry, computer vision, industrial robotics, mobile robotics (legged and wheeled robots), artificial intelligence, and energy systems.

UMA has large experience in viticulture, especially in spray application technology. Precision Agriculture linked to pesticide application equipment, variable rate application, development of new technologies to improve efficacy of sprayers.

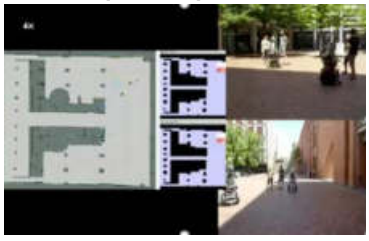
- Robotics
- Social robotics
- Artificial Intelligence
- Human-body prediction
- Perception systems
- Precision Farming

Universitat Politècnica de Catalunya (UPC) : IRI

Collaborative, cooperative and Social Robotics

- Deep and Reinforcement Learning
- Path and action planning
- Shared planning and reasoning

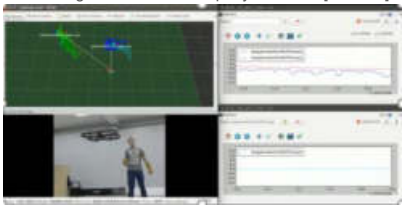
Searching and tracking people with cooperative mobile robots [AURO 2018]



Anticipative kinodynamic planning: multi-objective robot navigation [AURO 2019]

People's V-formation model adapted to accompany groups of people [IROS 2019]

Teaching a Drone to Accompany a Person [IROS19]



Universitat Politècnica de Catalunya (UPC) : IRI

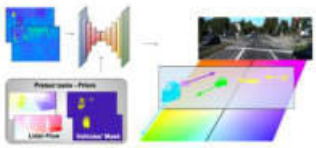
Aerial Robotics Localization and map building (SLAM)

- Sensory data fusion for localization
- SLAM and Deep Learning
- Object detection and tracking using Deep Learning

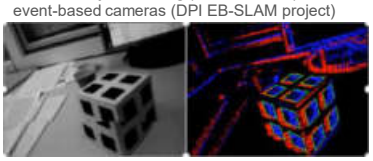
Sensor fusion in unmanned aerial vehicles (H2020 AEROARMS project) [Auton. Robots 2018]

Precise localization in aerial grasping (EU ARCAS project)

3D Lidar Deep learning for object tracking [ICPR, 2018]



Ultra fast object tracking (microseconds) with event-based cameras (DPI EB-SLAM project)

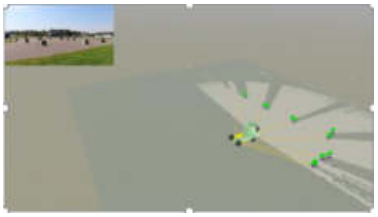


Universitat Politècnica de Catalunya (UPC) : IRI

Robotics applied to logistics and transport; ADAS

- Perception, path planning and decision making
- Deep learning for vehicle detection and tracking

Real-time SLAM in a truck (EU LOGIMATIC project)



Sensor fusion for advanced driving assistance systems (FICOSA), [ECMR17]

Autonomous navigation of straddle carrier in port container terminals (H2020 LOGIMATIC project)

Delivery of persons and goods (DPI ColRobTransp project)

Universitat Politècnica de Catalunya (UPC):UMA

Pesticide application
Precision farming

Universitat Politècnica de Catalunya (UPC)

IRI Projects

AI4EU: A European AI On Demand Platform and Ecosystem (H2020-ICT-2018-2-825619)[2019-2021]

TERRINet: The European Robotics Research Infrastructure Network (H2020-INFRAIA-2017-1-two-stage-730994)[2017-2021]

ROBOCOM++: Rethinking Robotics for the Robot Companion of the future (FLAG-ERA JCT 2016)[2017-2020]

SciRoc: European Robotics League plus Smart Cities Robot Competitions (H2020-ICT-2017-1-780086)[2018-2022]

GAUSS: Galileo-EGNOS as an Asset for UTM Safety and Security (H2020-GALILEO-GSA-2017-1-776293)[2018-2021]

Universitat Politècnica de Catalunya (UPC)

IRI Projects

AEROARMS: AErial RObotics System integrating multiple ARMS and advanced manipulation capabilities for inspection and maintenance
(H2020_ICT-2014-1-644271)[2015-2019]

LOGIMATIC: Tight integration of EGNSS and on-board sensors for port vehicle automation
(H2020-Galileo-2015-687534) [2016-2019]

ECHORD++: European Clearing House for Open Robotics Development Plus Plus
(FP7-ICT-2012-601116)[2013-2018]

Cargo-ANTS: Cargo handling by Automated Next generation Transportation Systems for ports and terminals
(FP7-SST-2013- 605598) [2013-2016]

ARCAS: Aerial Robotics Cooperative Assembly System
(FP7-INFSO-ICT-287617)[2011-2015]

Universitat Politècnica de Catalunya (UPC)

UMA Projects

NOVATERRA: Integrated novel strategies for reducing the use and impact of pesticides, towards sustainable mediterranean vineyards and olive groves
(H2020)[2020-2024]

INNOSETA: Accelerating Innovative practices for Spraying Equipment, Training and Advising in European agriculture through the mobilization of Agricultural Knowledge and Innovation Systems
(H2020) [2018-2021]

OPTIMA: Optimized Pest Integrated Management to precisely detect and control plant diseases in perennial crops and open-field vegetables
(H2020)[2018-2021]

AGRICT – Erasmus +: Precision farming education
(H2020)[2018-2021]

Università degli Studi di Cassino (UNICLAM)



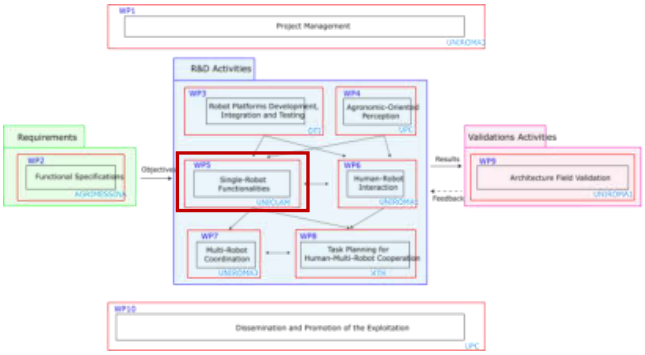
Description

- Public research university founded by the Italian Ministry of Education, University and Research in 1979.
- UNICLAM University is organized in 5 Departments enrolling about 9.000 students and having about 500 academic and professional staff.
- Our Engineering Department (DIEI) was selected by the Italian Ministry of Public Education as one of the 180 Departments of Excellence in 2018.

Università degli Studi di Cassino (UNICLAM)

Role in the project

- Leadership of **WP5** (Single Robot Functionalities)
- Leadership of Task 5.1 (Two Arms Coordination Functionalities)
- Leadership of Task 5.2 (Robot Safety Functionalities)
- Leadership of Task 5.3 (Robot Physical Interaction Functionalities)
- Leadership of Task 9.2 (Field Validation of the Robot Manipulation Functionalities)



Università degli Studi di Cassino (UNICLAM)

Alessandro Marino
Associate Professor

Stefano Chiaverini
Full Professor

Gianluca Antonelli
Full Professor

Filippo Arrichiello
Associate Professor

Giuseppe Fusco
Associate Professor

Paolo Di Lillo
Post Doc

Daniele Di Vito
Post Doc

Giuseppe Gillini
Post Doc

Giacomo Golluccio
PhD Student

webuser.unicas.it/lai/robotica

Università degli Studi di Cassino (UNICLAM)

Industrial & Service Robotics

Marine Robotics

Assistive Robotics

Cooperative Manipulation

Human-Robot-Interaction

Multiple-robot systems

Several National and European past and ongoing projects

Università degli Studi di Cassino (UNICLAM)

Potenza

Napoli

Robotics Network 1:
Prisma Lab
Projects of Robotics for Industry and Services, Mechatronics and Automation Laboratory

Cassino

Salerno

Napoli 2

Università degli Studi di Cassino (UNICLAM)

Pisa

Genova

Robotics Network 2:
ISME
Interuniversity Center of Integrated Systems for the Marine Environment

Cassino

Ancona

Lecce

Firenze

Università degli Studi di Cassino (UNICLAM)

EUMR H2020 (2018-21)
Robotic subsea exploration technologies

TARMEM QNRF (2018-21)
CMU Doha

C4E - PON (2018-21) Monitoring of illegal spills through the synergistic use of advanced technologies

Progetto Dipartimenti di Eccellenza
MIUR (2018-22)

ROBILAUT PON (2019-2022)
MoBILe sampling robot with underground autonomous navigation

ROBUST H2020 (2015-20)
Robotic subsea exploration technologies

AEROARMS H2020 (2015-19)
Aerial Robots with multiple arms

WiMUST H2020 (2015-18)
Widely scalable Mobile Underwater Sonar Technology

DexROV H2020 (2015-18) Dexterous ROV Operations Communications Latencies

Università degli Studi di Cassino (UNICLAM)

Academic Spin-off

- To bridge the gap between research and implementation
- Expertise in several fields of robotics

EVERYBOTICS

EveryBotics

Coding
- C++
- Python
- ROS
- PLC

Robotics
- Industrial robotics
- Mobile robotics
- Multi-robot systems
- Marine robotics

IOT
- Big Data
- Satellite Imagery Mining
- Signal Processing
- Advanced Networks

www.everybotics.it

Danish Technological Institute (DTI)

Description

- Self-owned and not-for-profit institution that dates back to 1906, organized in 7 major divisions with more than 40 centers of expertise.
- DTI's Centre for Robot Technology is located in Odense and is a leading European robotics innovator with a staff of around 45 robotic experts and 2800m2 of innovation facilities.
- DTI is a pioneer for application-orientated technology and knowledge transfer between research and the business community, particularly for SMEs.

Danish Technological Institute (DTI)

Areas of expertise

Danish Technological Institute (DTI)

Role in the Project

DTI is lead on WP3

- HW and SW development and integration of the robotic prototypes.
- Design, develop and test required prototype mechanisms.
- Endow the robotic prototype with autonomous localization and navigation capabilities.
- Acceptance testing of the robotic prototypes.

Danish Technological Institute (DTI)

Role in the Project

- Leadership of Task T2.2 in WP2 (robot specifications and KPIs)
- Leadership of Task T9.1 in WP9 (field validation of robot navigation)

Danish Technological Institute (DTI)

Team

Lars Dalgaard
Section Leader

Tsampikos Kounalakis
Consultant – CANOPIES project manager

Kasper Camillus Jeppesen
Consultant

Jonas Bæch
Consultant

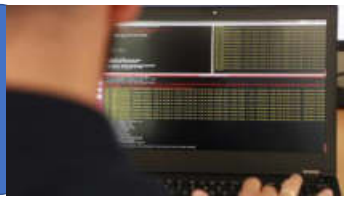
Xaver Kroischke
Specialist

Danish Technological Institute (DTI)

Expertise

Precision Farming

Autonomous navigation



Robot prototyping

Robot integration

ROS / ROS2

Artificial intelligence

Agronomic vision

AR / VR

Safety

Human-Robot-Interaction

Danish Technological Institute (DTI)

Relevant Projects

agROBOfood – DIH network
(DT-ICT-02, 2019-2024)
[2019 – 2024]

S3CAV - Simultaneous Safety and Surveying for Collaborative Agricultural Vehicles
(ICT-Agri)
[2016 – 2018]

TPR – Tomato Picking Robot
(Eurostars)
[2018-2020]

COVR – Safety for Collaborative Robots
(H2020-ICT)
[2018-2021]

TEDAI – Tethered drones for semi-automated inventory checking
(Eurostars)
[2018-2021]

Cobot Knowledge Lab
(national project)
[2019-2021]

SafeCOP –Safe Cooperating Cyber-Physical Systems using Wireless Communication
(ECSEL-JU)
[2016-2019]

R5-COP –Reconfigurable ROS-based Resilient Reasoning Robotic Cooperating Systems
(ECSEL-JU)
[2014-2017]

PaleBlue AS (PALEBLUE)

Description

- PaleBlue is a leading simulation company with experience in VR, AR and 3D simulators. 2019 Top 10 Simulation company.

- Founded in 2013 in Stavanger, Norway. Now offices in NO, NL, RU and US.
- Delivering simulators across segments for Oil & Gas (Neptune Energy), Space (NASA and ESA), Healthcare (Gullak), and Governmental.

PaleBlue AS (PALEBLUE)

Role in the Project

- Lead the development of the 3D and VR simulation platform components and interfaces to facilitate virtual environments for interactions between robots, humans and the environment.
- Lead the development of:
  - VR Multi-Human-Multi-Robot Interaction Component
  - VR Multi-Robot Component
  - VR Human-Robot Interaction Component
  - VR Agronomic-Oriented Perception
  - VR Farming Environment.

PaleBlue AS (PALEBLUE)

Role in the Project

- Leadership of Task T2.6 in WP2 (Virtual Reality Farming Environment Specifications)
- Leadership of Task T3.7 in WP3 (Simulated Environment and Basic Robotic Components)
- Leadership of Task T4.4 in WP4 (VR Agronomic-Oriented Perception Component)

PaleBlue AS (PALEBLUE)

Role in the Project

- Leadership of Task T5.4 in WP5 (VR Mobile-Robot Component)
- Leadership of Task T6.5 in WP6 (VR Human-Robot-Interaction Component)
- Leadership of Task T7.5 in WP7 (VR Multi-Robot Component)
- Leadership of Task T8.4 in WP8 (VR Multi-Human-Multi-Robot Interaction Component)

PaleBlue AS (PALEBLUE)

Team Members

Dr. Felix Gorbatsevich | Juan Correa | Vladimir Keda | Urte Villnow | Vladimir Dukhanin

PaleBlue AS (PALEBLUE)

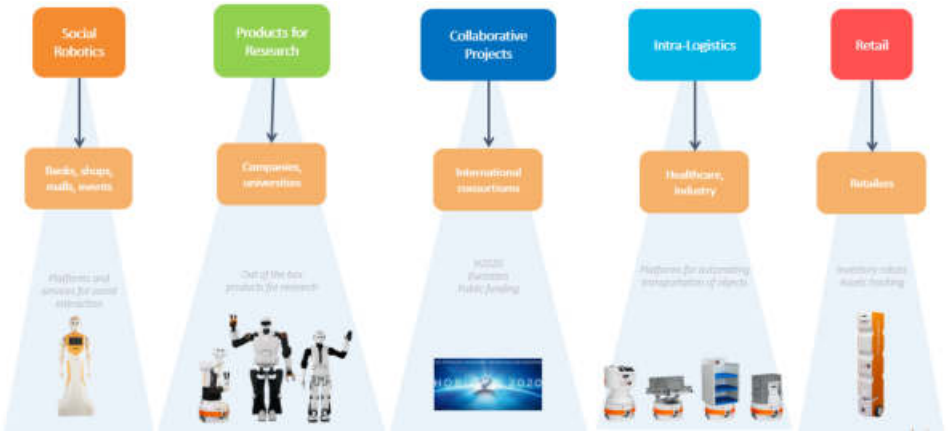
Expertise

- Training simulators
- Kinematic physics simulation
- Real-time 3D and Virtual Reality
- Multi-user collaboration
- Simulation for robotics

PAL Robotics (PAL)

- Founded in 2004
- Located in Barcelona
- 15 nationalities
- 80% Engineers
- 10% Ph.D.
- Robots sales +30 countries

PAL Robotics (PAL)



PAL Robotics (PAL)

Team

Principal Investigator

Francesco Ferro
francesco.ferro@pal-robotics.com
CEO

Project administration

Sarah Terreri
sarah.terreri@pal-robotics.com
European Project Manager

Research Team

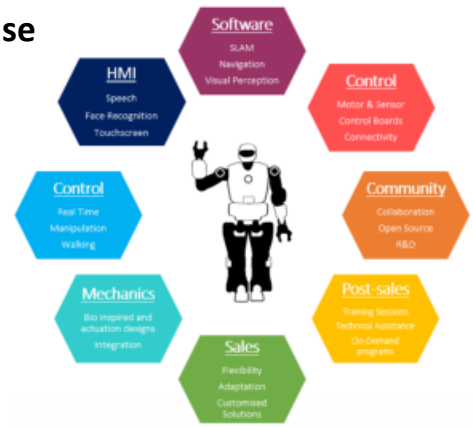
Dr. Alessandro Di Fava
alessandro.difava@pal-robotics.com
Robotics Engineer
Technical coordination of PAL Robotics' EU projects team

Dr. Jordi Pages
jordi.pages@pal-robotics.com
Head of Intra-logistics Solutions
TIAGo Product Manager

CANOPIES Internal Group
canopies@pal-robotics.com
Technical team

PAL Robotics (PAL)

Expertise



PAL Robotics (PAL)

Role in CANOPIES

- Agronomic dual arms system design (**T3.2 leaders**)
  - Starting point: PAL Robotics' **TIAGo++ upper body**
  - **Customizations** include: torque sensors for each arm's joint, 2 DoFs in the torso base, investigating the increase in IP rating for dust and water protection, etc.
- Agronomic end-effectors design for harvesting and pruning (**T3.3 leaders**)
- Expose a **hardware abstraction layer** with open interfaces for the mid-level control (WP3, WP5, WP6, WP8)
- Participation in Requirements, Validation, Dissemination and Exploitation activities (WP2, WP9, WP10, **T10.5 leaders**)
- Timeline
  - First Release of Robot Prototypes at **M14**
  - Final Release of Robot Prototypes at **M40**

Agrimessina (AGRIMESSINA)

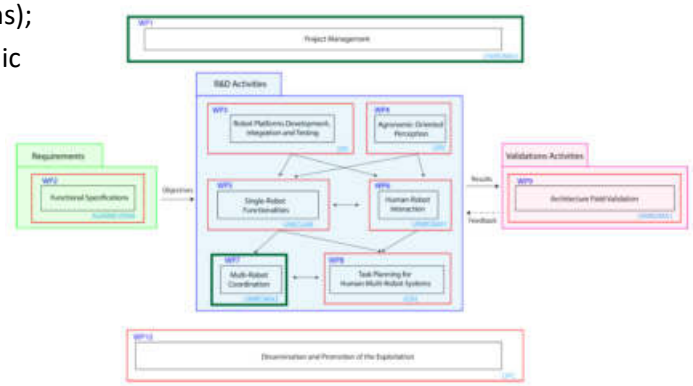
Description

- Table grapes grower and marketer since 1960;
- More than 12.000 Tons of grapes yearly harvested;
- 350 Hectare total production around Puglia;
- 60 varieties of table grapes (mostly seedless);
- Main Italian marketer in UK with 70% market share in supermarkets chain.

Agrimessina (AGRIMESSINA)

Role in the Project

- Leadership of WP2 (Functional Specifications);
- Leader in task 2.1 (Representative Agronomic Activities)
- Support in task 4.3 (Agronomic Quality Assessment);
- Support in task 5.1 (Two arms coordination Functionalities);
- Support in task 6.3 (Human-Robot Communication);
- Support in task 8.1 (Learning from Human Demonstrations)



Agrimessina (AGRIMESSINA)

Team

Francesco Messina

Agrimessina
sales manager

Giuseppe Valenzano

Agronomist

Agrimessina (AGRIMESSINA)

Expertise

- Table grapes agronomic aspects;
- Harvesting operations;
- Pruning operations;
- Post-harvest techniques;
- Table grapes industry.

RSA Srl (RSA)

Shorth Company profile

Founded in 2001, RSA is an Italian SME specializing in **management consulting services** for high-end innovation processes and industrial development. Main activities focus on:

(i) **Technical assistance** to facilitate client's access to European and Italian funding instruments such as:

- ✓ SMEs support funding for innovative industrial investments.
- ✓ R&D funding (Industry, Academia and PRBs).
- ✓ EFRD (2007-14; 2014-2020) funding schemes for innovation.
- ✓ FP6 - FP7 – **H2020** (mainly EASME funding schemes like SME Instrument, FTI).

(ii) **Project management** applied to Italian and EU [FP7, H2020, LIFE] funding schemes. Main activities include:

- ✓ Support partnership creation.
- ✓ Support structuring the project.
- ✓ Design and development of appropriate management structures (customized on project's needs)
- ✓ Proposal co-writing.
- ✓ Project's monitoring and coordination.

(iii) **Business planning & feasibility studies** to support Tech Transfer in Research infrastructures and SMEs) such as (active):

- ✓ **Socio-economic impact assessment** of EUPRAXIA research infrastructure in the regional (Lazio) and national context and study on **technological spill-over effects** (INFN-LNF).
- ✓ **Business planning and cost-effective resource management** of LATINO (Laboratory in Advanced Technologies for INnovation) and SABINA (Source of Advanced Beam Imaging for Novel Applications) innovation projects co-financed by EFRD Lazio Italian Institute for Nuclear Physics (INFN-LNF).

(iii) **Programme monitoring** (EFRD), **evaluation** (EFRD, Medio Credito Centrale, Italian Ministry for Economic Development - MISE), **external independent auditing** (EFRD, EAFRD, FP7, H2020); **anti-fraud auditing** (Medio Credito Centrale, Invitalia).

RSA Srl (RSA)

Role in CANOPIES

T1.2 Project Management.

This task deals with the implementation of all typical organizational and coordination actions relating to the management of the GA and CA. Main RSA activities will include:

- ❑ support the CO to run the overall management of the Project and workplan monitoring;
- ❑ support the CO in organizing all periodic meetings to be held among partners on a regular basis;
- ❑ support the Project Management Committee (PMC);
- ❑ keep track of the budget through the monitoring of the Use of the Resources (UoR) on a regular basis (every 6 months);
- ❑ support the CO as additional point of contact with the Commission for any contractual matter; liaison with EC, covering of review meetings, submission of deliverables, etc.

Assigned Deliverables: D1.1, D1.2, D1.3 + **Monitoring of UoR**

RSA Srl (RSA)

Staff involved

Dr. **Alessandro ALBINO FREZZA**

- ❑ Former Head of the Industrial Liaison Office and EU Fund Raising office at UNIROMA TRE (1996-2016). 25+ years of experience in the identification, designing and management of Research and Technological Development projects (R&TD) and TT Initiatives at international (including EC Framework Programmes), national and local level.
- ❑ Expert in accessing and managing multi-partner initiatives in the field of, collaborative research (Academia – SMEs), industrial research and SMEs support.
- ❑ EU Projects management (including financial auditing).
- ❑ Technical. assistance for the implementation of local development integrated projects (EFRD, ESF). Independent expert evaluator for R&TD projects (FP6, H2020-EIC-FTI-2018-2020_23-05-2019, H2020-SC1-PHE-CORONAVIRUS-2020-2) and Italian regional development programmes within EFRD ESF funds.
- ❑ Active H2020 coordination tasks:
  - ✓ GISCAD-OV - Galileo Improved Services for Cadastral Augmentation Development On-field Validation (GA No. 870231) - H2020-SPACE-EGNSS-2019 – Type of Action IA
  - ✓ FLASH - Far-infrared Lasers Assembled using Silicon Heterostructures (GA No. 766719) - H2020 FETOPEN-1-2016-2017 – Type of Action RIA
  - ✓ PANTHEON - Precision Farming of Hazelnut Orchards (GA No. 774571) - H2020-SFS-2017-1 – Type of Action RIA.

Let’s Now Enjoy the Coffee Break!!!

Don’t be shy!

Let’s get to know each other!

A Collaborative Paradigm for Human Workers and Multi-Robot Teams in Precision Agriculture Systems

Project Overview, Ambition and Objectives

This project is funded by the European Union
G.A No 101016906

1

CANOPIES – Where it all started…

International Forum of Agricultural Robotics 2019 (FIRA 2019)

- Discussion with *Giuseppe Valenzano*
- Real-Needs of the Farmers
  1. **Shortage** of farmworkers
  2. **Standardized quality** of table-grape
  3. **Modern sustainable** operational model
- Meeting with *Francesco Messina* and *Giuseppe Valenzano*

2

Call: H2020-ICT-2018-20 (ICT-46-2020)

Specific Challenge - Overview

- While robots originated in large-scale mass manufacturing, they are now **spreading** to more and more application areas.
- In these new settings, robots are often faced with **new** technical and non-technical **challenges**.
- This topic addresses these issues in a **modular** and **open** way and **reduce** the **barriers** that prevent a more widespread adoption of robots.

Call: H2020-ICT-2018-20 (ICT-46-2020)

Specific Challenge - Priority Areas

Four Priority Areas (PAs) are targeted:

- Healthcare
- Inspection and maintenance of infrastructure
- **Agri-food**
- Agile production

Call: H2020-ICT-2018-20 (ICT-46-2020)

Specific Challenge - Ambition

- Develop appropriate **autonomous capability** that has **impact on the efficiency** of key applications in the Priority Areas and moves **beyond** the current **state of the art**.
- Autonomous capability should be built from **core technologies** and should be proved and tested through **pilot demonstrators** that embed within **real or near real environments**.

Call Overview: H2020-ICT-2018-20

Scope: Research and Innovation Actions (RIA) - Robotics Core Technology

- **AI and Cognition**: AI provides tools to make systems cognitive. Cognition equips robots with the ability to safely interact with people, their environments or other robots, to learn and to categorise, to make decisions and to derive knowledge.
- **Cognitive Mechatronics**: Mechatronic systems where sensing and actuation are closely coupled with cognitive systems are expected to deliver improved control, motion, interaction (including all modalities), adaptation and learning, and safer systems.
- **Socially cooperative human-robot interaction**: Cooperative human-robot interaction is critical in many work environments from collaborative support, e.g. passing tools to a worker, navigation in complex work environments, human-friendly and human assistive interactions, to the design of exo-skeletons able to provide motion that is sympathetic to the user.
- **Model-based design and configuration tools**: Deploying robotics at scale in application areas where tasks need to be defined by the user requires easy-to-use configuration tools. Embedding and sharing of knowledge between tools is essential, as is standardisation across the interfaces to connect systems and modules (taking into account cybersecurity issues, including security by design and data integrity).

Call Overview: H2020-ICT-2018-20 (ICT-46-2020)

Expected Impact

- Improved technical capability in each of the core technologies over the current state of the art.
- A greater range of applications in the prioritized application areas that can be demonstrated at TRL 3 and above.
- The lowering of technical barriers within the prioritized applications areas.

Call: H2020-ICT-2018-20

Call Overview

- Topic: ICT-46-2020
- Type of Action: RIA – IA – CSA
- Overall Submissions: 136 proposals
- Funded Research and Innovation Action (RIA): 6 proposals
- Funded Innovation Action (IA): 6 proposals
- Funded Coordination and Support Action (CSA): 1 proposal

Call: H2020-ICT-2018-20 (ICT-46-2020)

CANOPIES in a nutshell

- Type of Actions: RIA
- Priority Area: Agri-Food
- Robotics Core Technology: Socially cooperative human-robot interaction
- Expected Impact: **TRL 6**
- Budget: **€ 6 904 940**
- Consortium: 5 Countries, 5 Universities, 1 Research Center, 4 SMEs

Motivation: PA and Farming Future

The New Challenges Facing Agriculture

- The Agri-Food Sector is one of the most important **providers of livelihoods** and is central to the **fight against poverty and hunger**
- One challenge is **how to feed** the increasing world population without expanding the amount of land allocated to farming
- Another challenge is the **lack of farm workers**, due to the seasonal nature of the work and the migration of workforce to more stable productive sectors

Motivation: PA and Farming Future

The New Challenges Facing Agriculture

- The three major challenges of the agri-food sector are:

  i) **feeding** a **growing** population;
  ii) providing a **livelihood** for farmers and farmworkers,
  iii) **protecting** the environment.

Motivation: PA and Farming Future

The Role of Precision Agriculture (PA)

*"PA is a **management strategy** that gathers, processes and analyses **temporal**, **spatial** and **individual data** and combines it with other information to **support management decisions** according to **estimated variability** for **improved resource use efficiency**, **productivity**, **quality**, **profitability** and **sustainability** of agricultural production"*

[cit. International Society of Precision Agriculture (www.ispa.org)]

Motivation: PA and Farming Future

The Role of Precision Agriculture (PA)

- PA can make a significant contribution to **food security** and **safety**:
  - Producing more with less by enhancing food safety and plant health.
- PA can promote more **sustainable** ways of **farming**:
  - Environmentally friendly and generate sustainable productivity gains.
- PA will trigger wider **societal changes**:
  - Enhancement of work practice, farmland conditions and business models;
- PA requires the learning of **new skills**:
  - technological skills; environmental skills; and managerial skills.

Motivation: PA and Farming Future

How Robotic Technology could make a difference

- Intelligent agricultural robots improve **repeatability**, **precision**, **operational consistency** and **efficacy** and minimize soil compaction and drudgery.
- Robots with human-like or improved skills can can help **mitigate** labour shortages and can be adapted to **human-unfriendly** operating conditions.
- **Scalability** over large fields can be achieved by deploying fleets of robots and by developing tailored **Multi-Robot Coordination** (MRC) strategies.

Motivation: PA and Farming Future

How Robotic Technology could make a difference

Agricultural Robots must possess various capabilities:

- Safety: robots must never cause harm to humans, to animals or valuable items, despite working in largely unstructured and dynamic environments.
- Flexibility: robots should be **easily reconfigurable** based on crop parameters (variety, size, maturity) and based on the given agronomic intervention;
- Adaptability: robots should **adapt** to different working conditions (e.g., different terrain, soil and wheatear conditions) by **learning while working** *from human and/or from experience*

Motivation: PA and Farming Future

Why Agriculture needs Humans

- Humans within the system provide additional benefits for handling **complex tasks** and/or **unexpected situations**, detecting and correcting **anomalies** during task execution and **supporting** automated decision making.
- **Multiple task modes** can be envisaged, where the **level of autonomy** can be changed according to the task, operating conditions and robot capabilities (which might change over time if the robots can learn).
- Humans **complement** the robot by making the overall system **flexible** and **adaptive** in **unpredictable** situations, where robots alone would fail.

Motivation: PA and Farming Future

Let us put together all the ingredients…

- Full autonomy would be hard (is possible at all) to achieve for **highly dynamic** outdoor environments such as for the PA of permanent crops
- An integrated system where farmworkers can **safely collaborate** with multi-robot systems will facilitate the **acceptance** and **usability** of the technology
- Efficient and intuitive Human-Robot interaction (**HRI**) along with Human-Robot Collaboration (**HRC**) skills are mandatory

Vision

A Collaborative Paradigm for Human-Multi Robot Cooperation in PA

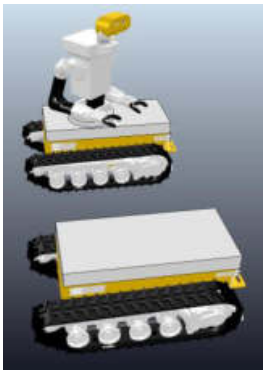
*CANOPIES aims to develop novel human-robot interactions (**HRI**), human-robot collaboration (**HRC**) and multi-robot coordination (**MRC**) methodologies for implementing an **effective collaborative paradigm** between **human workers** and **multi-robot teams** in **Precision Agriculture** systems.*

Vision

A Collaborative Paradigm for Human-Multi Robot Cooperation in PA

We envision a PA setting where **farmworkers interact** with **two** different **kinds** of **robot platforms**:

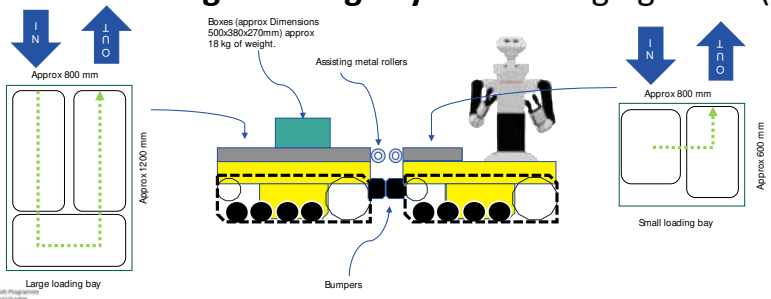
- a farming robot (**F-R**): dedicated to the execution of **agronomic tasks** such as harvesting the fruits or pruning the vines;
- a logistics robot (**L-R**): dedicated to the execution of **logistics tasks** such as the transportation of boxes of harvested grapes or removed branches.



Vision

A Collaborative Paradigm for Human-Multi Robot Cooperation in PA

- **F-R** is equipped with **two arms** for executing agronomic tasks in a human-like manner and **small loading bay** for exchanging boxes (F-R BEM)
- **L-R** is equipped with a **large loading bay** for exchanging boxes (L-R BEM)



Vision

A Collaborative Paradigm for Human-Multi Robot Cooperation in PA

Tight collaboration between human workers and farming robots:

- Each **farmworker** interacts with a **small team of robots** to **supervise** and **facilitate** robot activities and help with agronomic or robotic tasks.
- The human operator may:
  - **improve** agronomic task execution: e.g., during the harvesting operation by removing single ruined fruits belonging to clusters to be harvested;
  - **assist** the farming platform: e.g., with the harvest by cutting any harvest-quality bunch of fruits which the robot fails to detect or cannot cut;

Vision

A Collaborative Paradigm for Human-Multi Robot Cooperation in PA

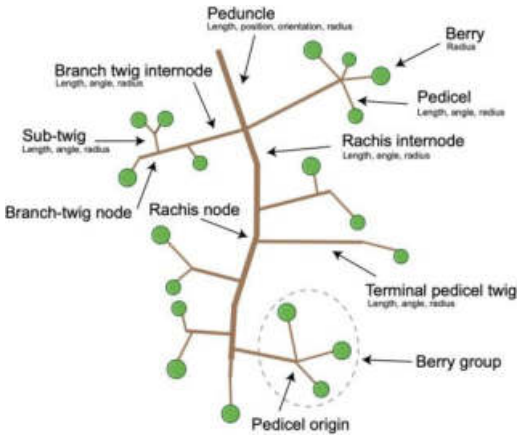
Tight cooperation between farming robots and logistic robots:

- L-R side: scheduling the **provision** of services in such a way to **minimize** the occurrence of any **peak of inactivity** for the F-Rs
- F-R side: scheduling the **request** of services in such a way to **minimize** the occurrence of any **peak of requests** for the L-Rs.

Case Study

Table-Grape Vineyard

- Produced for **direct consumption** while **fresh**
- **Extreme care** is required due to
  - the **fragility** of the table-grape
  - the **long productive** life of the vine



Case Study

Pergola Training System

Overhead shade structure usually supported with some form of columns

- **Vines** are **trained** on this overhead structure so that the **fruit** develops **under** the canopy
- In this way fruits are
  - **easy** to **reach**
  - **protected** from **sunburn**

Case Study

Agronomic Interventions

Task	Human	Robot
Harvesting (July-September)	• Identification of clusters • Assurance of quality control • Proper management of harvested clusters • Human positioning for optimal cutting process • Logistic organization in field • Searching for clusters hidden behind leaves • Confirming a suggested cutting point	• Localization of ripe, top quality clusters and particularly the peduncle • Generating movements to detect position of clusters • Identification of good quality clusters through image evaluation (colour, shape, size…) • Precise positioning of cutting devices • Location of optimal cutting position for multiple clusters at the same location • Accurate management of clusters to avoid damage • Careful box-filling process
Pruning (December-January)	• Define optimal position of selected buds allowed to become grape clusters • Identify optimal cutting point for branches to be removed • Evaluate the average number of remaining branches in the managed zone	• Identify branches to be removed and cutting site • Optimal placement of cutting devices • Removing process rejected buds • Identification of optimal distance between remained buds

Objectives

Three Macro Objectives

1. **Human-Robot Interaction**
2. **Human-Robot Collaboration and Multi-Robot Coordination**
3. **PA Integrated System**

Objectives

Objective-1: Human-Robot Interaction (HRI)

- Develop novel **perception** and **collaborative** techniques to promote and facilitate the **interaction** between the human workers and the robotic platforms

- Four Specific Objectives are identified:
  - **Safe HRI** in shared outdoor workspaces both with and without physical interaction
  - **Predicting future positions** of human torso and arms in motion
  - **Efficient communication** between robots and humans
  - Enable both parties to be **fully aware** of **each other intentions**

Objectives

Objective-2: Human-Robot Collaboration (HRC) and Multi-Robot Coordination (MRC)

- Development of **techniques** and **control strategies** for **collaborative implementation** of agronomic operations

- Four Specific Objectives are identified:
  - **Human-like bimanual** robot **manipulation** leading to intuitive HRC
  - Successful robot programming using **learning by demonstration** (LbD)
  - Learning from unexpected events with **human-in-the-loop**
  - **Multi-robot coordination** for collaborative tasks

Objectives

Objective-3: PA Integrated System

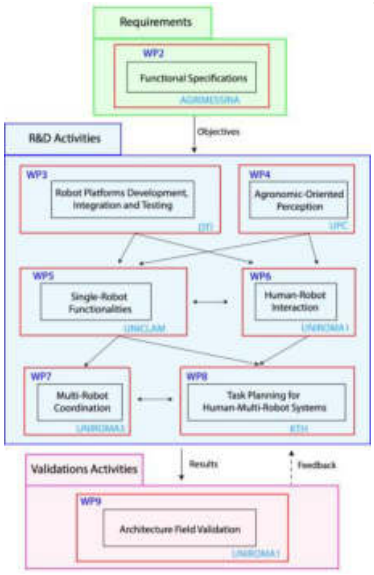
- Develop and implement the elements needed for a **physical demonstration** of the HRI, HRC, and MRC objectives in a permanent crops **piloting scenario**.

- Three Specific Objectives are identified:
  - **Collaborative robots** capable of carrying out the required **agronomic tasks** safely
  - **Simulated farming environments** for algorithm prototyping
  - **Table-Grape vineyard** case-study implementation

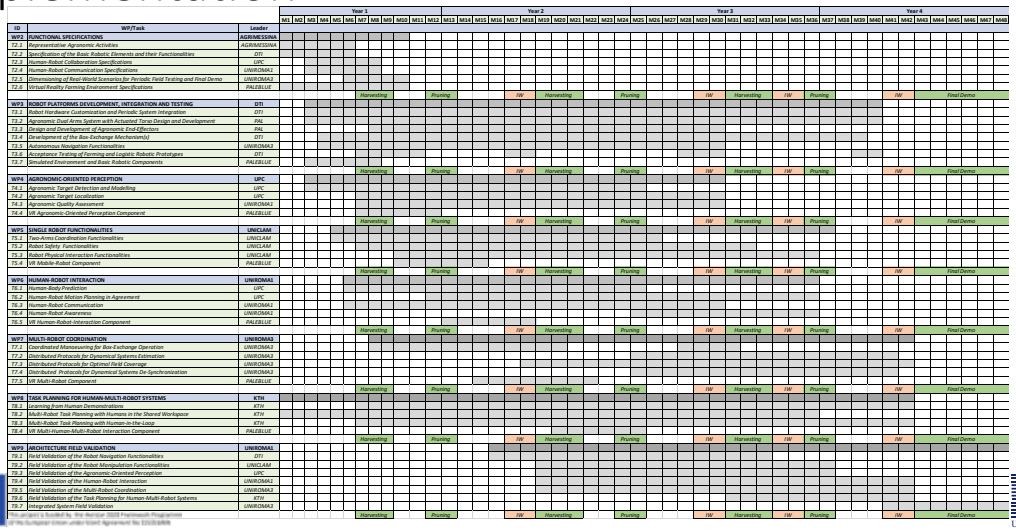
Implementation

Work Plan

WP No	Work Package Title	Lead Participant Short Name	Start Month	End month
1	Project Management	UNIROMA3	M1	M48
2	Functional Specifications	AGRIMESSINA	M1	M10
3	Robot Platforms Development, Integration and Testing	DTI	M3	M40
4	Agronomic-Oriented Perception	UPC	M3	M30
5	Single Robot Functionalities	UNICLAM	M5	M36
6	Human-Robot Interaction	UNIROMA1	M6	M36
7	Multi-Robot Coordination	UNIROMA3	M8	M42
8	Task Planning for Human-Multi-Robot Systems	KTH	M7	M42
9	Architecture Field Validation	UNIROMA1	M16	M48
10	Dissemination and Promotion of the Exploitation	UPC	M1	M48



Implementation



Implementation

Milestones

Milestone Number	Description	Related WP(s)	Due date	Means of verification
MS1	All technical specifications finalised	WP2	M6	Deliverable D2.1
MS2	First Release of Farming and Logistic Robot Prototypes	WP3	M14	Deliverable D3.2
MS3	Final Release of the VR Farming Environment	WP [3,4,5,6,7,8]	M25	Software Released and Validated by a User Group
MS4	Robotic Navigation and Coordination Field Validation	WP9	M33	Deliverable D9.1
MS5	Human-Robot Interaction: Safety and Communication	WP5, WP6	M36	Deliverables D5.2, D6.2
MS6	Human-Robot Collaboration: Planning in Agreement, Task Planning	WP6, WP8	M36	Deliverables D6.1, D8.1
MS7	Experimental validation of the integrated system with respect to the pilot scenario	WP9	M48	Deliverable D9.4

Implementation

Common Development Platform

- To **reduce** the **risk of compatibility** issues and **speed up** the **integration** process
- **Promote** the **interaction between partners** and **facilitate interaction** between robot components
- **Facilitate** intermediate **algorithm validation** during the development stage
- A set of **best practices** and **guidelines** to produce code and documentation **must be discussed**

Implementation

Assessment

- Hardware and software components will be tested before each operational period, i.e., in **June** before harvesting and in **November** before pruning.
- Each robotic prototype will go through **full testing** and **safety assessment** under **laboratory conditions** at DTI (Factory Assessment Test - FAT).
- During the **integration weeks**, all **changes** will be **evaluated** in **in-field testing** before the in-field validations (Site Acceptance Test - SAT).

Implementation

Integration Weeks (IWs)

- **Full weeks** during which partners will **work together** to **integrate** the developed components and **check** for potential issues.
- **Four IWs** are envisioned over the project duration:
  - **One** at the **second year** before harvesting season,
  - **Two** at the **third year** before harvesting and pruning seasons,
  - **One** at the **fourth year** before the final demo
- IWs **costs** have been **included** in the budget of each Partner.

Implementation

Piloting at "Cooperativa Agricola Corsira"

- A **community** of about 20 small producers in the municipality of Aprilia, Lazio, Italy
- Vineyards trained on a **pergola** trellis system
- **Planting Pattern**: 2,60 x 2,60 m
- **Height**: 1,85 – 1,95 m
- **Varieties**: Vittoria, Matilde, Pizzutello

CANOPIES LOGO

Design Credits

- **Delia García**
  - Graphic Designer @ PAL ROBOTICS

N.B: Thanks to everybody for the help provided in the definition the logo!!!

CANOPIES LOGO

CANOPIES LOGO

CANOPIES LOGO

LOGOTYPE

Thanks for your attention!!!

A Collaborative Paradigm for Human Workers and Multi-Robot Teams in Precision Agriculture Systems

WP1 - Project Management

This project is funded by the European Union G.A No 101016906

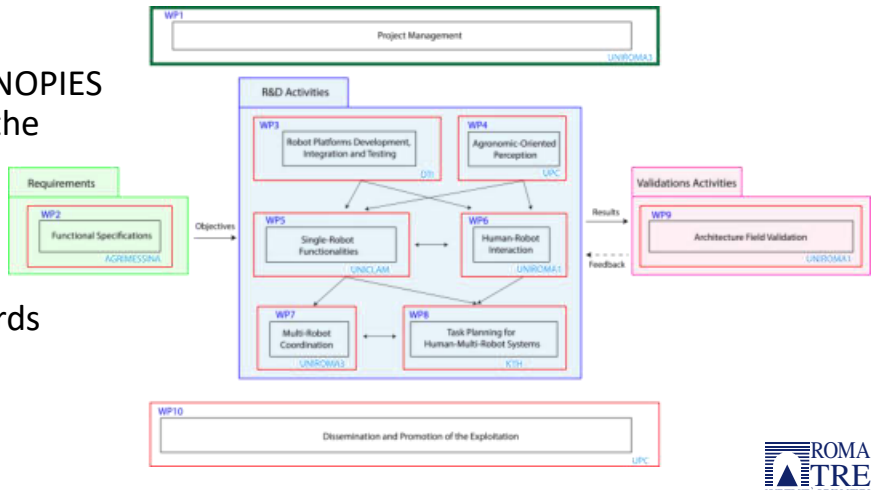
1

Project Management

Goal:

To guarantee that CANOPIES evolves according to the defined:

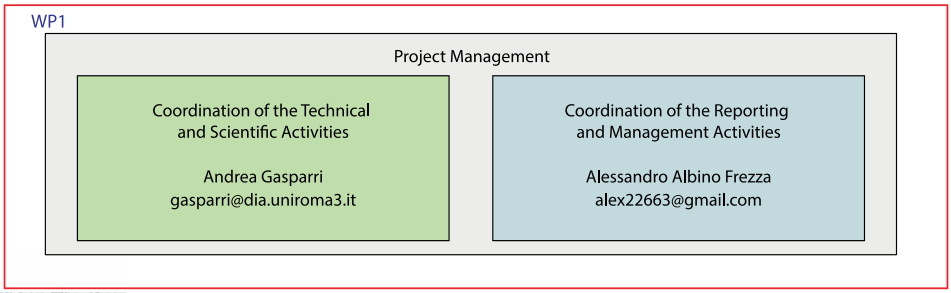
1. Time schedule
2. Budget
3. Quality standards



2

Objectives

- Objective 1 – Coordination of the **technical** and **scientific** activities (**UNIROMA3**)
- Objective 2 – Coordination of the **reporting** and **management** actions required by the H2020 procedures (**RSA**)



Tasks Description

Task 1.1 – Technical and Scientific Coordination [M1-M48]

(Leader: **UNIROMA3**)

Partner	UNIROMA3	KTH	UNIROMA1	UPC	UNICLAM	DTI	PALEBLUE	PAL	AGRIM.	RSA
PM	6	1	1	1	0	0	1	1	0	0

Task 1.2 – Management [M1-M48]

(Leader: **RSA**)

Partner	UNIROMA3	KTH	UNIROMA1	UPC	UNICLAM	DTI	PALEBLUE	PAL	AGRIM.	RSA
PM	0	0	0	0	0	0	0	0	0	36

Tasks Description

Task 1.3 – Risk Assessment [M1-M48]

(Leader: **UNIROMA3**)

Partner	UNIROMA3	KTH	UNIROMA1	UPC	UNICLAM	DTI	PALEBLUE	PAL	AGRIM.	RSA
PM	6	1	1	0	2	2	0	0	1	0

Deliverables

D1.1: Project Management Guidelines	Leader: RSA	Delivery Month: **M1**
It comprises the guidelines for all partners on the procedures to be followed for fully complying with the EC procedures on scientific, technical and financial reporting		
D1.2: KoM Report	Leader: RSA	Delivery Month: **M1**
It collects the outcome of the kick-off meeting.		
D1.3: Monitoring on the Use of the Resources (UoR)	Leader: RSA	Delivery Month: **M6-M12-M24-M36-M42**
It tracks the UOR and provides updates on the reshaping of the GANTT chart and of the effort distribution by the partners.		
D1.4: Risk Assessment and Contingency Plan	Leader: UNIROMA3	Delivery Month: **M4**
It provides the plan for the constant monitoring of proper synchronization of the partners contributions and of the project activities so to respect the project timeline and to assess actual risk and anticipate future criticalities.		

Risk Assessment – Goal and Main Actions

Goal:

- Identification of the challenges of the **research activates**
- Identification of the challenges of the **implementation process**

Main Actions:

- Definition of a set of **performance** and **qualitative metrics** and **standards**
- **Constant monitoring** for a prompt detection of relevant future criticalities
- **Timely proposition** of adequate countermeasures and mitigation actions

Risk Assessment – Risks Taxonomy

Risks Taxonomy

Five different kind of risks were identified at proposal time:

- **Safety** Risks (human-robot interaction, …)
- **Technological** Risks (HW/SW components integration, …)
- **Experimental** Risks (development delays vs. vegetative seasons, …)
- **Research** Risks (computation, communication, VR environment, ...)
- **Management**, **Dissemination** and **IPR** Risks (performances, visibility, …)

T1.2 main actions and expected outputs

- Support the CO to run the overall management of the Project.
- Support the Project Management Committee (PMC).
- Keep track of the budget through the monitoring of the Use of the Resources (UoR) on a regular basis.
- Support the CO as additional point of contact with the EC for any contractual matter; covering of reporting periods, submission of deliverables, etc..
- Support the CO in organizing all periodic meetings to be held among partners on a regular basis.

- ❖ Deliverable D1.1 – Project Management Guidelines
- ❖ Deliverable D1.2 – KoM Report
- ❖ Deliverable D1.3 – Monitoring of the UoR @ M06 (!)

(!) Additional monitoring of UoR:
M12, M24,M30, M42

D1.1 Project management guidelines

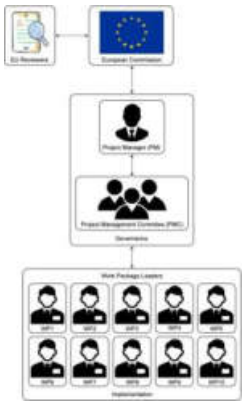
❑ **Scope**:

- To complement the existing binding project documentation including GA and CA.
- To set and clarify the procedures to be followed within CANOPIES to ease its smooth implementation.
- To be considered as a live document; some sections may be updated over the time based on the decision of the PMC

❑ **Content**:

- Governance
- Financial management
- Periodic Reporting
- Monitoring of UoR
- Project documents
- Deliverables

Governing and decisional structure



- **Coordinator (CO)** responsible for the overall management, communication, and coordination of CANOPIES. Prof. **Andrea GASPARR**I (gasparri@dia.uniroma3.it) is the representative of the CO (UNIROMA TRE) and the PI in charge of coordinating and supervising all the scientific aspects of the project.
- **Project Management Committee (PMC)** is chaired by the CO. It is composed by one representative of each beneficiary. Each beneficiary shall nominate a senior representative with budget responsibility, enabling to take consistent decisions and to represent the beneficiary's' interests. The PMC will be empowered to make decisions affecting the budget and the objectives of the project.
- **Work Package Leaders (WPLs)** are responsible for the proper and timely performance of the respective work packages according the work plan and the objectives of the project. Each WPL is responsible for the progress control and the successful completion of the work package as well as timely delivery of project milestones and deliverables.
- **Project Manager (PM)** This role is assigned to partner # 10 RSA. The PM will fully support the CO in the interaction with the EC and the Consortium to supervise the financial and administrative progress of the project and to coordinate and ensure a constant and timely communication among the beneficiaries.

(!) PMC Members to be appointed at KoM

Financial management

(EURO)

Total costs	Max EC Grant amount	Prefinancing amount	Guarantee Fund (5%)	Actual prefinancing
6.904.940,00	6.904.940,00	3.682.634,67	345.247,00	3.337.387,67

#	Beneficiary	Project costs (GA)	Max EC Grant amount	Project share	Prefinancing amount
1	UNIROMA3	910.960,00	910.960,00	13,19%	440.297,33
2	KTH	883.125,00	883.125,00	12,79%	426.843,75
3	UNIROMA1	741.888,75	741.888,75	10,74%	358.579,56
4	UPC *	765.830,00	765.830,00	11,09%	370.151,17
5	UNICLAM	739.375,00	739.375,00	10,71%	357.364,58
6	DTI	886.198,75	886.198,75	12,83%	428.329,40
7	PALEBLUE	797.812,50	797.812,50	11,55%	385.609,38
8	PALROBOTICS	847.500,00	847.500,00	12,27%	409.625,00
9	AGRIMESSINA	132.500,00	132.500,00	1,92%	64.041,67
10	RSA	199.750,00	199.750,00	2,89%	96.545,83
	TOTAL	6.904.940,00	6.904.940,00	1,00	3.337.387,67

** including third party CSIC*

The following are the payments made/to be made by the EC (GA Art. 21.1):

- **One pre-financing payment**: processed by the EC and the CO (**03/02/2021**)
- **Two interim payments** (GA Art. 21.3) made within 90 days from receiving the periodic reports at the end of P1 and P2. The total amount of pre-financing and interim payments must not exceed 90% of the maximum grant amount set out in art. 5.1 of the GA.
- **One payment of the balance** (GA Art. 21.4) reimbursing the remaining part of the eligible costs incurred by the beneficiaries. At the payment of the balance, the amount retained for the Guarantee Fund will be released.

Periodic reporting

CANOPIES is divided into **3 reporting** periods covering M1-18 (RP1) M19-36 (RP2) and M37-M48 (RP3) plus the **final reporting**. The CO must submit a Periodic Report within 60 days following the end on each reporting period.

The **periodic report** must include the following:
- ❑ a periodic **technical report**
- ❑ a periodic **financial report**, containing the **individual financial statements (FS)**

Technical Report
Each Beneficiary must provide in good time the data needed for the technical reports. Contributions are expected from all partners monitored through the WPLs. Revisions, if required for the report's final acceptance, are managed by the CO.

Financial report: the CO and the PM will provide support/supervision:
- by informing about required documents;
- by clarifying how to enter figures into SyGMa;
- and by reviewing the cost explanations for consistency and completeness.

Beneficiaries will autonomously enter their financial information into **SyGMa**, electronically sign the **FS** and submit them to the CO.

Monitoring of the UoR and related costs

- ❑ The **allocation of resources is controlled on a half-year basis** by the CO supported by the PM. First results of this monitoring exercise are to be included in **Deliverable D1.3**.
- ❑ The additional six-months- based assessments shall be carried out (at M12 – M24 – M30 – M42) for **internal purposes**.
- ❑ Beneficiaries will be asked to report the **distribution of their Person Months**; data will be reviewed by the CO, supported by the PM, mainly to verify whether the efforts are consistent with those planned in the Annex I and reflect the actual flowing of the project according to the active GANTT.
- ❑ This data collection will allow the CO to track the manpower allocation per partner throughout the project and therefore will provide a detailed summary of **planned versus actual** Person Months deployed for mere internal controlling purposes.
- ❑ Each beneficiary will also be asked to **justify any major overuse/underuse** of Person Months to make sure that the deviations from the planned scheme will not result in an overall delay of the project or otherwise jeopardize the project's objectives.

Project documents: preparation & approval chain

Type of document	Prepared by	Approved by
Deliverables	TS	WPL - RW - CO
Technical notes	TS	WPL - RW - CO
Coordination memos	CO - PM	CO
Minutes of meetings	WPL (WP meetings) - CO/PM	WPL - CO - BEN

TS: Technical Staff
MS: Mamagement staff
CO: Coordinator
WPL: Work Package Leaders
RW: Internal rewievers
PM: Project Manager

- A set of general templates for the deliverables and internal/external presentations has been prepared by the CO and will be made available to all beneficiaries. During CANOPIES' implementation, a wide range of documents will be widely used, either for internal use, for reporting to the EC or for dissemination and exploitation purposes.

Deliverables 1/3

- ❑ The project's workplan includes 10 Work Packages and 37 deliverables. One additional WP (WP11) and 4 deliverables have been generated by the EC to comply with the H2020 Ethics Requirements.
- ❑ Main authors and internal reviewers of the technical deliverables to be submitted in the first 12 months of the project, will be identified by the CO and the WPL following the technical discussion to be held during the KoM meeting. Adjustments, if needed, will be adopted during project implementation.
- ❑ Authors and reviewers for the additional technical deliverables will be identified on a yearly basis. There will be at least one internal reviewer per deliverable.
- ❑ D1.1 and D1.2 will be reviewed and approved by the CO before the submission. The CO has already agreed with the PO the delay of the submission of D1.1 and D1.2 by M2. The same applies to D1.3
- ❑ As indicative internal work schedule for the timely production of the deliverables, some 6 weeks will be devoted to the preparation of the deliverables; in addition, 1 week/10 days will be dedicated to the internal review. Timing is subject to variations according to the complexity of the deliverables themselves.

Deliverables 2/3

Each technical deliverable (Report) should respect the following customary structure:

- **Executive Summary** – a brief summary of the key points of the main document
- **Table of Con**tent
- **Abbreviations and Acronyms**
- **Introduction** – an outline of the aims and objectives of the deliverable and where it fits in the context of the CANOPIES project.
- **Main body of the report** – this section will explain the task that was carried out and the results generated and illustrate the technical and scientific progress made within the task.
- **Conclusions** – summarizing the major outputs of the deliverable and the implications of the results on other parts of the project or the impact on that the results will have for the CANOPIES stakeholders and targeted users' community. The conclusions should also highlight the deficiencies in the work carried out and where future improvements or further work should be directed.
- **References**
- **Annexes**

This is the proposed structure to correctly encode the deliverables and facilitate their tracking and storage:

[CANOPIES]-WPX_D.X.x_V.X.x_[DRAFT/FINAL/SUBMITTED] _YYYMMDD

Deliverables 3/3

Due dates		Deliverables						Lead beneficiary			
Jan-21	M1	**D1.1**	**D1.2**					**RSA**			
Feb-21	M2	D10.1						UPC			
Mar-21	M3	D10.3	*D11.1*					UPC	UNIROMA3		
Apr-21	M4	D1.4	D2.1					UNIROMA3	AGRIMESSINA		
May-21	M5										
Jun-21	M6	D1.3	D2.2	D10.2	***D11.2***	***D11.3***	***D11.4***	RSA	DTI	UPC	**UNIROMA3**
Jul-21	M7										
Aug-21	M8	D3.4						PALEBLUE			
Sep-21	M9										
Oct-21	M10	D2.3	D2.4	D3.1				UNIROMA3	PALEBLUE	DTI	
Nov-21	M11										
Dec-21	M12	D4.3	**UoR**					PALEBLUE	RSA		
Jan-22	M13										
Feb-22	M14	D3.2						DTI			
Mar-22	M15	D5.4						PALEBLUE			
Apr-22	M16										
May-22	M17										
Jun-22	**M18**	D6.4						PALEBLUE			
Jul-22	M19										
Aug-22	M20	D7.1						UNIROMA3			
Sep-22	M21										
Oct-22	M22	D7.3						PALEBLUE			
Nov-22	M23										
Dec-22	M24	**UoR**						RSA			
Jan-23	M25	D8.4						PALEBLUE			
Feb-23	M26	D5.1						UNICLAM			
Mar-23	M27										
Apr-23	M28										
May-23	M29										
Jun-23	M30	**D4.1**	**D4.2**	D6.2	**UoR**			**UPC**	UNIROMA1	RSA	
Jul-23	M31										
Aug-23	M32	D5.2						UNICLAM			
Sep-23	M33	D9.1						DTI			
Oct-23	M34										
Nov-23	M35										
Dec-23	**M36**	D5.3	**D6.1**	**D6.3**	D8.2			UNICLAM	**UNIROMA1**	KTH	
Jan-24	M37										
Feb-24	M38										
Mar-24	M39										
Apr-24	M40	D3.3						DTI			
May-24	M41										
Jun-24	M42	D7.2	**D8.1**	**D8.3**	D9.2	**D9.3**	**UoR**	UNIROMA3	**KTH**	UPC	RSA
Jul-24	M43										
Aug-24	M44										
Sep-24	M45										
Oct-24	M46										
Nov-24	M47										
Dec-24	**M48**	D9.4						UNIROMA1			

Project Management Guidelines

The Project Management Guidelines (D1.1) are intended to be a quick reference guide complementing the Grant Agreement and the Consortium Agreement.

Further guidelines may also be found on the EC Participant Portal within the H2020 Online Manual:

https://ec.europa.eu/research/participants/docs/h2020-funding-guide/index_en.htm

If further assistance or advice is required, please contact:

- CO – Prof. Andrea GASPARRI – andrea.gasparri@uniroma3.it
- PM – Dr. Alessandro ALBINO FREZZA – alex22663@gmail.com;

Technical Discussion (Management Structure)

1. **Project Management Committee (PMC)**
   - Partner Representative Appointment
2. **Work Package Leaders (WPLs)**
   - Partner Representative Appointment for the Leadership of each WP

N.B.: Each WP Leader is responsible for the appointment of the Partner Representative of each Task Leader. This information should then be shared with the PI and the PM.

Let’s move on to the next WP…

Any questions?

A Collaborative Paradigm for Human Workers and Multi-Robot Teams in Precision Agriculture Systems

WP2 – Functional Specifications

This project is funded by the European Union
G.A No 101016906

1

Objectives

- Objective 1 – Best practice & functional specifications analysis;
- Objective 2 – Functional requirements & benchmarking;
- Objective 3 – Define table grapes scenario for final validation;
- Objective 4 – ELS issues (Ethical, Legal and Societal).

Tasks Description

Task 2.1 – Representative Agronomic Activities: Requirements, Specifications and Performance Indexes [M1-M6]

(Leader: **AGRIMESSINA**)

Partner	UNIROMA3	KTH	UNIROMA1	UPC	UNICLAM	DTI	PALEBLUE	PAL	AGRIM.	RSA
PM	1	0	0,5	1,5	0	0	0	0	2	0

Task 2.2 – Specification of Basic Robotic Elements and their Functionalities [M1-M6]

(Leader: **DTI**)

Partner	UNIROMA3	KTH	UNIROMA1	UPC	UNICLAM	DTI	PALEBLUE	PAL	AGRIM.	RSA
PM	1	1	0	0	1	3	0	2	1	0

Tasks Description

Task 2.3 – Human-Robot Collaboration Specifications [M3-M8]

(Leader: **UPC**)

Partner	UNIROMA3	KTH	UNIROMA1	UPC	UNICLAM	DTI	PALEBLUE	PAL	AGRIM.	RSA
PM	0	1	0	1,5	1	0	0	1	1	0

Task 2.4 – Human-Robot Communication Specifications [M3-M8]

(Leader: **UNIROMA1**)

Partner	UNIROMA3	KTH	UNIROMA1	UPC	UNICLAM	DTI	PALEBLUE	PAL	AGRIM.	RSA
PM	0	1	2	0	0	1	0	1	1	0

Tasks Description

Task 2.5 – Dimensioning of Real-World Scenarios for Periodic Field Testing and Final Demo [M6-M10]

(Leader: **UNIROMA3**)

Partner	UNIROMA3	KTH	UNIROMA1	UPC	UNICLAM	DTI	PALEBLUE	PAL	AGRIM.	RSA
PM	1	1	0,5	1	1	3	0	1	2	0

Task 2.6 – Virtual Reality Farming Environment Specifications [M1-M10]

(Leader: **PALEBLUE**)

Partner	UNIROMA3	KTH	UNIROMA1	UPC	UNICLAM	DTI	PALEBLUE	PAL	AGRIM.	RSA
PM	1	0	1	0	1	1	3	0	1	0

Deliverables

D2.1: Requirements, Specifications and Benchmarks	Leader: AGRIMESSINA	Delivery Month: **M4**
Requirements and Specifications definition. Identification of performance indices		
D2.2: Specifications and KPIs for the two robot prototypes	Leader: DTI	Delivery Month: **M6**
Definition of report for monitoring KPIs and robot specifications		
D2.3: Dimensioning of the Real-World Scenario for Final Demo	Leader: UNIROMA1	Delivery Month: **M10**
Description and dimensioning of table-grape vineyard and all the agronomic operations		
D2.4: VR Farming Environment Specifications	Leader: PALEBLUE	Delivery Month: **M10**
Description of the Specifications to the Virtual Reality Environment		

Milestones

# Mil.	Description	Related WP(s)	Due Date	Means of verification
MS1	All technical specifications finalised	WP2	M6	Requirements, Specifications and Benchmarks
MS2	First Release of Farming and Logistic Robot Prototypes	WP3	M14	Deliverable D3.2
MS3	Final Release of the VR Farming Environment	WP[3,4,5,6,7,8]	M25	Deliverable D3.4, D4.3, D5.4, D6.4, D7.3, D8.4
MS4	Robotic Navigation and Coordination Field Validation	WP9	M33	Deliverable D9.1
MS5	Human-Robot Interaction: Safety and Communication	WP5, WP6	M36	Deliverables D5.2, D6.2
MS6	Human-Robot Collaboration: Planning in Agreement, Task Planning	WP6, WP8	M36	Deliverables D6.1, D8.1
MS7	Experimental validation of the integrated system with respect to the pilot scenario	WP9	M48	Deliverable D9.4

Technical Discussion

Agronomic aspects

Harvesting

Pruning

Technical Discussion – Agronomic aspects

- **Soil:** Very heterogenous. Mostly medium texture with a rich calcareous component. (Other type of soil clayey, sandy, silty);
- **Spacing:** commonly 2.7 m x 2.5 m (range 2.4x2.4 – 3.0x3.0);
- **Planting density:** from 1.100 to 2.000 vines per hectare;
- **Grapes distance from the ground**: commonly 1.8 m; (range 1.5 and 2.0 m)

Technical Discussion – Agronomic aspects

- **Yield per hectare**: generally 30 tons (range 20 – 40 tons)
- **Clusters per plant**: 30 depending on plant spacing and specific variety (range 25-60)
- **Bunch weight**: 800 g; (range 400 g – 1500 g)
- **Canopy management for harvesting**: all the leafs should be above the bunches allowing all bunches to have a “free space” without touching each other.

Technical Discussion – Agronomic aspects

Vine training systems:

- "Tendone/Pergola" the most used in Italy and Spain, is a pergola with a **closed horizontal roof**, 2.0 m from the ground and with crossed practicability;
- "Y" system (gable) is a lower structure with Y shape largely used in California, South Africa, Australia.

Grassing: maintaining the surface of the ground covered by an herbaceous crop.
👍 Easier to work through vineyard with grass cover
👎 Could be too grassy

Soil Management

Tillage: from 5 to 20 cm deep.
👍 Grass absence
👎 Rough/irregular surface
👎 Rain could affect ground operations

Technical Discussion – Harvesting

- **Canopy adjustment**: collection and recognition of bunches;
- **Fruit selection**: removal of bunches not suitable for sale / thinning;
- **Supervision and management**: quality control;
- **Bunch placing:** adjustment of the bunches in the box;
- **Picking grapes** not harvested by the robot but still compliant.

HUMAN ROBOT INTERATION

Technical Discussion – Pruning

Targets

- **Plant Containment** - plant must remain within certain dimensions, parametrized to specific variety, age of the vineyard, planting distance;
- **Productive balance** - each branch must have a specific number of buds;

Parameters

- Year of production
- Variety
- Number of branches/canes
- Number of buds per branch (branch length)
- Promote the lymphatic flow

Technical Discussion – Experimental Site

Soil: Sandy
Spacing: 2.6 m x 2.6 m
Planting density: 1.480 plants/hectare
Grapes distance from the ground: 1.8 m
Yield per hectare: 30 tons/hectare
Clusters per plant: 30 bunches/plant
Bunch weight: 800 g (range 400 g – 1500 g)
Varieties: Vittoria, Matilde, Pizzutello, Italia
Vine training system: Pergola/Tendone
Soil management: Tillage (20 cm)

Corsira Soc. Coop Agricola
Via Corsira, 04011 Aprilia RM

Critical Activities - Sensors Identification

Clusters localization	RGB-D, stereovision, Lidars
Brix definition	Near Infrared Spectrometer
Physical characteristics analysis (color, berry-size, diseases and physical damages)	RGB-D, Lidars, Infra Red
Identify perfect steam cutting area	RGB-D, Lidars
Identify canes and buds in pruning (and cutting area)	RGB-D, Lidars

Critical Activities – Sensors identification

Refractometer that allow non-invasive measurement:

ATAGO PAL-HIKARi 2

Brix can be measured by placing the fruit on the sample stage
It requires no more cumbersome wiping and cleansing after each measurement.
Measurement Time 4 seconds

SCiO

Near Infrared Spectrometer miniaturized. Patented optical head is just a few millimeters in size. Low power consumption and zero warm up time make it highly responsive and efficient.

PaleBlue: Objectives

- Objective 2.6 – Virtual Reality Farming Environment Specifications

PaleBlue: Technical Goals

- Identify requirements for VT environment.
- Identify environment elements, dynamic object and interaction actors for 3D modelling.
- Identify actors and real time interaction.
- Decision between Standalone and PC-based hardware setup.

PaleBlue: Technical Challenges

- None at the moment.

PaleBlue: Technical Discussion

- None at the moment.

Coordination and Planning of Activites

- **Monthly meetings** to measure the status of achievement of the WP
- The **leading unit** of each task is responsible for **its timely completion**
- **The leading unit** of each task is responsible for the **drafting of the related deliverable** (all involved units must contribute)
- The **leading unit** of the WP is responsible for **communicating with the PI** in the case of difficulties

Thank you

Let’s move on the next WP

A Collaborative Paradigm for Human Workers and Multi-Robot Teams in Precision Agriculture Systems

WP3 - Robot Platforms Development, Integration and Testing

This project is funded by the European Union G.A No 101016906

1

Robot Platforms Development, Integration and Testing

2

Overall Goal

- Design and implement **two robotic prototypes** required to carry out the research activities.
- Develop or integrate all required **hardware**, i.e., perceptual system, box-exchange-mechanism, dual arm setup, etc.
- Develop or integrate all required **software**, i.e., drivers, ROS interface with all components, overall software architecture, etc.
- Develop a **VR/robotics simulator** that represents the farming environment.

Objectives

- Objective 1 – Robot prototype localization and autonomous navigation.
- Objective 2 – Integration/development of robotic components.
- Objective 3 – Integration/development of required in-field infrastructure.
- Objective 4 – Integration/development of core simulation and VR interaction.
- Objective 5 – Continuous acceptance testing and integration phases.

Tasks Description

Task 3.1 – Robot Hardware Customization and Periodic System Integration [M3-M40]

(Leader: **DTI**)

Partner	UNIROMA3	KTH	UNIROMA1	UPC	UNICLAM	DTI	PALEBLUE	PAL	AGRIM.	RSA
PM	1	0	0	2	0	10	0	8	0	0

- **First integration phase** developing the two robot prototypes and accompanying infrastructure, i.e., local wireless network, GPS base, etc.
- **Second integration phase** of the dual arm and gripper prototypes.
- **Third integration phase** of the Box-Exchange-Mechanism in both robot prototypes.
- **Revisions based on what we learned** during the project and in the field (T3.6 and WP9)

Tasks Description

Task 3.2 – Agronomic Dual Arms System with Actuated Torso Design and Development [M3-M40]

(Leader: **PAL**)

Partner	UNIROMA3	KTH	UNIROMA1	UPC	UNICLAM	DTI	PALEBLUE	PAL	AGRIM.	RSA
PM	0	0	0	0	2	0	0	12	0	0

- Starting from the **upper body** of the **TIAGo++**
- Integration of **torque sensors and brakes** in at least the first 4 joints of the arms
- **F/T sensor** between the end-effector and the arm end-tip
- Migration from CAN to **EtherCAT** to have higher control bandwidth
- Add the **rotating DoF** in the base of the upper body
- Investigate increase of **IP rating** for dust and water protection
- Expose a **hardware abstraction layer** with open interfaces for the mid-level control
- Integration with vehicle Alitrak DCT-350P

Tasks Description

Task 3.3 – Design and Development of Agronomic End-Effectors [M8-M30]

(Leader: **PAL**)

Partner	UNIROMA3	KTH	UNIROMA1	UPC	UNICLAM	DTI	PALEBLUE	PAL	AGRIM.	RSA
PM	0	0	0	0	1	0	0	12	1	0

- Agronomic **end-effectors** design for **harvesting** and **pruning**
- PAL would investigate if a single robust new end-effector can do the above functions by adding tools
- Requirements about the tasks that the end-effector has to do with the tools [Agronomic experts feedback needed]

Tasks Description

Task 3.4 –Development of the Box-Exchange Mechanism(s) (BEM) [M4-M39]

(Leader: **DTI**)

Partner	UNIROMA3	KTH	UNIROMA1	UPC	UNICLAM	DTI	PALEBLUE	PAL	AGRIM.	RSA
PM	0	0	0	0	0	4	0	0	0	0

- **Creating BEM concepts** for each robot prototype.
- Develop the **concepts.**
- Integrating the **sensory suite.**
- Develop the **low-level control software.**

Tasks Description

Task 3.5 – Autonomous Navigation Functionalities [M4-M30]

(Leader: **UNIROMA3**)

Partner	UNIROMA3	KTH	UNIROMA1	UPC	UNICLAM	DTI	PALEBLUE	PAL	AGRIM.	RSA
PM	12	0	4	0	0	10	0	0	0	0

- Develop **low level control algorithms**.
- Create **basic navigation capabilities**.
- Endow the mobile platform with **autonomous navigation and localization functionalities**.

Tasks Description

Task 3.6 – Acceptance Testing of Farming and Logistic Robotic Prototypes [M7-M40]

(Leader: **DTI**)

Partner	UNIROMA3	KTH	UNIROMA1	UPC	UNICLAM	DTI	PALEBLUE	PAL	AGRIM.	RSA
PM	0	0	0	0	0	6	0	6	0	0

- **Periodic testing** of the robot prototypes before the on-field testing.
- **Factory acceptance test**, performing test under lab conditions. (**matching KPIs of lab testing**)
- **Site acceptance test**, performed during integration weeks (**matching KPIs of field testing**)

Tasks Description

Task 3.7 – Simulated Environment and Basic Robotic Components[M3-M8]

(Leader: **PALEBLUE**)

Partner	UNIROMA3	KTH	UNIROMA1	UPC	UNICLAM	DTI	PALEBLUE	PAL	AGRIM.	RSA
PM	0	0	0	0	1	3	6	0	0	0

- Creating the **basic table-grape farming VR/simulation environment**.
- **Modelling the robotic prototypes** in the VR/simulation environment
- **Modelling prototype mechanism**, e.g., BEM, in the VR/simulation environment
- Developing **interfaces between simulation environments and robotic software**.

Deliverables

D3.1: Guidelines for the Integration of System Components	Leader: DTI	Delivery Month: **M10**
Robot and software architecture is complete and the guidelines for building compatible software and hardware is shared to all partners.		
D3.2: First Release of Farming and Logistic Robot Prototypes	Leader: DTI	Delivery Month: **M14**
The robot prototypes passed the first acceptance tests, can perform the basic functionalities and presented.		
D3.3: Final Release of Farming and Logistic Robot Prototypes	Leader: DTI	Delivery Month: **M40**
The matured versions of robot prototypes which comply with all the final specifications are presented.		
D3.4: Simulated Farming Environment and Basic Robotic Components	Leader: PALEBLUE	Delivery Month: **M8**
The first version of the developed simulation environment which allow the robotic simulation and VR interaction is presented.		

Milestones

# Mil.	Description	Related WP(s)	Due Date	Means of verification
MS1	All technical specifications finalised	WP2	M6	Deliverable D2.1
MS2	First Release of Farming and Logistic Robot Prototypes	WP3	M14	Deliverable D3.2
MS3	Final Release of the VR Farming Environment	WP[3,4,5,6,7,8]	M25	Software Released and Validated by a User Group
MS4	Robotic Navigation and Coordination Field Validation	WP9	M33	Deliverable D9.1
MS5	Human-Robot Interaction: Safety and Communication	WP5, WP6	M36	Deliverables D5.2, D6.2
MS6	Human-Robot Collaboration: Planning in Agreement, Task Planning	WP6, WP8	M36	Deliverables D6.1, D8.1
MS7	Experimental validation of the integrated system with respect to the pilot scenario	WP9	M48	Deliverable D9.4

Critical Activities (next 12 Months)

- Hardware Specifications: Identify requirements of the targeted task.
- Sensors Selection: We need to identify all the sensors required for navigation.
- Hardware Purchases: To be carried out **ASAP.**
- Software Architecture: that serves all partners, with characteristics of easy versioning, distribution and provides basic functionalities for all components.
- Robot Prototypes KPIs: Propose and agree with the targeted robot capabilities.
- Dual Arm and Gripper Concept Development: Create the concept and development leading to the first prototype realized in M14.
- BEM Concept Development: Create the concept and development leading to the first prototype realized in M14.
- Simulator Development: First version by M8.

Technical Discussion

- **Hardware integration**: Choosing common HW, optimizing integration effort.
- **Dual arm - initial concepts**: computational and power autonomy, gripper design, agronomic sensor positioning.
- **BEM – initial concepts**: Approach tactics, task specifications, hardware specifications, docking hardware (if any).
- **Software development** : ROS / ROS2, multi-ros system, basic navigation stack, deployment, version control and release.

Technical Discussion

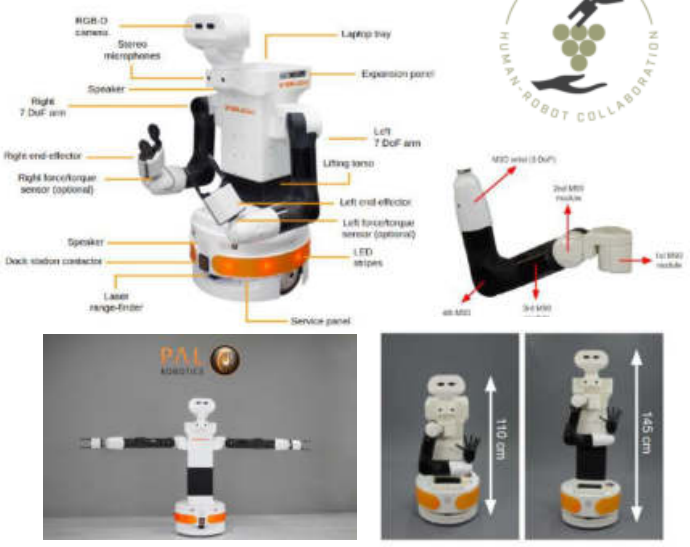
- **Hardware integration**: Choosing common HW, optimizing integration effort.
- **Dual arm - initial concepts**: computational and power autonomy, gripper design, agronomic sensor positioning.
- **BEM – initial concepts**: Approach tactics, task specifications, hardware specifications, docking hardware (if any).
- **Software development** : ROS / ROS2, multi-ros system, basic navigation stack, deployment, version control and release.

TIAGo++ overview

- Height: 110cm – 145cm
- Expandable
- Mobile manipulation
- Free Tutorials and simulations available online
- Research, Industry and Ambient Assisted Living
- ROS 100% Integrated

TIAGo++ specifications

- Base footprint: Ø 54 cm
- Weight: ~ 90 kg
- Torso lift stroke: 350 mm
- 7 DoFs each arm
- Optional 6-axis F/T sensors in the wrists
- Arm payload (without end-effector): 3 kg
- Arm reach: 87 cm
- 2x Li-Ion 36 V 20 Ah 2C batteries
- Average power consumption: 250 W

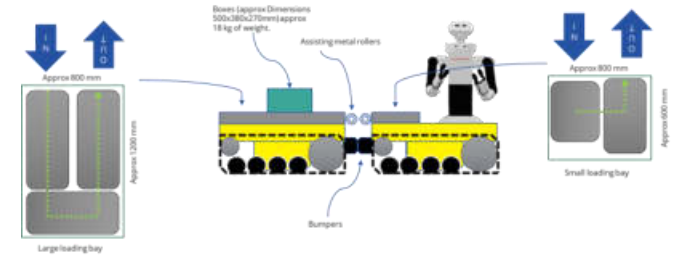


Technical Discussion

- **Hardware integration**: Choosing common HW, optimizing integration effort.
- **Dual arm - initial concepts**: computational and power autonomy, gripper design, agronomic sensor positioning.
- **BEM – initial concepts**: Approach tactics, task specifications, hardware specifications, docking hardware (if any).
- **Software development** : ROS / ROS2, multi-ros system, basic navigation stack, deployment, version control and release.

BEM concept

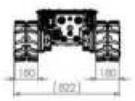
- Approach tactics,
- Task specifications,
- Hardware specifications,
- Docking hardware (if any).

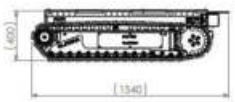


300x500x197mm

600x400x135cm

600x400x135mm





Technical Discussion

- **Hardware integration**: Choosing common HW, optimizing integration effort.
- **Dual arm - initial concepts**: computational and power autonomy, gripper design, agronomic sensor positioning.
- **BEM – initial concepts**: Approach tactics, task specifications, hardware specifications, docking hardware (if any).
- **Software development** : ROS / ROS2, multi-ros system, basic navigation stack, deployment, version control and release.

PaleBlue: Objectives

- Objective 3.7 – Simulated Environment and Basic Robotic Components

PaleBlue : Technical Goals

- Modelling and creation of overall VR environment.
  - Focus on table-grape farming environment
- Modelling and creation of basic robotic components.
- Kinematic model development of the mobile base.
- Develop software for communication between ROS and the produced simulation.
- Modelling of BEM (Box-Exchange Mechanism) mechanism.
- Robot simulation in 3D environment.

PaleBlue : Technical Challenges

- Physical engine comparison and selection
- Creation of graphical and physical model of the robot
- Realism of physical behaviour
- Integration with ROS

PaleBlue : Technical Discussion

- CAD data for robot
- Reference videos of robot motion & behaviour
- Protocols used in communication with ROS?

Coordination and Planning of Activities

- **Monthly meetings** to measure the status of achievement of the WP
- **Ad-hoc meetings** to cope with potential issues during the prototype development
- The **leading unit** of each task is responsible for **its timely completion**
- **The leading unit** of each task is responsible for the **drafting of the related deliverable** (all involved units must contribute)
- The **leading unit** of the WP is responsible for **communicating with the PI** in the case of difficulties

Let’s move on to the next WP…

Any questions?

A Collaborative Paradigm for Human Workers and Multi-Robot Teams in Precision Agriculture Systems

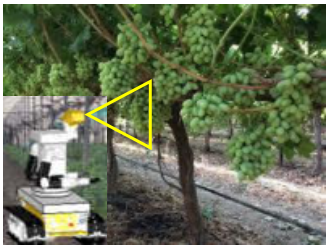
WP4 - Agronomic-Oriented Perception

This project is funded by the European Union
G.A No 101016906

1

Agronomic-Oriented Perception

Agronomic target detection & localization



Agronomic quality assessment

VR Agronomic-Oriented perception

2

Overall Goal

- Design new perception methods for modelling and detection of grapes, vineyard tree branches and other elements of the environment.
- Design algorithms to track the detected objects while the robot moves
- Design algorithms and systems to assess grape ripeness and quality
- Develop VR simulation tools and create a virtual environment for experiments

General Challenges

- Occlusions and self occlusions of leaves, branches and grapes
- Flexible and moving targets, due to environment (e.g. wind) and robot interaction
- Uneven lighting conditions, due to the weather and the trellis structure (frequent transitions from light to shadow)

Objectives

- Objective 1 – Agronomic target detection and modelling
- Objective 2 – Agronomic target localization
- Objective 3 – Agronomic quality assessment
- Objective 4 – VR agronomic-oriented perception

Tasks Description

Task 4.1 – Agronomic Target Detection and Modelling [M3-M30]
(Leader: **UPC**)

Task 4.2 – Agronomic Target Localization [M3-M30]
(Leader: **UPC**)

Task 4.3 – Agronomic Quality Assessment [M3-M30]
(Leader: **UNIROMA1**)

Task 4.4 – VR Agronomic-Oriented Perception Component [M3-M30]
(Leader: **PALEBLUE**)

Tasks PMs

Partner	UNIROMA3	KTH	UNIROMA1	UPC	UNICLAM	DTI	PALEBLUE	PAL	AGRIM.	RSA
PM	0	0	21	28	0	6	6	0	1	0

Deliverables

D4.1: Deliverable Agronomic target modelling, detection and localization	Leader: UPC	Delivery Month: **M30**

This report will describe the diverse techniques that will be developed and outcomes at lab conditions.

D4.2: Agronomic Quality Assessment	Leader: UPC	Delivery Month: **M30**

This report will describe the techniques used for grape quality assessment.

D4.3: VR Agronomic-Oriented Perception Component	Leader: PALEBLUE	Delivery Month: **M12**

This deliverable will consist of the release of the VR Agronomic-Oriented Perception software module. It will include virtual sensors generating data that will be integrated for initial recognition by robots.

Milestones

# Mil.	Description	Related WP(s)	Due Date	Means of verification
MS3	Final release of VR farming environment	WP4	M25	Software Released and Validated by a User Group

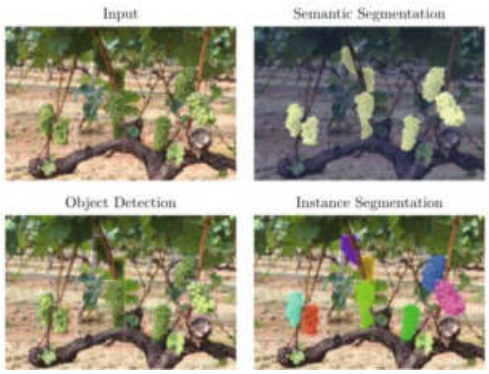
Task 4.1 – Agronomic Target Detection and Modelling [M3-M30](Leader: UPC)

Objectives:

- Detect and model grapes
- Detect and model vineyard branches

Critical issues:

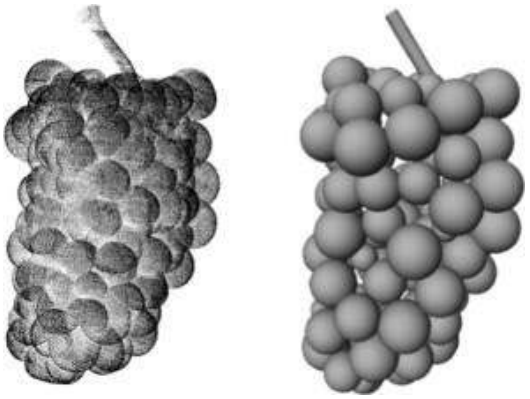
- Lighting and cast shadows
- Partial occlusions by leaves, branches,…
- Small artifacts



Thiago T. Santos, Leonardo L. de Souza, Andreza A. dos Santos, Sandra Avila, Grape detection, segmentation, and tracking using deep neural networks and three-dimensional association, Computers and Electronics in agriculture, Volume 170, 2020

Task 4.1 – Agronomic Target Detection and Modelling [M3-M30](Leader: UPC)

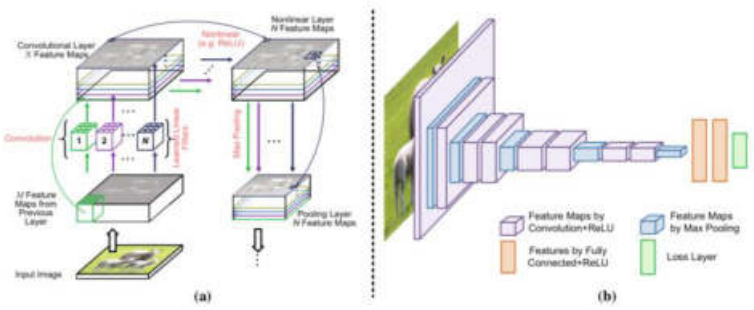
- Detection and tracking based on RGBD sensors to mitigate the effects of shadows
- Use of on-line learning and transfer learning to make it robust to different conditions
- Use of synthetic data generation to mitigate the lack of real data due to the specificity of the fruit and the seasonality



Rist, F.; Herzog, K.; Mack, J.; Richter, R.; Steinhage, V.; Töpfer, R. High-Precision Phenotyping of Grape Bunch Architecture Using Fast 3D Sensor and Automation. *Sensors* **2018**, *18*, 763

Task 4.1 – Agronomic Target Detection and Modelling [M3-M30](Leader: UPC)

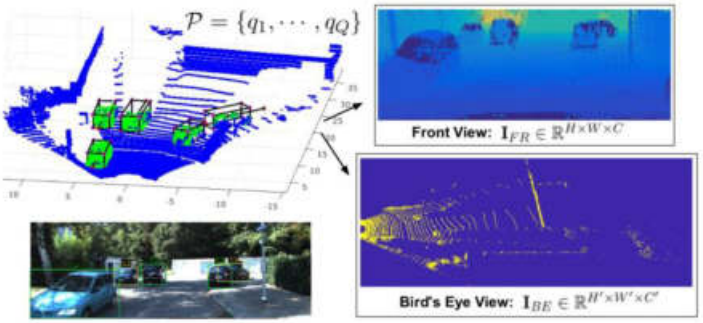
- **Methods:**
  - CNNs for grape detection
  - CNNs for branch detection
  - Computer vision techniques



Task 4.2 – Agronomic Target Localization [M3-M30] (Leader: UPC)

Objectives:

- Localize and track the grapes in 3D
- Localize and track the branches to be pruned in 3D



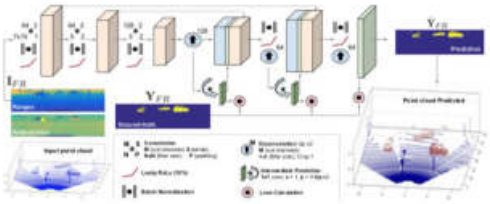
Critical issues:

- Lighting and cast shadows
- Partial occlusions
- Low density of point clouds

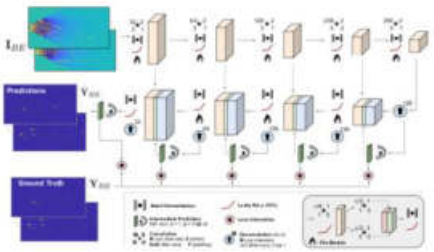
Task 4.2 – Agronomic Target Localization [M3-M30] (Leader: UPC)

Methods:

- CNNs of Lidar and stereo cameras
- Computer vision techniques



Example of a front view network Lidar



Example of a bird's eye view network Lidar

Task 4.3 – Agronomic Quality Assessment [M3-M30](Leader: UNIROMA1)

Both the **ripeness of the fruit** and the **external characteristics** contribute to the quality assessment task.

The robot has to pick the **right grapes at the right day** to collect the highest quality product.

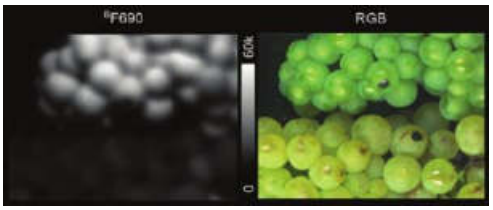
This sub-task will use and advance the SotA of data driven fruit quality estimation.

Task 4.3 – Agronomic Quality Assessment [M3-M30](Leader: UNIROMA1)

Proposed solution:

There is a vast literature of indexes based on radiation emission/absorption characteristics of plants that are currently used in agronomy for various tasks, such as ripeness estimation (e.g. NDVI, EVI).

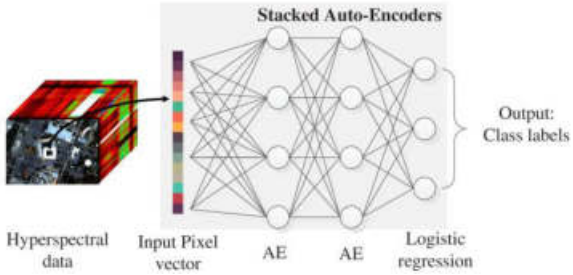
While this **handcrafted indexes** are effective and well understood, recent developments of computer vision techniques show that for many problems it is possible to **learn more effective representation** by systematic experimentation thorough deep learning.



Sándor Lenk, Laury Chaerle, Erhard E. Pfündel, Gabriele Langsdorf, Dik Hagenbeek, Hartmut K. Lichtenthaler, Dominique Van Der Straeten, Claus Buschmann, **Multispectral fluorescence and reflectance imaging at the leaf level and its possible applications**, *Journal of Experimental Botany*, Volume 58, Issue 4, March 2007, Pages 807–814

Task 4.3 – Agronomic Quality Assessment [M3-M30](Leader: UNIROMA1)

Representation Learning for QA



Li, Shutao, et al. **Deep learning for hyperspectral image classification: An overview**. *IEEE Transactions on Geoscience and Remote Sensing* 57.9 (2019): 6690-6709.

Given a multi-spectral and multi-modal input, Deep Networks architectures could be able to find new representations potentially with more predictive power with respect to grape quality.

At the same time it would be possible to perform **inferential analysis on the learned representations** to gain insights on the physical and physiological properties of the plants.

Task 4.3 – Agronomic Quality Assessment [M3-M30](Leader: UNIROMA1)

Specific Challenges

- The availability of data depends on seasons and weather. Collecting useful data in relevant quantity is a critical aspect.
- HW limitations: a low number of bands in multispectral cameras could limit the potential of the learning technique.
- High quality data annotation is always cumbersome.

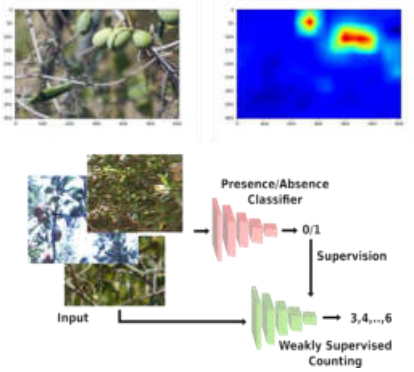
Task 4.3 – Agronomic Quality Assessment [M3-M30](Leader: UNIROMA1)

Possible solutions

- Use of **transfer learning** and **domain adaptation** from other variety of grapes, or depending on the task, other fruits.
- **Data augmentation**.
- **Semi-supervised methods** to reduce the amount of labelled data.

Task 4.3 – Agronomic Quality Assessment [M3-M30](Leader: UNIROMA1)

Semi-supervised techniques



E. Bellocchio, T. A. Ciarfuglia, G. Costante and P. Valigi, **Weakly Supervised Fruit Counting for Yield Estimation Using Spatial Consistency**, in *IEEE Robotics and Automation Letters*, vol. 4, no. 3, pp. 2348-2355, July 2019

We know from our previous experience with other fruits, such as olives, that it is possible to train classifiers and regression networks using weak labeling (1-0 image labels).

The feature maps learned in this way, whose performance was proven on a complex task such as counting, have high probability of being very effective in detection and segmentation too.

Task 4.4 – VR Agronomic-Oriented Perception Component [M3-M30](Leader: PALEBLUE)

Technical goals:

- Virtual sensors & Virtual motors development.
- Run virtual experiments on virtual environment model.
- Sensor calibration on virtual environment model.
- Design and implementation of signal feeding to perception agents.
- Testing of Point cloud.
- Testing 3D ray casting.

Task 4.4 – VR Agronomic-Oriented Perception Component [M3-M30](Leader: PALEBLUE)

Technical challenges:

- Grape virtual models
  - Visual model
  - Physical model
  - Sensor-specific model(s)
- Implementation of specific sensors
- Integration using signal communication bus

Task 4.4 – VR Agronomic-Oriented Perception Component [M3-M30](Leader: PALEBLUE)

Technical discussion:

- Sensors identified so far
- Signal communication bus/network

Critical Activities (next 12 Months)

- **Sensors Selection:** We need to have identified all the sensors and its robot pose. This work has to be done in WP2.
  - Sensors for detection of grapes and vineyard branches (RGB cameras, stereo cameras, Lidar,…)
  - Sensors for quality assessment of grapes (multi spectral camera)
  - Other sensors?
  - Sensors for VR
- **Data collection:**
  - Harvesting campaigns: 1rst on months August-September 2021; 2nd on months August-September 2022
  - Pruning campaigns: 1rst on months December 2021-January 2022; 2nd on months December 2022-January 2023.
- **Data labelling:**
  - After the data collection campaigns

Coordination and Planning of Activities

- **Monthly meetings** to measure the status of achievement of the WP
- The **leading unit** of each task is responsible for **its timely completion**
- **The leading unit** of each task is responsible for the **drafting of the related deliverable** (all involved units must contribute)
- The **leading unit** of the WP is responsible for **communicating with the PI** in the case of difficulties

Let's move on to the next WP…

Any questions?

A Collaborative Paradigm for Human Workers and Multi-Robot Teams in Precision Agriculture Systems

WP5 – Single Robot Functionalities

This project is funded by the European Union
G.A No 101016906

1

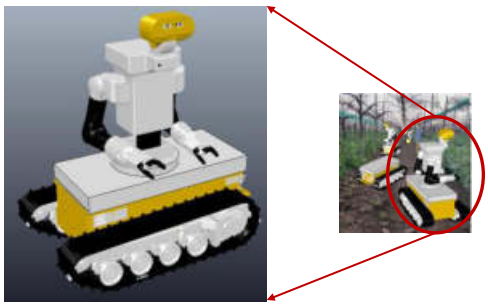
Single Robot Functionalities

Farming robots

Two Farming robots for agronomic tasks (quality measurement, harvesting, pruning)

Dual-arm system mounted on a mobile base equipped by several sensors

Human-robot interaction capabilities at different levels



2

Overall Goal

- Design and develop basic arm motion functionalities for:
  - Grapes quality check
  - Harvesting and pruning
- Design and develop functionalities to interact both with humans and environment
- To setup a VR based environment to run human-in-the-loop simulations

Specific Objectives

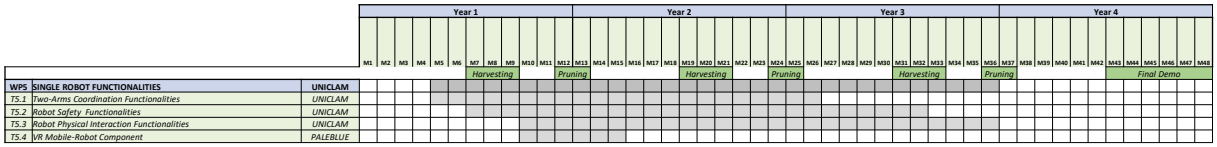
- Objective 1 – To provide the farming robot with control strategies for the arms and the mobile base
- Objective 2 – To provide to the arm human-like motions to increase the robot acceptability
- Objective 3 – To account for the safety of the farmer during robot motion
- Objective 4 – To allow farming robots to interact both with farmers and the environment by equipping them with advanced force control algorithms.
- Objective 5 – To setup a VR environment to run realistic simulations

Work Package Description

WP5 – Single Robot Functionalities [M5-M36]

(Leader: **UNICLAM**)

Partner	UNIROMA3	KTH	UNIROMA1	UPC	UNICLAM	DTI	PALEBLUE	PAL	AGRIM.	RSA	Tot
PM	2	6	0	2	46	0	6	3	1	0	**66**



Tasks Description

Task 5.1 – Two-Arms Coordination Functionalities [M5-M26]

(Leader: **UNICLAM**)

Partner	UNIROMA3	KTH	UNIROMA1	UPC	UNICLAM	DTI	PALEBLUE	PAL	AGRIM.	RSA
PM	2	2	0	0	16	0	0	1	1	0

Task 5.2 – Robot Safety Functionalities [M7-M32]

(Leader: **UNICLAM**)

Partner	UNIROMA3	KTH	UNIROMA1	UPC	UNICLAM	DTI	PALEBLUE	PAL	AGRIM.	RSA
PM	0	2	0	2	16	0	0	1	0	0

Tasks Description

Task 5.3 – Physical Interaction Functionalities [M10-M36]

(Leader: **UNICLAM**)

Partner	UNIROMA3	KTH	UNIROMA1	UPC	UNICLAM	DTI	PALEBLUE	PAL	AGRIM.	RSA
PM	0	2	0	0	12	0	0	1	0	0

Task 5.4 –VR Mobile-Robot Component [M10-M15]

(Leader: **PALEBLUE**)

Partner	UNIROMA3	KTH	UNIROMA1	UPC	UNICLAM	DTI	PALEBLUE	PAL	AGRIM.	RSA
PM	0	0	0	0	2	0	6	0	0	0

Deliverables

D5.1: Cooperative arms and mobile base functionalities	Leader: UNICLAM	Delivery Month: **M26**
The motion capabilities of the arms are tested both in simulation and in the real field		
D5.2: Mobile arms safety functionalities	Leader: UNICLAM	Delivery Month: **M32**
The design, implementation and testing of the human-robot safety functionalities are complete		
D5.3: Mobile arms physical interaction	Leader: UNICLAM	Delivery Month: **M36**
The farming robot includes force control algorithms which are implemented and tested on the field		
D5.4: VR Mobile-Robot Component	Leader: PALEBLUE	Delivery Month: **M15**
Robots and humans are able to interact and move in the Virtual Environment		

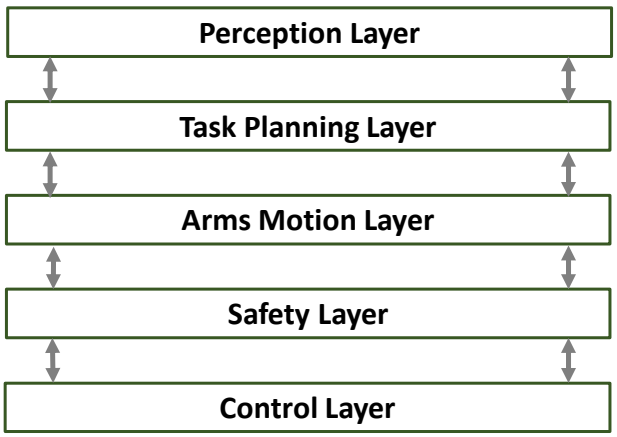
Milestones

# Mil.	Description	Related WP(s)	Due Date	Means of verification
MS1	All technical specifications finalised	WP2	M6	Deliverable D2.1
MS2	First Release of Farming and Logistic Robot Prototypes	WP3	M14	Deliverable D3.2
MS3	Final Release of the VR Farming Environment	WP[3,4,5,6,7,8]	M25	Software Released and Validated by a User Group
MS4	Robotic Navigation and Coordination Field Validation	WP9	M33	Deliverable D9.1
MS5	Human-Robot Interaction: Safety and Communication	WP5, WP6	M36	Deliverables D5.2, D6.2
MS6	Human-Robot Collaboration: Planning in Agreement, Task Planning	WP6, WP8	M36	Deliverables D6.1, D8.1
MS7	Experimental validation of the integrated system with respect to the pilot scenario	WP9	M48	Deliverable D9.4

Technical Discussion – Overall system architecture

A *possible architecture*. The overall farming robot architecture might be based on a classical layered architecture

- The *Perception Layer* provides scene understanding
- The *Task Layer* provides trajectory planning for agronomic task execution and human-robot interaction
- The Arms *Motion Layer* receives agronomic significant trajectories from the Task Layer and generates motion commands for the arms
- The *Safety Layer* takes into account the presence of obstacles, in general, and human safety requirements, in particular
- The *Control Layer* is in charge of providing low level control loops



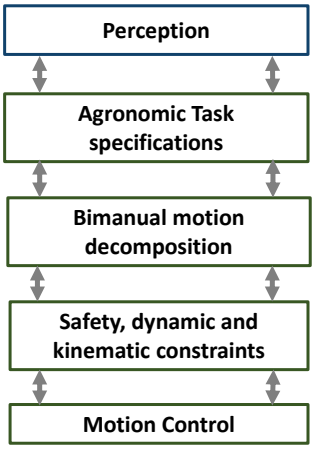
Technical Discussion – Task 5.1

Task 5.1- Two-Arms Coordination Functionalities. The idea is to endow the robot with motion primitives both for single and cooperating arms to be adopted for agronomic tasks and HRI

These primitive skills might be inspired by human manipulation; this feature influences how robots are perceived, and their motion predicted by human partners.

Concepts to be exploited:

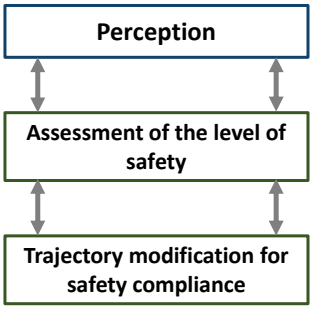
- Elbow elevation angle (swivel angle)
- Uni-modal bell-shaped hand velocity profile (smoothest movement)
- 2/3 Power Law (it relates tangential velocity and path curvature)
- Motion predictability (given a goal, motion meets human expectation) and legibility (given a trajectory the goal can be inferred)
- Human-Path-Planarity in unconstrained movements
- Spatio-Temporal coordination (minimization of dissimilarity measures between human and robot arm joint configuration)



Technical Discussion – Task 5.2

Task 5.2 - Robot Safety functionalities

- Human and robot sharing the same workspace during task execution
- Safety functionalities embedded in the robot architecture by exploiting RGB-D, lidars and hyperspectral cameras
- A possible approach exploits the definition of a safety field quantifying the level of the safety (several parameters to be considered)
- The robot trajectory parameters might be modified accordingly
- The estimate of the human motion and prediction of next action (WP6) will be taken into account for the assessment



Technical Discussion – Task 5.3

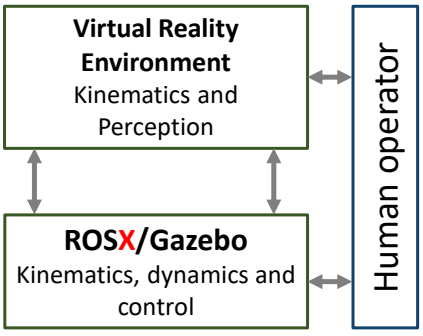
Task 5.3- Robot Physical Interaction Functionalities

- Robots will interact both with humans and the environment
- Wrist Force/Torque sensors to be exploited for the interaction with the environment
- Variable impedance and direct force control algorithms might be a viable solution
- Joint-Torque sensors will be exploited to estimate the human contact along the robot structure

Technical Discussion – Task 5.4

Task 5.4 - VR Mobile-Robot Component

- To allow to simulate in a realistic environment the robot motion and human-robot-interaction algorithms
- The robot perception will be modeled to include visual and range sensors (environment and human motion)
- A physical engine to generate, starting from VR world, interaction forces for control purposes
- The VR engine is connected to ROSX where the same algorithms used for simulation and real experiments are used for the robot motion in VR

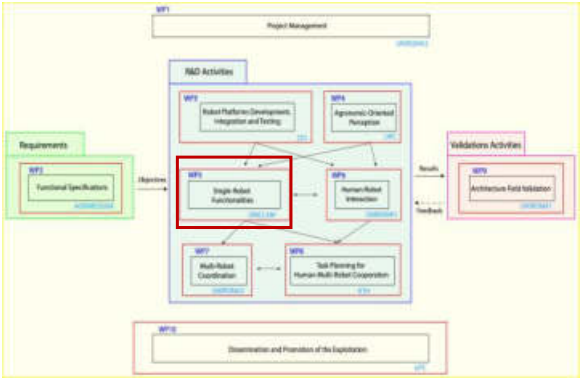


Correlation with other WPs

Main WP5 objective. Endow the farming robot with motion functionalities driven by agronomic needs

WP5 is related to
- WP3 (platform design and development)
- WP4 (agronomic perception)
- WP7 (multi-robot coordination)
- WP8 (planning and learning)

Role and contribution of participants:
- UNICLAM will design and develop arm functionalities
- KTH will cooperate to the design of safety functionalities and learning of agronomic tasks
- UNIROMA3 will contribute to the arm-based motion coordination
- AGRIMESSINA will contribute with its agronomic knowledge
- PALEBLUE will model robot motion and perception in VR
- PAL will support for the access to the hardware layer



Technical Discussion – Expected Inputs

Input	
From	
T2.3	Specifications concerning human-safety for agronomic operations
T2.5	Specifications concerning the vineyard dimension
T3.2	Design and development of the agronomic dual-arm system
T3.3	Design and development of the agronomic end-effectors
T4.2-4.3	Sensor motion requirements for agronomic target localization and quality assessment
T6.1	Human body prediction
T8.1	Manipulation skills learned from demonstration given by human coworkers

Critical Activities (next 12 Months)

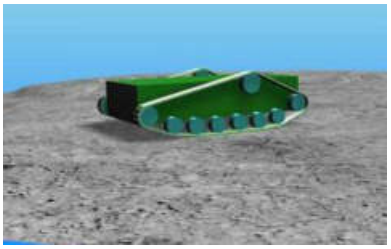
- Manipulators Functionalities: precisely define all tasks carried out by farming robots and the corresponding functionalities
- Manipulators Requirements: define robot requirements in terms of hardware and software, sensors equipment, payload, reachability and dexterous workspace.
- Farming Robot design: start designing the farming robot and prototyping motion algorithms in simulation environments
- Hardware Purchase: Mobile base already purchased. Other hardware already settled and orders ongoing (lidars, IMU, GPS)

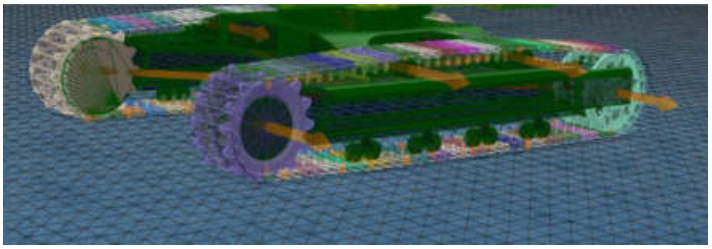
PaleBlue: Objectives

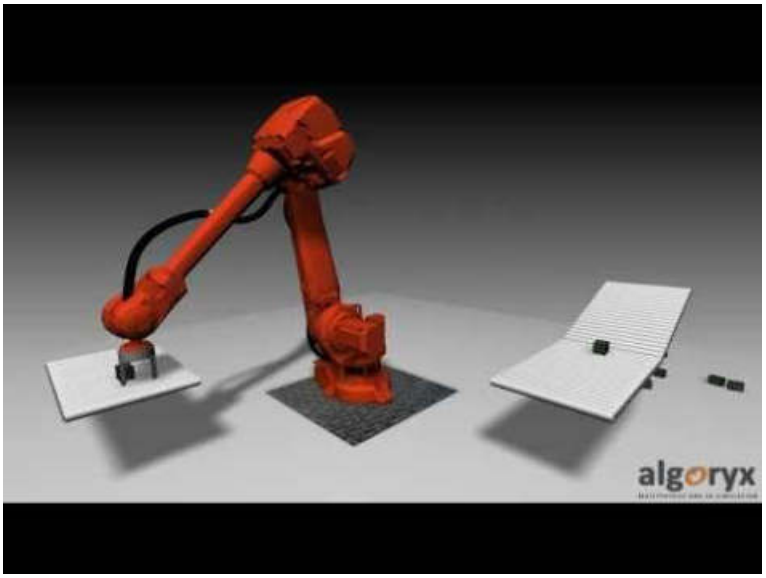
- Objective 5.4 – VR Mobile-Robot Component

PaleBlue: Technical Goals

- Virtual environment with Robot kinematic models to reproduce the robot motion as computed in ROS
- Kinematic physic engine for real time interactions (Force, collisions, friction, etc.)

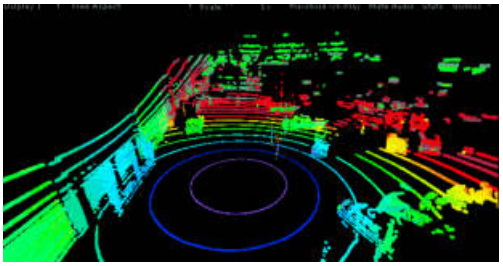


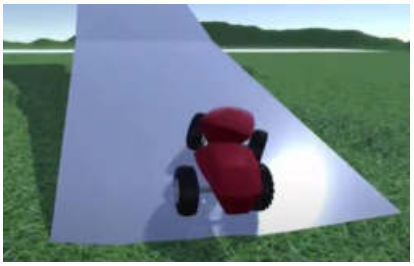




PaleBlue: Technical Goals

- Robot integration with ROS related to human safety aspects.
- Sensor calibration on virtual environment model.
- Design and implementation of signal feeding to perception agents.





PaleBlue: Technical Challenges

- Mechanisms for impact detection and measurement
- Sensor calibration

PaleBlue: Technical Discussion

- Detection of humans
- Sensor types indentified so far
- Signal exchange channels

Coordination and Planning of Activities

- **The WP leader** is responsible of monitoring all activities within the WP
- **Monthly meetings** to measure the status of achievement of the WP
- **Additional meetings** settled in case they are required
- The **leading unit** of each task is responsible for its timely completion
- **The deliverable responsible** oversees the correct drafting of the deliverable involving all units

Let’s move on to the next WP…

Any questions?

A Collaborative Paradigm for Human Workers and Multi-Robot Teams in Precision Agriculture Systems

WP6 - Human-Robot Interaction

This project is funded by the European Union
G.A No 101016906

Human-Robot Interaction (HRI)

- Field of study dedicated to understanding, designing, and evaluating robotic systems for use by or with humans
- Interaction requires communication between robots and humans:
  - Remote interaction: the human and the robot are separated spatially or even temporally
  - **Proximate interaction**: the human and the robot are in close proximity to each other (physical interaction)

Overall Goals

- Objective 1 – Prediction of Human-Body Motion
- Objective 2 – Human-Robot Joint Motion Plans
- Objective 3 – Human-Robot Communication
- Objective 4 – Awareness in Human-Robot Interaction
- Objective 5 – VR Human-Robot-Interaction Component

Tasks Description

Task 6.1 – Human-Body Prediction [M6-M25]

(Leader: **UPC**)

Partner	UNIROMA3	KTH	UNIROMA1	UPC	UNICLAM	DTI	PALEBLUE	PAL	AGRIM.	RSA
PM	0	0	0	12	0	0	0	1	0	0

Task 6.2 – Human-Robot Motion Planning in Agreement [M12-M36]

(Leader: **UPC**)

Partner	UNIROMA3	KTH	UNIROMA1	UPC	UNICLAM	DTI	PALEBLUE	PAL	AGRIM.	RSA
PM	0	0	0	18	0	0	0	0	0	0

Tasks Description

Task 6.3 – Human-Robot Communication [M6-M30]

(Leader: **UNIROMA1**)

Partner	UNIROMA3	KTH	UNIROMA1	UPC	UNICLAM	DTI	PALEBLUE	PAL	AGRIM.	RSA
PM	0	0	18	0	0	5	0	0	1	0

Task 6.4 – Human-Robot Awareness (Mental Model of Robotic Actions) [M25-M36]

(Leader: **UNIROMA1**)

Partner	UNIROMA3	KTH	UNIROMA1	UPC	UNICLAM	DTI	PALEBLUE	PAL	AGRIM.	RSA
PM	0	0	15	0	0	0	0	0	0	0

5

Tasks Description

Task 6.5 – VR Human-Robot-Interaction Component [M13-M18]

(Leader: **PALEBLUE**)

Partner	UNIROMA3	KTH	UNIROMA1	UPC	UNICLAM	DTI	PALEBLUE	PAL	AGRIM.	RSA
PM	0	0	6	0	0	3	7	0	0	0

6

Deliverables

D6.1: Human body prediction and human-robot motion planning	Leader: UPC	Delivery Month: **M36**
The methods for human body prediction and human-motion planning in agreement are described.		
D6.2: Human-Robot Communication	Leader: UNIROMA1	Delivery Month: **M30**
The design of the human-robot communication protocol is completed, and the communication modalities are defined.		
D6.3: Human-Robot Awareness	Leader: UNIROMA1	Delivery Month: **M36**
The design of a semantic representation of the environment and the action plans for both user and robot are described.		
D6.4: VR Human-Robot-Interaction Component	Leader: PALEBLUE	Delivery Month: **M18**
The VR farming environment includes modules for connecting human actors via VR and robot actors via ROS.		

7

Milestones

# Mil.	Description	Related WP(s)	Due Date	Means of verification
MS1	All technical specifications finalised	WP2	M6	Deliverable D2.1
MS2	First Release of Farming and Logistic Robot Prototypes	WP3	M14	Deliverable D3.2
MS3	Final Release of the VR Farming Environment	WP[3,4,5,6,7,8]	M25	Software Released and Validated by a User Group
MS4	Robotic Navigation and Coordination Field Validation	WP9	M33	Deliverable D9.1
MS5	Human-Robot Interaction: Safety and Communication	WP5, WP6	M36	Deliverables D5.2, D6.2
MS6	Human-Robot Collaboration: Planning in Agreement, Task Planning	WP6, WP8	M36	Deliverables D6.1, D8.1
MS7	Experimental validation of the integrated system with respect to the pilot scenario	WP9	M48	Deliverable D9.4

8

Critical Activities (next 12 Months)

Starting activities:

- M6 – Human-Body Prediction
- M6 – Human Robot Communication
- M12 – Human Robot Motion Panning in Agreement

Technical Discussion

- T6.1. Human-Body Prediction
- T6.2. Human-Robot Motion Planning in Agreement
- T6.3. Human-Robot Communication
- T6.4. Human-Robot Awareness (Mental Model of Robotics Actions)
- T6.5. VR Human-Robot Interaction Component

Task 6.1 – Human-Body Prediction [M6-M24](Leader: UPC)

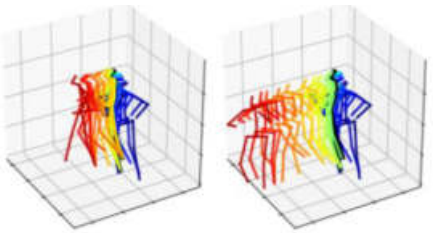
Objectives:

- Predict human-body motions in the next future
  - Predict the human-body with respect to the robot platform
  - Predict the human-arm and hand motion

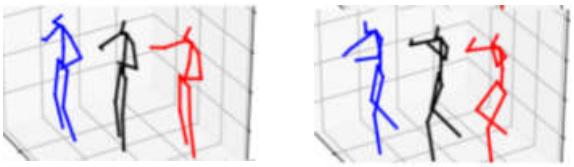
Important issues:

- Precise detection of human-joints
- Abrupt changes of human-arm and body
- Partial occlusions
- Real-time

Ground truth Prediction

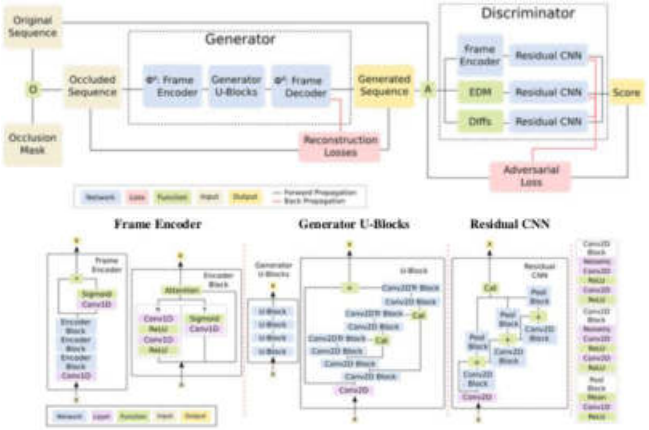


Sequences from ground truth to prediction



Task 6.1 – Human-Body Prediction [M6-M24](Leader: UPC)

- **Methods:**
  - CNNs for human-body motion prediction
  - CNNs for human-arm motion prediction
  - Computer vision techniques



A. Hernandez Ruiz, J. Gall and F. Moreno-Noguer. Human motion prediction via spatio-temporal inpainting, 17th International Conference on Computer Vision, 2019, Seoul, pp. 7133-7142.

Task 6.2 – Human-Robot Motion Planning [M12-M36](Leader: UPC)

Objectives:

- Develop shared motion plans between the robot and the human
  - Human-robot platform motion shared plan
  - Human-robot arm shared plan

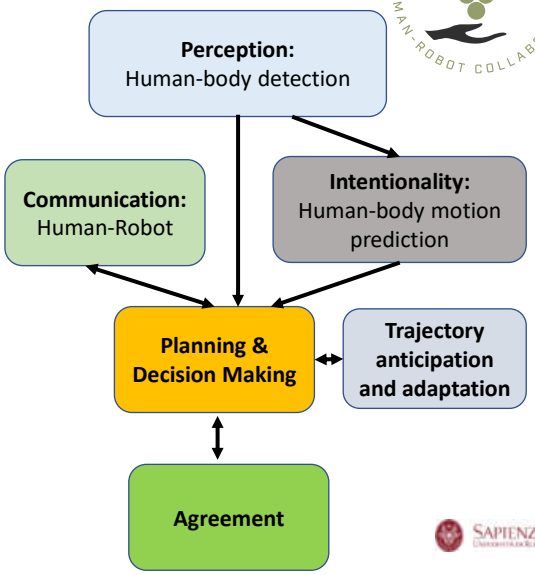
Important issues:

- Collision avoidance plan
- Sharing knowledge models
- Agreement models
- Anticipation models
- Real time

Task 6.2 – Human-Robot Motion Planning [M12-M36](Leader: UPC)

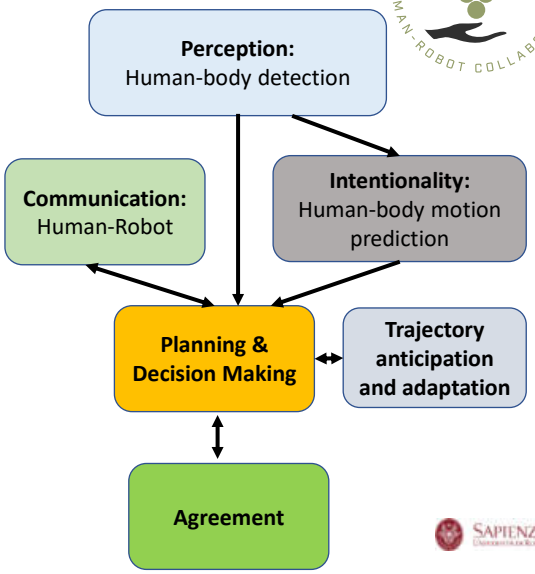
Methods:

- PRM motion plans of the robot and the human
- Reinforcement planning methods
- Motion anticipation and adaptation
- Agreement methods



Task 6.2 – Human-Robot Motion Planning [M12-M36](Leader: UPC)

E. Repiso, A. Garrell, A.Sanfeliu (2020) People's adaptive side-by-side model evolved to accompany groups of people by social robots. IEEE robotics and automation letters, Vol. 5, num. 2, p. 2387-2394



Task 6.3 – Human-Robot Communication [M6-M30] (Leader: UNIROMA1)

Goals:

- Development of the formal model of the language
- Communication modalities:
  - Spoken language
  - Gesture
  - Sound
  - Other devices

Selecting targets (grape clusters) using a gesture-based interface (Wiimote)

[**Images** taken from Adamides et al. article *«Human-Robot Interaction in Agriculture: Usability Evaluation of three Input Devices for Spraying Grape Clusters»*]

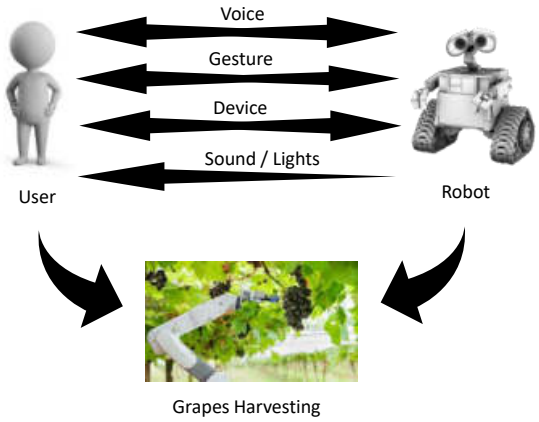
Selecting targets (grape clusters) using a typical pointing device (mouse)

Selecting targets (grape clusters) using a digital pen on a smart interactive whiteboard

Communication requirements

- Grounded terms between humans and robots (grape, bunch, harvest, prune)
- Simple language -> easily understandable
- Types of messages to be exchanged (requests, orders, tasks)
- Group consisting of several people and several robots
- Minimal interaction devices (hands free)

Multimodality



- ➢ Increase robustness -> overcome problems related to a single communication channel:
  - Noise (language)
  - Misunderstanding (language)
- ➢ Increase usability of the system
- ➢ Semantically rich input streams can support mutual disambiguation for the execution phase

Task 6.4 – Human-Robot Awareness [M25-M36] (Leader: UNIROMA1)

Goal: <u>Sharing of the cognitive model of the situation</u>

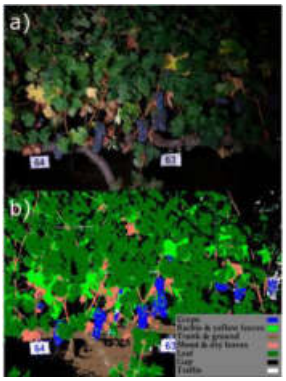
- Semantic Map (high level representation of the environment)
  - Addition of semantic information to the elements in the agriculture scenario
  - Robot ability to understand orders associated with human concepts and intended objects

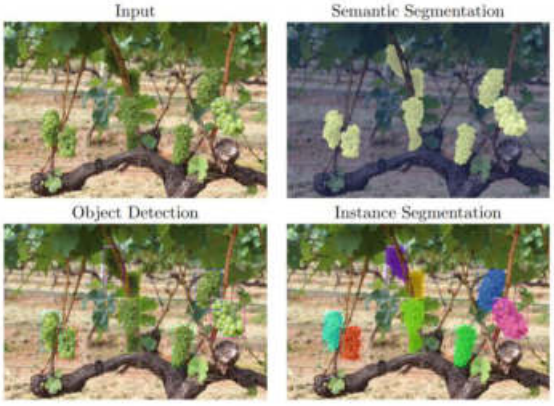
  [Article «Semantic Information for Robot Navigation: A Survey» from Crespo et al.]

- Execution plans through Petri Net Plans (high level representation of the tasks)
  - High-level plan representation formalism based on Petri Nets
  - Explicit and formal representation of actions and conditions
  - New application to HRI for collaborative working
  - Useful to design a cooperative execution of a task

  [Article «Petri Net Plans: A framework for collaboration and coordination in multi-robot systems» from Ziparo et al.]

Semantic Map

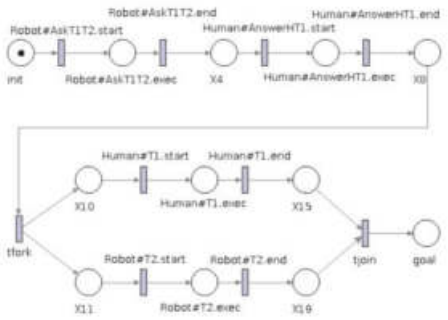




[**Left Image** taken from *Palacios et al. article: «A Non-Invasive Method Based on Computer Vision for Grapevine Cluster Compactness Assessment Using a Mobile Sensing Platform under Field Conditions»*]
[**Right image** taken from *Santos et al. article «Grape detection, segmentation and tracking using deep neural networks and three-dimensional association»*]

Petri Net Plans

- Goal: support in designing and implementing complex high-level multi-robot behaviours
  - Multi-robot system: need for coordination of robots actions to perform complex tasks
  - Collaborative behaviours: people and robots work together to accomplish a set of goals



[**Image** taken from Sebastiani et al. article *«Dealing with On-Line Human-Robot Negotiations in Hierarchical Agent-Based Task Planner»*]

Task 6.5 – VR Human-Robot-Interaction Component [M13-M18] (Leader: PaleBlue)

Technical Goals:

- 3D environment supporting communication.
- Awareness between humans and robots.
- Human-Robot motion planning.
- Human-Robot communication.
- Calibration of virtual environment related to Human-Robot awareness.

Technical Challenges: PaleBlue

- Human models: visual, physical, sensor-centric
- Physical model for interactions
- Voice communication

Technical Discussion: PaleBlue

- Sensors available so far
- Current human detection methods
- Gestures identified so far

Coordination and Planning of Activities

- **M6** next meeting for the starting of the activities
- **Monthly meetings** to measure the status of achievement of the WP
- Creation of WP6 **mailing list**

Let's move on to the next WP…

Any questions?

A Collaborative Paradigm for Human Workers and Multi-Robot Teams in Precision Agriculture Systems

WP7 - Multi-Robot Coordination

This project is funded by the European Union G.A No 101016906

1

Goal

Coordination of Heterogeneous Team of Robots

Logistic robots for logistic tasks, e.g., transport boxes of harvested grapes

Agricultural robots for agronomic tasks, e.g., harvesting or pruning

Design of **distributed** coordination control strategy to **optimally** carry out the requested agronomic activities

2

Objectives

- Objective 1 – Box-Exchange Coordinated Maneuvering
- Objective 2 – Distributed Estimation of Filling Time Dynamics
- Objective 3 – Distributed Optimal Field Coverage by Logistic Robots
- Objective 4 – Distributed De-Synchronization by Agricultural Robots

Tasks Description

Task 7.1 – Coordinated Maneuvering for Box-Exchange Operation [M8-M31]

(Leader: **UNIROMA3**)

Partner	UNIROMA3	KTH	UNIROMA1	UPC	UNICLAM	DTI	PALEBLUE	PAL	AGRIM.	RSA
PM	11	0	0	1	0	6	0	0	0	0

- We will start from the outcome of the Task 3.3 (design of the box exchange mechanism) to characterize a **relative state configuration** among the two robotic platforms to facilitate the **exchange of the boxes**.
- We will model this coordination problem as a **relative pose stabilization** problem and resort to tools coming from system and control theory to design a proper control law to achieve this objective.
- We will investigate whether a **dynamic local planner** may be required for handling **unmodeled factors** such the uneven nature of the terrain and the unexpected presence of obstacle appearing during the manoeuvring.

Tasks Description

Task 7.2 – Distributed Protocols for Dynamical Systems Estimation [M25-M41]

(Leader: **UNIROMA3**)

Partner	UNIROMA3	KTH	UNIROMA1	UPC	UNICLAM	DTI	PALEBLUE	PAL	AGRIM.	RSA
PM	11	0	0	1	0	6	0	0	0	0

- We will start by developing a simply **dynamical model** encoding the **time required for filling** a box due for example to fruit harvesting or vine pruning.
- We will resort to observer-based techniques in order to design a **distributed protocol** for **estimating** the (average of the) **main parameters** of the box-filling dynamics carried out by each agricultural robot in the field.

Tasks Description

Task 7.3 – Distributed Protocols for Optimal Field Coverage [M18-M42]

(Leader: **UNIROMA3**)

Partner	UNIROMA3	KTH	UNIROMA1	UPC	UNICLAM	DTI	PALEBLUE	PAL	AGRIM.	RSA
PM	11	0	0	1	0	6	0	0	0	0

- We will develop distributed methodologies for **spatially coordinating** the logistic robots in order to **optimally fulfil** the box-exchange **service requests**.
- We will model the occurring of box-exchange by means of **time-varying** and **spatially varying functions** by exploiting the outcome of Task 7.2 and we will compute the **priority** that each logistic robot may give with respect to any of the box-exchange service requests by resorting to a **distributed data association** problem.
- We will encode the optimal field coverage problem as an **optimization problem** and design **distributed coordination** strategy to let each logistic robot move towards the next agricultural robot likely to be served.

Tasks Description

Task 7.4 –Distributed Protocols for Dynamical Systems De-Synchronization [M25-M41]

(Leader: **UNIROMA3**)

Partner	UNIROMA3	KTH	UNIROMA1	UPC	UNICLAM	DTI	PALEBLUE	PAL	AGRIM.	RSA
PM	14	2	0	0	5	0	0	0	0	0

- We will develop **distributed coordination** methodologies for **controlling the execution** of the tasks carried out by the agricultural robots by resorting to the dynamical modelling of the filling time obtained as outcome of Task 7.2.
- We will attempt to schedule the request of services in such a way to **minimize the occurrence of any peak** of requests in order to **facilitate the optimal field coverage** investigated on Task 7.3.

Tasks Description

Task 7.5 – VR Multi-Robot Component [M15-M22]

(Leader: **PALEBLUE**)

Partner	UNIROMA3	KTH	UNIROMA1	UPC	UNICLAM	DTI	PALEBLUE	PAL	AGRIM.	RSA
PM	14	2	0	0	5	0	0	0	0	0

- Enhancement of the VR farming environment with **support of multiple robot participants** in order to facilitate the **validation of robot coordination** developed in this WP.
- The 3D environment will be used as the medium for virtual interactions between the robot actors. Main aspects:
  - modelling of the **relative perception capabilities** (e.g., laser-based, camera-based) among the robots, using software components develop to mimic real interactions, and transferring the interactions to the virtual space.
  - modelling of the **pairwise communication** among the robotic agents (e.g., anisotropic communication channel with distance-based fading reliability) based on 3D space calculation and signal distribution models.

VR Multi-Robot Component

Technical Goals:

- VR farming environment with multiple robot participants.
- Relative perception for visual perception between robots.
- Modelling communication between robotic agents.

Deliverables

D7.1: Box-Exchange Coordinated Manoeuvring	Leader: UNIROMA3	Delivery Month: **M20**
The control algorithm for manoeuvring is complete and can enable the box-exchange through the specific tool.		
D7.2: Multi-Robot Distributed Protocols	Leader: UNIROMA3	Delivery Month: **M42**
The design of the multi-robot distributed protocols for dynamical systems estimation and de-synchronization as well as field coverage is complete.		
D7.3: VR-Robot Component	Leader: PALEBLUE	Delivery Month: **M22**
The VR farming environment includes the robots' perception capabilities and the pairwise communication among the robots.		

Milestones

# Mil.	Description	Related WP(s)	Due Date	Means of verification
MS1	All technical specifications finalised	WP2	M6	Deliverable D2.1
MS2	First Release of Farming and Logistic Robot Prototypes	WP3	M14	Deliverable D3.2
MS3	Final Release of the VR Farming Environment	WP[3,4,5,6,7,8]	M25	Software Released and Validated by a User Group
MS4	Robotic Navigation and Coordination Field Validation	WP9	M33	Deliverable D9.1
MS5	Human-Robot Interaction: Safety and Communication	WP5, WP6	M36	Deliverables D5.2, D6.2
MS6	Human-Robot Collaboration: Planning in Agreement, Task Planning	WP6, WP8	M36	Deliverables D6.1, D8.1
MS7	Experimental validation of the integrated system with respect to the pilot scenario	WP9	M48	Deliverable D9.4

Critical Activities (next 12 Months)

I. <u>Box-Exchange</u>
   I. Sensors and Communication Selection (by the end of **February**)
   II. Main aspects of BEM Mechanical Design (by the end of **April**)
   III. Robot-to-Robot Interaction Simulation (by the end of **December**)

II. <u>Coordination at large</u>
   I. Multi-Robot Simulation Environment (basic version by the end of **December**)

Technical Discussion

- **Numerical Validation:**
  - Definition of an (intermediate) Simulation Environment (Gazebo?)
  - Integration of Gazebo models with PALEBLUE VR Environment
  - Definition of Robot Models (unique model for both environments?)

- **Experimental Validation:**
  - Maneuvering: how to handle the logistic? (in Denmark?)

Coordination and Planning of Activities

- **Monthly meetings** to measure the status of achievement of the WP
- The **leading unit** of each task is responsible for **its timely completion**
- **The leading unit** of each task is responsible for the **drafting of the related deliverable** (all involved units must contribute)
- The **leading unit** of the WP is responsible for **communicating with the PI** in the case of difficulties

Let’s move on to the next WP…

Any questions?

KoM Day 2

A Collaborative Paradigm for Human Workers and Multi-Robot Teams in Precision Agriculture Systems

Consortium Introduction

This project is funded by the European Union
G.A No 101016906

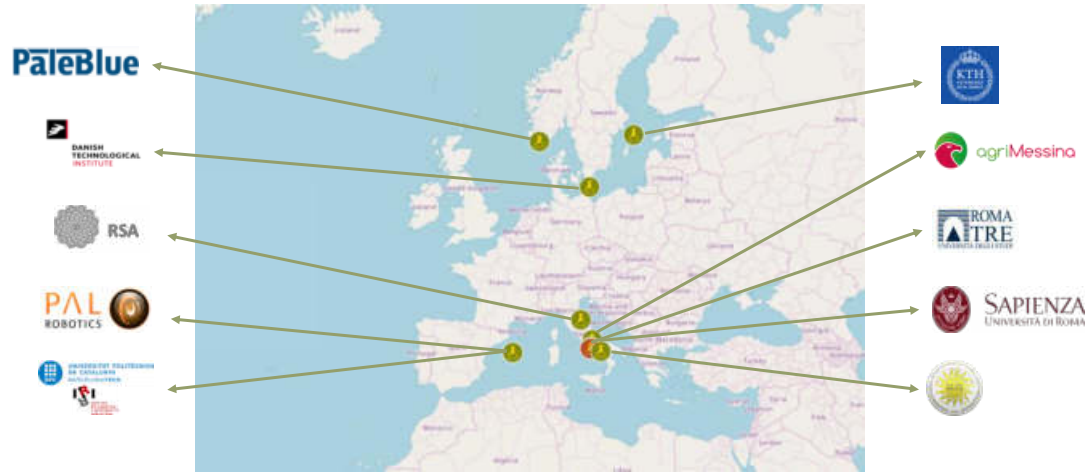
1

Canopies Project

Consortium

- 5 Countries
- 5 Universities
- 1 Research Center
- 4 SMEs

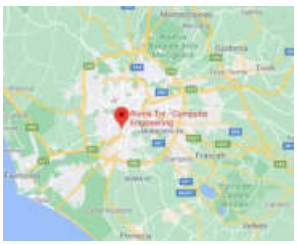
Canopies: where do we come from?



Università degli Studi Roma Tre (UNIROMA3)

Description

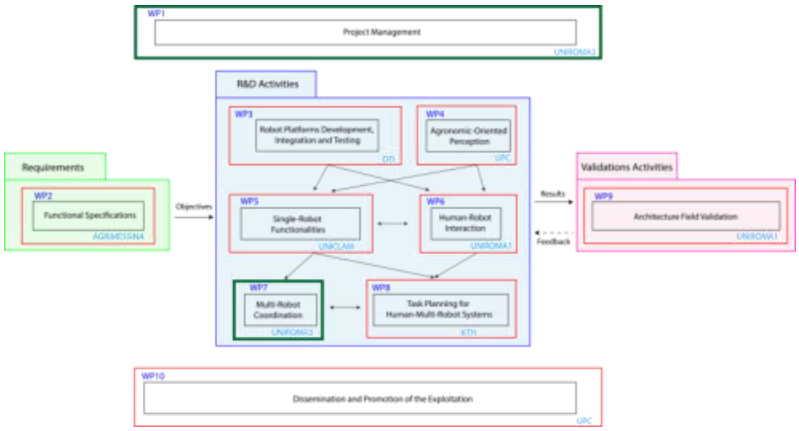
- Young **public research university** founded by the Italian Ministry of Education, University and Research in **1992**.
- Roma Tre University is organized in **12 Departments** enrolling about **35.000** students and having about **1.400** academic and professional staff.
- Our **Engineering Department** was selected by the Italian Ministry of Public Education as one of the 180 **Departments of Excellence** in 2018.



Università degli Studi Roma Tre (UNIROMA3)

Role in the Project

- Project Coordination
- Leadership of WP1 (technical and scientific project coordination)
- Leadership of WP7 (Design of distributed estimation, coordination and field coverage protocols)



Università degli Studi Roma Tre (UNIROMA3)

Role in the Project

- Leadership of Task 1.1 in WP1 (technical and scientific coordination)
- Leadership of Task 1.3 in WP1 (risk assessment)
- Leadership of Task T2.5 in WP2 (dimensioning of real-world scenarios for periodic field testing and final demo)
- Leadership of Task T3.5 in WP3 (design of the autonomous navigating functionalities of the mobile robotic platform)

Università degli Studi Roma Tre (UNIROMA3)

Role in the Project

- Leadership of Task T7.1 in WP7
  (coordinated maneuvering for box-exchange operation)
- Leadership of Task T7.2 in WP7
  (distributed protocols for dynamical systems estimation)
- Leadership of Task T7.3 in WP7
  (distributed protocols for optimal field coverage)
- Leadership of Task T7.4 in WP7
  (distributed protocols for dynamical systems de-synchronization)

Università degli Studi Roma Tre (UNIROMA3)

Role in the Project

- Leadership of Task T9.5 in WP9
  (field validation of the multi-robot coordination capabilities)
- Leadership of Task T9.7 in WP9
  (final demonstration of the integrated system within a real-world (1:1 scale) table- grape vineyard)
- Leadership of Task T10.3 in WP10
  (dissemination and synergies with DIH-agROBOfood)

Università degli Studi Roma Tre (UNIROMA3)

Team

Andrea Gasparri
Associate Professor

Stefano Panzieri
Full Professor

Giovanni Ulivi
Full Professor

Federica Pascucci
Associate Professor

Martina Lippi
Research Affiliate

Antonio Furchì
Ph.D Student

Matteo Santilli
Research Affiliate

Renzo Carpio
Ph.D Student

Università degli Studi Roma Tre (UNIROMA3)

Expertise

- Field Robotics
- Autonomous Navigation
- SLAM
- Multi-Robot Coordination
- Distributed Estimation
- Distributed Control

Autonomous Navigation in Dynamic Environment

Large-Scale Simultaneous Mapping and Localization

Multi-Robot Coordination with limited FOV

Multi-Robot Collaboration

Università degli Studi Roma Tre (UNIROMA3)

Projects

PANTHEON – PRECISION FARMING OF HAZELNUT ORCHARDS
(H2020-SFS-2017-1)
[2017 – 2021]

PARADISE – PRECISION FARMING FOR SUSTAINABLE PRODUCTION IN SUBURBAN AREAS
(POR-FESR 2014-2020 REGIONE LAZIO)
[2020 – 2022]

RESISTO – RESILIENCE ENHANCEMENT AND RISK CONTROL PLATFORM FOR COMMUNICATION INFRASTRUCTURE OPERATORS
(H2020-CIP-2016-2017)
[2018 – 2021]

COCKPITCI – CYBERSECURITY ON SCADA: RISK PREDICTION, ANALYSIS AND REACTION TOOLS FOR CRITICAL INFRASTRUCTURES
(FP7-SEC-2011-1)
[2012 – 2014]

ATENA – ADVANCED TOOLS TO ASSESS AND MITIGATE THE CRITICALITY OF ICT COMPONENTS AND THEIR DEPENDENCIES OVER CRITICAL INFRASTRUCTURES
(H2020-DS-2015-1)
[2016 – 2019]

NECTAR – NETWORKED COOPERATIVE TEAMS OF AUTONOMOUS ROBOTS
(FIRB FUTURO IN RICERCA 2008)
[2010 – 2014]

Kungliga Tekniska Högskolan (KTH)

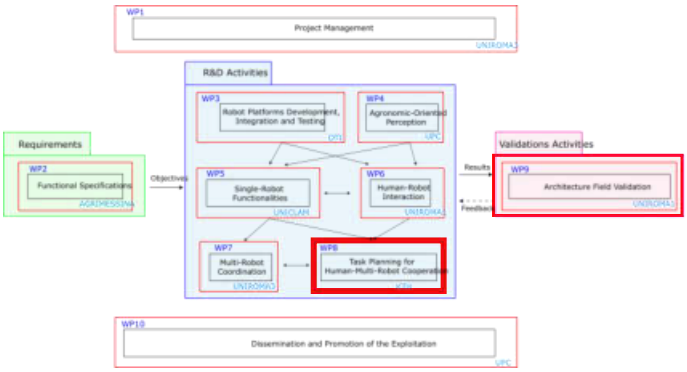
Description

- Largest technical university in Sweden (1/3 of Sweden's capacity for engineering and technical research at post-secondary level)
- Part of WASP and KTH Digital Future environments
- Expertise & perspectives from the private and public sectors provided in collaborations & knowledge exchange with external partners and other universities

Kungliga Tekniska Högskolan (KTH)

Role in the Project

- Leadership of WP8 (Task Planning for Human-Multi-Robot Systems)
- Leadership of Task T9.6 in WP9 (Field Validation of the Task Planning for Human-Multi-Robot Systems)



Kungliga Tekniska Högskolan (KTH)

Unit Members:

Decision and Control Systems (DCS) Lab

Dimos Dimarogonas

Wenceslao Shaw Cortez

Pushpak Jagtap

Carlos Rodríguez de Cos

Expertise:

Task planning, Control of multi-robot systems

Kungliga Tekniska Högskolan (KTH)

Unit Members:

Robotics, Perception, and Learning (RPL) Lab

Danica Kragic

Hang Yin

Ali Ghadirzadeh

Expertise:

- Vision for robotics
- Learning

Kungliga Tekniska Högskolan (KTH)

Projects:

- Horizon 2020 Areoworks (2015-2018)
- H2020 Co4Robots (2017-2020)
- ERC StG BUCOPHSYS (2015-2020)
- SSF FACT (2016-2020)
- H2020 socSMCs (2015-2019)

Sapienza Università di Roma (UNIROMA1)

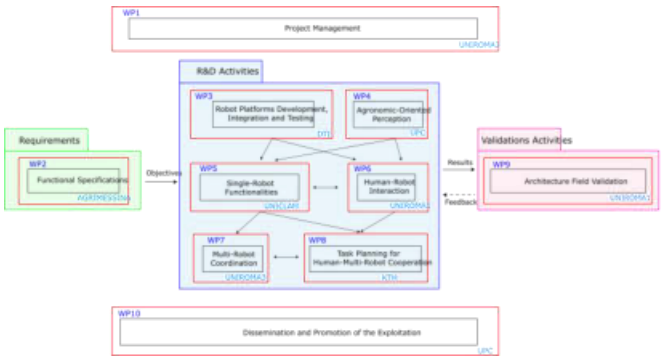
Description

- One of the oldest (1303) and largest Universities, the largest in Eu.
- Sapienza University is organized in 68 Departments, 12 Faculties enrolling about 115.000 students with about 5500 academic and professional staff.
- Our Department was selected by the Italian Ministry of Public Education among the 180 Departments of Excellence focused on Cyber Security, 2018.

Sapienza Università di Roma (UNIROMA1)

Role in the Project

- Leadership of WP6 (Human Robot Interaction)
- Leadership of WP9 (Field Validation)



Sapienza Università di Roma (UNIROMA1)

Role in the Project

- Leadership of Task T2.4 (Human-Robot Communication Specifications)
- Leadership of Task T4.3 in WP4 (Grape Quality Estimation)
- Leadership of Task T6.3 in WP6 (Human Robot Communication)
- Leadership of Task T6.4 in WP6 (Human Robot Awareness)
- Leadership of Task T9.4 in WP9 (Field validation of the hri capabilities)

Sapienza Università di Roma (UNIROMA1)

Lab RoCoCo http://www.diag.uniroma1.it/~labrococo

Daniele Nardi

Luca Iocchi

Giorgio Grisetti

Mulham Fawakerij WP4

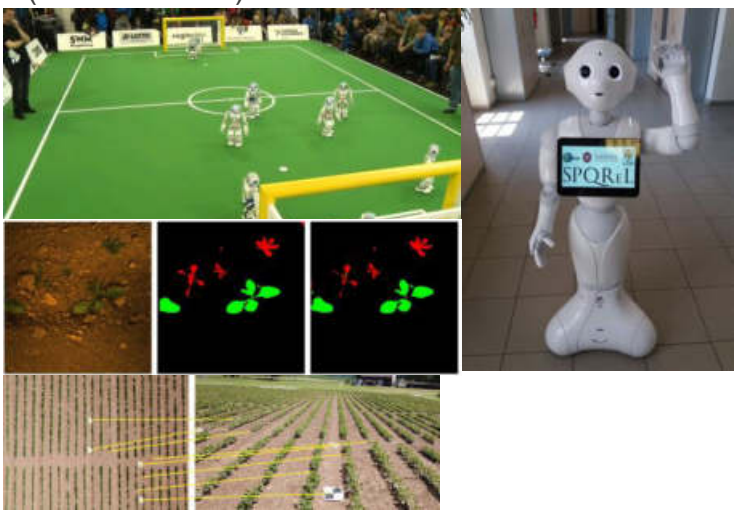
Thomas Ciarfuglia WP4

Sara Kaszuba WP6

Sapienza Università di Roma (UNIROMA1)

Team Expertise

- Artificial Intelligence
- Human Robot Interaction
- SLAM
- Action Planning
- Robot Perception
- AI and Robotics for Precision Farming



Projects

SciRoc — European Robotics League plus Smart Cities Robot Competitions
CA H2020 2019-2021

BUBBLES — BUBBLES: Defining the **BU**ilding **B**asic **Bl**ocks for a U-Space S**E**paration Management **S**ervice
FP7 2013-2016

AI4EU — A European AI on demand platform and Ecosystem
H2020 2019-2021

Flourish — European Robotics League plus Smart Cities Robot Competitions
H2020 2015-2018

AIPlan4EU — Bringing AI Planning to the European AI On-Demand Platform
Bringing AI Planning to the European AI On-Demand Platform
H2020 2021-2023

Rovina — Robots for Exploration, Digital Preservation and Visualization of Archeological Sites
FP7 2013-2016

Universitat Politècnica de Catalunya (UPC)

Description

- The Universitat Politècnica de Catalunya (UPC) (www.upc.edu) is a public institution dedicated to research and higher education and it is one of the biggest universities in Spain, with over 32.000 students, 33 departments and 205 research groups. UPC participates in this project with IRI and UMA.
- The Institut de Robòtica i Informàtica Industrial (IRI, www.iri.upc.edu) is a Joint Research Institute that hosts researchers both from the Universitat Politècnica de Catalunya (UPC) and from the Spanish Scientific Research Council (CSIC), and participate in this project as a Joint Research Unit (JRU), with UPC leading the participation, and CSIC acting as 3rd party.
- Unit of Agricultural Machinery (http://www.uma.deab.upc.edu) is a recognized research group bellowing to UPC. Main activities of UMA are focused in research, education and extension activities related with agricultural machinery.

EXCELENCIA MARÍA DE MAEZTU

Universitat Politècnica de Catalunya (UPC)

Role in the Project

- Leadership of WP4 (Agronomic-oriented perception)
- Leadership of WP10 (Dissemination and Promotion of the Exploitation)

Universitat Politècnica de Catalunya (UPC)

Role in the Project

- Leadership of Task T4.1 in WP4 (Agronomic Target Detection and Modelling)
- Leadership of Task T4.2 in WP4 (Agronomic Target Localization)
- Leadership of Task T6.1 in WP6 (Human-Body Prediction)
- Leadership of Task T6.2 in WP6 (Human-Robot Motion Planning)
- Leadership of Task T10.1 in WP10 (Website Construction and Updates)
- Leadership of Task T10.2 in WP10 (Dissemination)
- Leadership of Task T10.4 in WP10 (Communication Activities and Event)

Universitat Politècnica de Catalunya (UPC)

Unit Members

- Alberto Sanfeliu (UPC-IRI)
- Emilio Gil (UPC-UMA)
- Juan Andrade-Cetto (CSIC-IRI)
- Antonio Grau (UPC-IRI)
- Yolanda Bolea (UPC-IRI)
- Rene Alquezar (UPC-IRI)
- Ana Puig-Pey (UPC-IRI)
- Joan Vallbè (UPC-IRI)
- Francesc Moreno-Noguer (CSIC-IRI)
- Anais Garrell (CSIC-IRI)
- Joan Solá (CSIC-IRI)

Universitat Politècnica de Catalunya (UPC)

Expertise

IRI focuses its activity in human-centered robotics research with expertise in various areas of robotics, such as computational kinematics and geometry, computer vision, industrial robotics, mobile robotics (legged and wheeled robots), artificial intelligence, and energy systems.

UMA has large experience in viticulture, especially in spray application technology. Precision Agriculture linked to pesticide application equipment, variable rate application, development of new technologies to improve efficacy of sprayers.

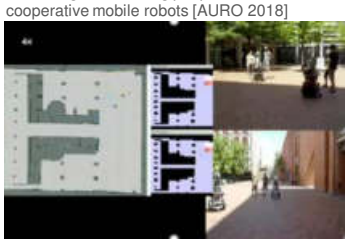
- Robotics
- Social robotics
- Artificial Intelligence
- Human-body prediction
- Perception systems
- Precision Farming

Universitat Politècnica de Catalunya (UPC): IRI

Collaborative, cooperative and Social Robotics

- Deep and Reinforcement Learning
- Path and action planning
- Shared planning and reasoning

Searching and tracking people with cooperative mobile robots [AURO 2018]



Anticipative kinodynamic planning: multi-objective robot navigation [AURO 2019]

People's V-formation model adapted to accompany groups of people [IROS 2019]

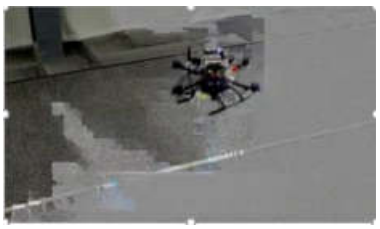
Teaching a Drone to Accompany a Person [IROS19]

Universitat Politècnica de Catalunya (UPC): IRI

Aerial Robotics Localization and map building (SLAM)

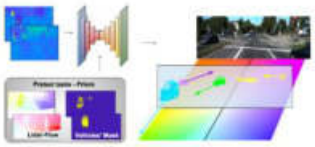
- Sensory data fusion for localization
- SLAM and Deep Learning
- Object detection and tracking using Deep Learning

Sensor fusion in unmanned aerial vehicles (H2020 AEROARMS project) [Auton. Robots 2018]

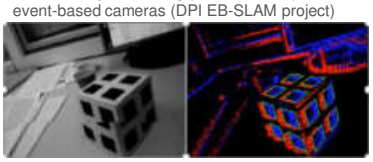


Precise localization in aerial grasping (EU ARCAS project)

3D Lidar Deep learning for object tracking [ICPR, 2018]



Ultra fast object tracking (microseconds) with event-based cameras (DPI EB-SLAM project)

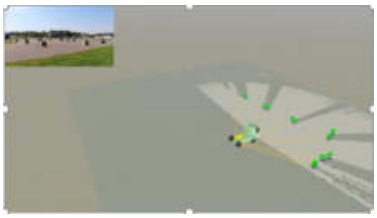


Universitat Politècnica de Catalunya (UPC): IRI

Robotics applied to logistics and transport: ADAS

- Perception, path planning and decision making
- Deep learning for vehicle detection and tracking

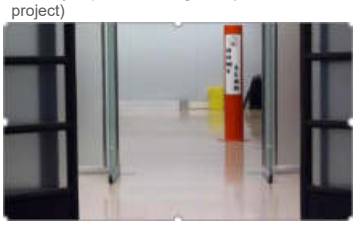
Real-time SLAM in a truck (EU LOGIMATIC project)



Sensor fusion for advanced driving assistance systems (FICOSA), [ECMR17]

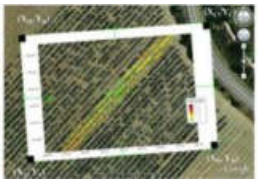
Autonomous navigation of straddle carrier in port container terminals (H2020 LOGIMATIC project)

Delivery of persons and goods (DPI ColRobTransp project)



Universitat Politècnica de Catalunya (UPC): UMA

Pesticide application
Precision farming

Universitat Politècnica de Catalunya (UPC)

IRI Projects

AI4EU: A European AI On Demand Platform and Ecosystem
(H2020-ICT-2018-2-825619)[2019-2021]

TERRINet: The European Robotics Research Infrastructure Network
(H2020-INFRAIA-2017-1-two-stage-730994)[2017-2021]

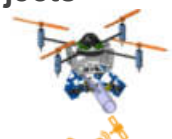
ROBOCOM++: Rethinking Robotics for the Robot Companion of the future
(FLAG-ERA JCT 2016)[2017-2020]

SciRoc: European Robotics League plus Smart Cities Robot Competitions
(H2020-ICT-2017-1-780086)[2018-2022]

GAUSS: Galileo-EGNOS as an Asset for UTM Safety and Security
(H2020-GALILEO-GSA-2017-1-776293)[2018-2021]

Universitat Politècnica de Catalunya (UPC)

IRI Projects



AEROARMS: AErial RObotics System integrating multiple ARMS and advanced manipulation capabilities for inspection and maintenance (H2020_ICT-2014-1-644271)[2015-2019]

LOGIMATIC: Tight integration of EGNSS and on-board sensors for port vehicle automation (H2020-Galileo-2015-687534) [2016-2019]

ECHORD++: European Clearing House for Open Robotics Development Plus Plus (FP7-ICT-2012-601116)[2013-2018]

Cargo-ANTS: Cargo handling by Automated Next generation Transportation Systems for ports and terminals (FP7-SST-2013- 605598) [2013-2016]

ARCAS: Aerial Robotics Cooperative Assembly System (FP7-INFSO-ICT-287617)[2011-2015]

Universitat Politècnica de Catalunya (UPC)

UMA Projects

NOVATERRA: Integrated novel strategies for reducing the use and impact of pesticides, towards sustainable mediterranean vineyards and olive groves (H2020)[2020-2024]

INNOSETA: Accelerating Innovative practices for Spraying Equipment, Training and Advising in European agriculture through the mobilization of Agricultural Knowledge and Innovation Systems (H2020) [2018-2021]

OPTIMA: Optimized Pest Integrated Management to precisely detect and control plant diseases in perennial crops and open-field vegetables (H2020)[2018-2021]

AGRICT – Erasmus +: Precision farming education (H2020)[2018-2021]

Università degli Studi di Cassino (UNICLAM)

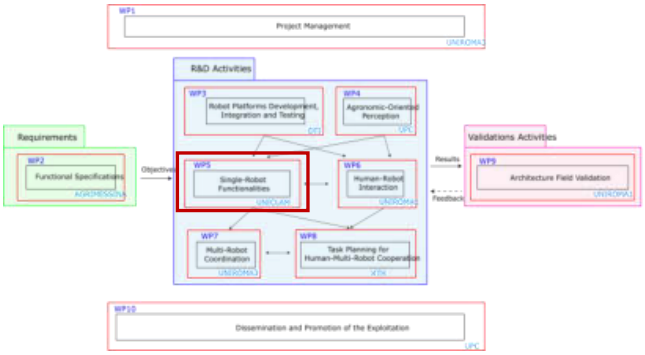
Description

- Public research university founded by the Italian Ministry of Education, University and Research in 1979.
- UNICLAM University is organized in 5 Departments enrolling about 9.000 students and having about 500 academic and professional staff.
- Our Engineering Department (DIEI) was selected by the Italian Ministry of Public Education as one of the 180 Departments of Excellence in 2018.

Università degli Studi di Cassino (UNICLAM)

Role in the project

- Leadership of **WP5** (Single Robot Functionalities)
- Leadership of Task 5.1 (Two Arms Coordination Functionalities)
- Leadership of Task 5.2 (Robot Safety Functionalities)
- Leadership of Task 5.3 (Robot Physical Interaction Functionalities)
- Leadership of Task 9.2 (Field Validation of the Robot Manipulation Functionalities)



Università degli Studi di Cassino (UNICLAM)

Alessandro Marino
Associate Professor

Stefano Chiaverini
Full Professor

Gianluca Antonelli
Full Professor

Filippo Arrichiello
Associate Professor

Giuseppe Fusco
Associate Professor

Paolo Di Lillo
Post Doc

Daniele Di Vito
Post Doc

Giuseppe Gillini
Post Doc

Giacomo Golluccio
PhD Student

webuser.unicas.it/lai/robotica

Università degli Studi di Cassino (UNICLAM)

Industrial & Service Robotics

Marine Robotics

Assistive Robotics

Cooperative Manipulation

Human-Robot-Interaction

Multiple-robot systems

Several National and European past and ongoing projects

Università degli Studi di Cassino (UNICLAM)

EUMR H2020 (2018-21)
Robotic subsea exploration technologies

TARMEM QNRF (2018-21)
CMU Doha

C4E - PON (2018-21) Monitoring of illegal spills through the synergistic use of advanced technologies

Progetto Dipartimenti di Eccellenza
MIUR (2018-22)

ROBILAUT PON (2019-2022)
MoBILe sampling robot with underground autonomous navigation

ROBUST H2020 (2015-20)
Robotic subsea exploration technologies

AEROARMS H2020 (2015-19)
Aerial Robots with multiple arms

WiMUST H2020 (2015-18)
Widely scalable Mobile Underwater Sonar Technology

DexROV H2020 (2015-18) Dexterous ROV Operations Communications Latencies

Università degli Studi di Cassino (UNICLAM)

Academic Spin-off

- To bridge the gap between research and implementation
- Expertise in several fields of robotics

EVERYBOTICS

EveryBotics

Coding
- C++
- Python
- ROS
- PLC

Robotics
- Industrial robotics
- Mobile robotics
- Multi-robot systems
- Marine robotics

IOT
- Big Data
- Satellite Imagery Mining
- Signal Processing
- Advanced Networks

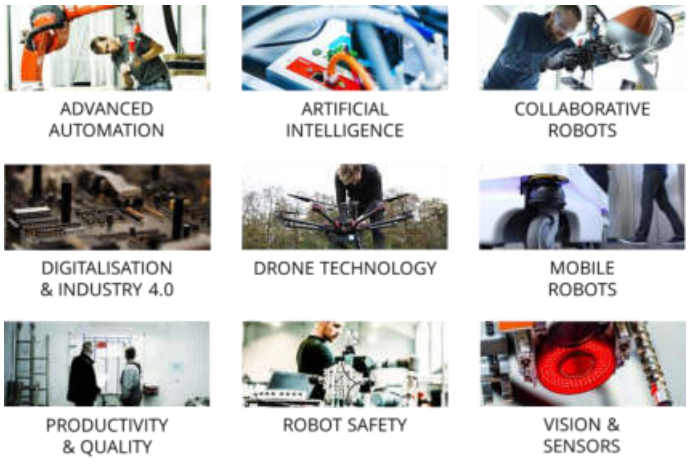
www.everybotics.it

Danish Technological Institute (DTI)

- **Description**
- Self-owned and not-for-profit Research & Technology Organisation (RTO) that dates back to 1906, organized in 7 major divisions with more than 40 centers of expertise.
- DTI's Centre for Robot Technology is located in Odense and is a leading European robotics innovator with a staff of around 45 robotic experts and 2,800m2 of innovation facilities.
- DTI is a pioneer for application-orientated technology and knowledge transfer between research and the business community, particularly for SMEs.

Danish Technological Institute (DTI)

Areas of expertise



Danish Technological Institute (DTI)

Role in the Project

DTI is lead on WP3

- HW and SW development and integration of the robotic prototypes.
- Design, develop and test required prototype mechanisms.
- Endow the robotic prototype with autonomous localization and navigation capabilities.
- Acceptance testing of the robotic prototypes.

Danish Technological Institute (DTI)

Role in the Project

- Leadership of Task T2.2 in WP2 (robot specifications and KPIs)
- Leadership of Task T9.1 in WP9 (field validation of robot navigation)

Danish Technological Institute (DTI)

Team

Lars Dalgaard
Section Leader

Tsampikos Kounalakis
Consultant – CANOPIES project manager

Kasper Camillus Jeppesen
Consultant

Jonas Bæch
Consultant

Xaver Kroischke
Specialist

Danish Technological Institute (DTI)

Expertise

Precision Farming

Autonomous navigation

Robot prototyping

Robot integration

ROS / ROS2

Artificial intelligence

Agronomic vision

AR / VR

Safety

Human-Robot-Interaction

Danish Technological Institute (DTI)

Relevant Projects

agROBOfood – DIH network
(DT-ICT-02, 2019-2024)
[2019 – 2024]

S3CAV - Simultaneous Safety and Surveying for Collaborative Agricultural Vehicles
(ICT-Agri)
[2016 – 2018]

TPR – Tomato Picking Robot
(Eurostars)
[2018-2020]

COVR – Safety for Collaborative Robots
(H2020-ICT)
[2018-2021]

TEDAI – Tethered drones for semi-automated inventory checking
(Eurostars)
[2018-2021]

Cobot Knowledge Lab
(national project)
[2019-2021]

SafeCOP –Safe Cooperating Cyber-Physical Systems using Wireless Communication
(ECSEL-JU)
[2016-2019]

R5-COP –Reconfigurable ROS-based Resilient Reasoning Robotic Cooperating Systems
(ECSEL-JU)
[2014-2017]

PaleBlue AS (PALEBLUE)

Description

- PaleBlue is a leading simulation company with experience in VR, AR and 3D simulators. 2019 Top 10 Simulation company.
- Founded in 2013 in Stavanger, Norway. Now offices in NO, NL, RU and US.

- Delivering simulators across segments for Oil & Gas (Neptune Energy), Space (NASA and ESA), Healthcare (Gullak), and Governmental.

PaleBlue AS (PALEBLUE)

Team Members

Felix Gorbatsevich

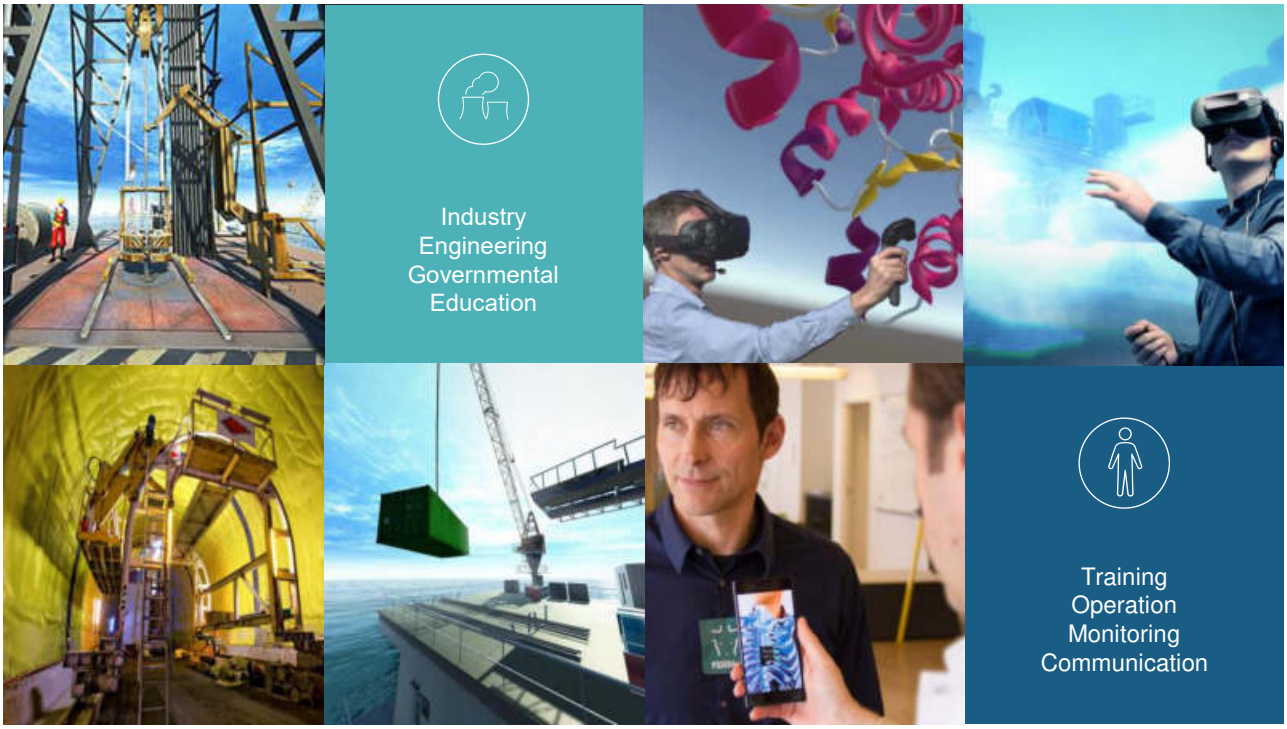
Juan Correa

Vladimir Keda

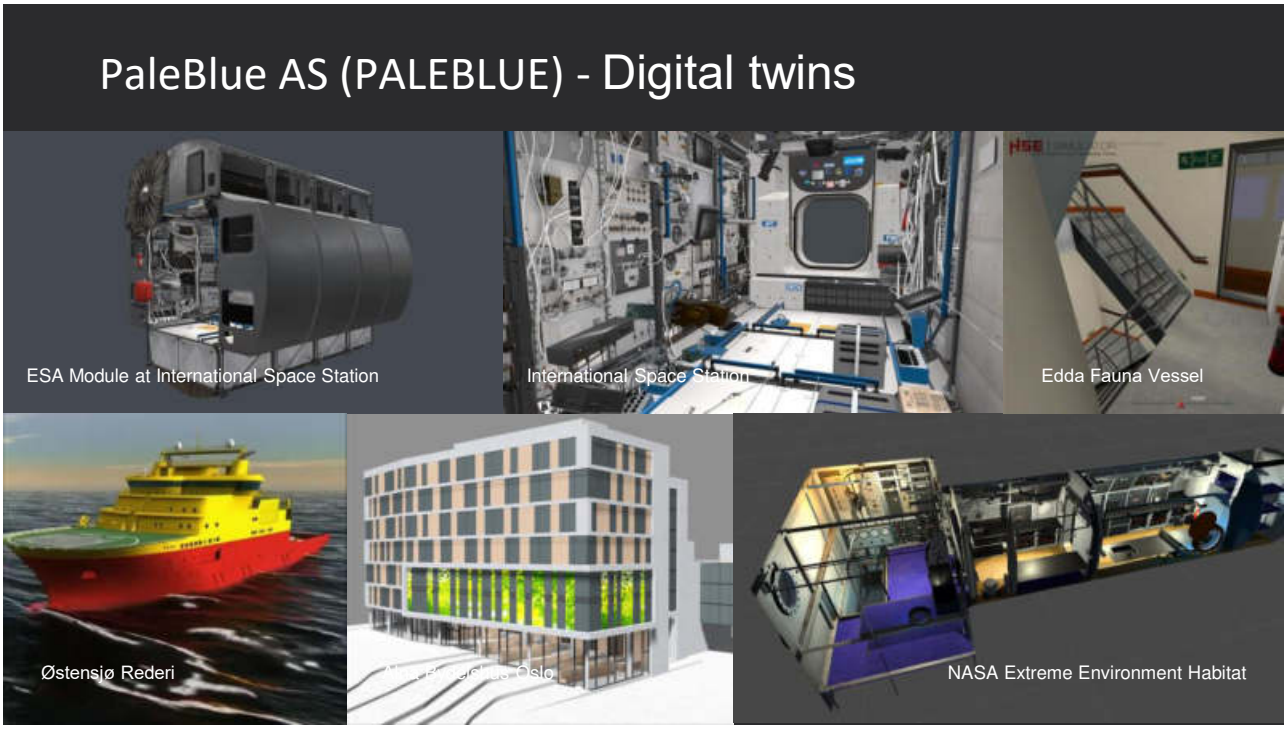
Urte Villnow

Vladimir Dukhanin

Pascal Serrarens


Industry
Engineering
Governmental
Education
Training
Operation
Monitoring
Communication

51


PaleBlue AS (PALEBLUE) - Digital twins
ESA Module at International Space Station
International Space Station
Edda Fauna Vessel
Østensjø Rederi
NASA Extreme Environment Habitat

52

PaleBlue AS (PALEBLUE)

Selected projects

Modeling operations with PaleBlue VR toolset for Extreme Environments training

Building a tool for Alna District to familiarize with the new town hall, and perform employee training

Industry 4.0 tools providing AR Condition Monitoring tools to the factories & plants

VR training for astronauts in Zero Gravity making a digital twin of the International Space Station

One of the largest HSE & Diving professional training providers in South-East Asia and Oceania

Continuously adding industrial partners that leverage on the PaleBlue Simulation Platform

PaleBlue AS (PALEBLUE)

PaleBlue AS (PALEBLUE)

Role in the Project

- Lead the development of the 3D and VR simulation platform components and interfaces to facilitate virtual environments for interactions between robots, humans and the environment.
- Lead the development of:
  - VR Multi-Human-Multi-Robot Interaction Component
  - VR Multi-Robot Component
  - VR Human-Robot Interaction Component
  - VR Agronomic-Oriented Perception
  - VR Farming Environment.

PaleBlue AS (PALEBLUE)

Role in the Project

- Leadership of Task T2.6 in WP2 (Virtual Reality Farming Environment Specifications)
- Leadership of Task T3.7 in WP3 (Simulated Environment and Basic Robotic Components)
- Leadership of Task T4.4 in WP4 (VR Agronomic-Oriented Perception Component)

PaleBlue AS (PALEBLUE)

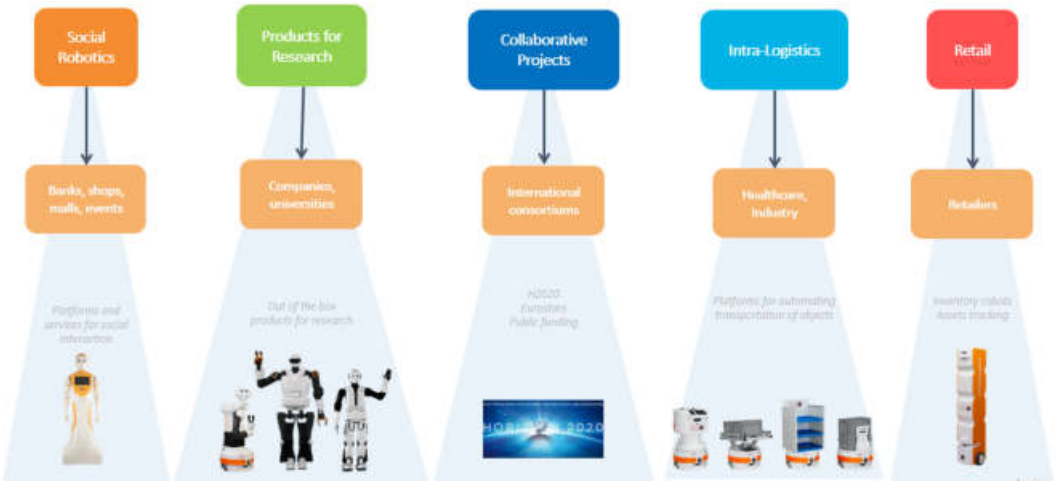
Role in the Project

- Leadership of Task T5.4 in WP5 (VR Mobile-Robot Component)
- Leadership of Task T6.5 in WP6 (VR Human-Robot-Interaction Component)
- Leadership of Task T7.5 in WP7 (VR Multi-Robot Component)
- Leadership of Task T8.4 in WP8 (VR Multi-Human-Multi-Robot Interaction Component)

PAL Robotics (PAL)

- Founded in 2004
- Located in Barcelona
- 15 nationalities
- 80% Engineers
- 10% Ph.D.
- Robots sales +30 countries

PAL Robotics (PAL)



PAL Robotics (PAL)

Team

Principal Investigator

Francesco Ferro
francesco.ferro@pal-robotics.com
CEO

Project administration

Sarah Terreri
sarah.terreri@pal-robotics.com
European Project Manager

Research Team

Dr. Alessandro Di Fava
alessandro.difava@pal-robotics.com
Robotics Engineer
Technical coordination of PAL Robotics' EU projects team

Dr. Jordi Pages
jordi.pages@pal-robotics.com
Head of Intra-logistics Solutions
TIAGo Product Manager

CANOPIES Internal Group
canopies@pal-robotics.com
Technical team

PAL Robotics (PAL)

Expertise

PAL Robotics (PAL)

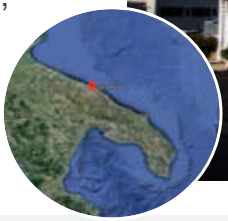
Role in CANOPIES

- Agronomic dual arms system design (**T3.2 leaders**)
  - Starting point: PAL Robotics' **TIAGo++ upper body**
  - **Customizations** include: torque sensors for each arm's joint, 2 DoFs in the torso base, investigating the increase in IP rating for dust and water protection, etc.
- Agronomic end-effectors design for harvesting and pruning (**T3.3 leaders**)
- Expose a **hardware abstraction layer** with open interfaces for the mid-level control (WP3, WP5, WP6, WP8)
- Participation in Requirements, Validation, Dissemination and Exploitation activities (WP2, WP9, WP10, **T10.5 leaders**)
- Timeline
  - First Release of Robot Prototypes at **M14**
  - Final Release of Robot Prototypes at **M40**

Agrimessina (AGRIMESSINA)

Description

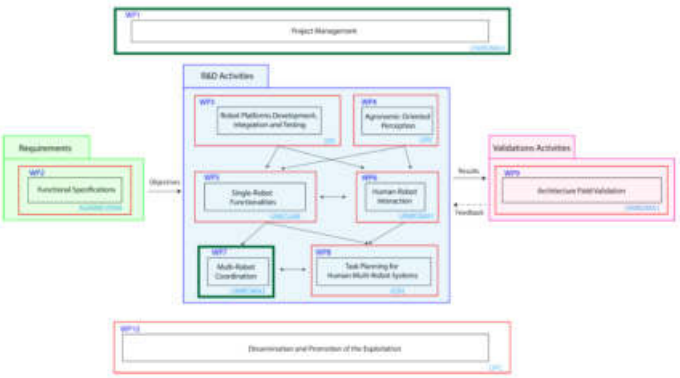
- Table grapes grower and marketer since 1960;
- More than 12.000 Tons of grapes yearly harvested;
- 350 Hectare total production around Puglia;
- 60 varieties of table grapes (mostly seedless);
- Main Italian marketer in UK with 70% market share in supermarkets chain.



Agrimessina (AGRIMESSINA)

Role in the Project

- Leadership of WP2 (Functional Specifications);
- Leader in task 2.1 (Representative Agronomic Activities)
- Support in task 4.3 (Agronomic Quality Assessment);
- Support in task 5.1 (Two arms coordination Functionalities);
- Support in task 6.3 (Human-Robot Communication);
- Support in task 8.1 (Learning from Human Demonstrations)



Agrimessina (AGRIMESSINA)

Team

Francesco Messina

Agrimessina sales manager

Giuseppe Valenzano

Agronomist

Agrimessina (AGRIMESSINA)

Expertise

- Table grapes agronomic aspects;
- Harvesting operations;
- Pruning operations;
- Post-harvest techniques;
- Table grapes industry.

RSA Srl (RSA)

Shorth Company profile

Founded in 2001, RSA is an Italian SME specializing in **management consulting services** for high-end innovation processes and industrial development. Main activities focus on:

(i) **Technical assistance** to facilitate client's access to European and Italian funding instruments such as:

- ✓ SMEs support funding for innovative industrial investments.
- ✓ R&D funding (Industry, Academia and PRBs).
- ✓ EFRD (2007-14; 2014-2020) funding schemes for innovation.
- ✓ FP6 - FP7 – **H2020** (mainly EASME funding schemes like SME Instrument, FTI).

(ii) **Project management** applied to Italian and EU [FP7, H2020, LIFE] funding schemes. Main activities include:

- ✓ Support partnership creation.
- ✓ Support structuring the project.
- ✓ Design and development of appropriate management structures (customized on project's needs)
- ✓ Proposal co-writing.
- ✓ Project's monitoring and coordination.

(iii) **Business planning & feasibility studies** to support Tech Transfer in Research infrastructures and SMEs) such as (active):

- ✓ **Socio-economic impact assessment** of EUPRAXIA research infrastructure in the regional (Lazio) and national context and study on **technological spill-over effects** (INFN-LNF).
- ✓ **Business planning and cost-effective resource management** of LATINO (Laboratory in Advanced Technologies for INnovation) and SABINA (Source of Advanced Beam Imaging for Novel Applications) innovation projects co-financed by EFRD Lazio Italian Institute for Nuclear Physics (INFN-LNF).

(iii) **Programme monitoring** (EFRD), **evaluation** (EFRD, Medio Credito Centrale, Italian Ministry for Economic Development - MISE), **external independent auditing** (EFRD, EAFRD, FP7, H2020); **anti-fraud auditing** (Medio Credito Centrale, Invitalia).

RSA Srl (RSA)

Role in CANOPIES

T1.2 Project Management.

This task deals with the implementation of all typical organizational and coordination actions relating to the management of the GA and CA. Main RSA activities will include:

- ❑ support the CO to run the overall management of the Project and workplan monitoring;
- ❑ support the CO in organizing all periodic meetings to be held among partners on a regular basis;
- ❑ support the Project Management Committee (PMC);
- ❑ keep track of the budget through the monitoring of the Use of the Resources (UoR) on a regular basis (every 6 months);
- ❑ support the CO as additional point of contact with the Commission for any contractual matter; liaison with EC, covering of review meetings, submission of deliverables, etc.

Assigned Deliverables: D1.1, D1.2, D1.3 + **Monitoring of UoR**

RSA Srl (RSA)

Staff involved

Dr. **Alessandro ALBINO FREZZA**

- Former Head of the Industrial Liaison Office and EU Fund Raising office at UNIROMA TRE (1996-2016). 25+ years of experience in the identification, designing and management of Research and Technological Development projects (R&TD) and TT Initiatives at international (including EC Framework Programmes), national and local level.
- Expert in accessing and managing multi-partner initiatives in the field of, collaborative research (Academia – SMEs), industrial research and SMEs support.
- EU Projects management (including financial auditing).
- Technical. assistance for the implementation of local development integrated projects (EFRD, ESF). Independent expert evaluator for R&TD projects (FP6, H2020-EIC-FTI-2018-2020_23-05-2019, H2020-SC1-PHE-CORONAVIRUS-2020-2) and Italian regional development programmes within EFRD ESF funds.
- Active H2020 coordination tasks:
  - ✓ GISCAD-OV - Galileo Improved Services for Cadastral Augmentation Development On-field Validation (GA No. 870231) - H2020-SPACE-EGNSS-2019 – Type of Action IA
  - ✓ FLASH - Far-infrared Lasers Assembled using Silicon Heterostructures (GA No. 766719) - H2020 FETOPEN-1-2016-2017 – Type of Action RIA
  - ✓ PANTHEON - Precision Farming of Hazelnut Orchards (GA No. 774571) - H2020-SFS-2017-1 – Type of Action RIA.

A Collaborative Paradigm for Human Workers and Multi-Robot Teams in Precision Agriculture Systems

Project Overview, Ambition and Objectives

This project is funded by the European Union
G.A No 101016906

1

CANOPIES – Where it all started…

International Forum of Agricultural Robotics 2019 (FIRA 2019)

- Discussion with *Giuseppe Valenzano*
- Real-Needs of the Farmers
  1. **Shortage** of farmworkers
  2. **Standardized quality** of table-grape
  3. **Modern sustainable** operational model
- Meeting with *Francesco Messina* and *Giuseppe Valenzano*

2

Call: H2020-ICT-2018-20 (ICT-46-2020)

Specific Challenges

- Develop appropriate **autonomous capability** that has **impact on the efficiency** of key applications in the Priority Areas and moves **beyond** the current **state of the art**.
- Autonomous capability should be built from **core technologies** and should be proved and tested through **pilot demonstrators** that embed within **real or near real environments**.

Priority Areas

- **Agri-Food**

Robotics Core Technology

- **Socially cooperative human-robot interaction**

CANOPIES Vision

A Collaborative Paradigm for Human-Multi Robot Cooperation in PA

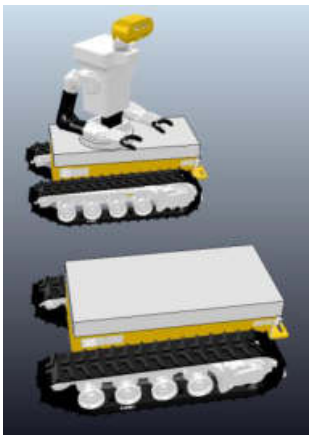
*CANOPIES aims to develop novel human-robot interactions (**HRI**), human-robot collaboration (**HRC**) and multi-robot coordination (**MRC**) methodologies for implementing an **effective collaborative paradigm** between **human workers** and **multi-robot teams** in **Precision Agriculture** systems.*

CANOPIES Vision

A Collaborative Paradigm for Human-Multi Robot Cooperation in PA

We envision a PA setting where **farmworkers interact** with **two** different **kinds** of **robot platforms**:

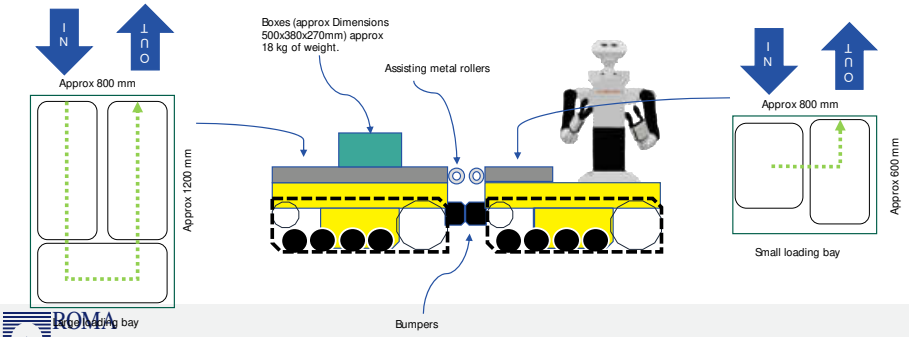
- a farming robot (**F-R**): dedicated to the execution of **agronomic tasks** such as harvesting the fruits or pruning the vines;
- a logistics robot (**L-R**): dedicated to the execution of **logistics tasks** such as the transportation of boxes of harvested grapes or removed branches.



CANOPIES Vision

A Collaborative Paradigm for Human-Multi Robot Cooperation in PA

- **F-R** is equipped with **two arms** for executing agronomic tasks in a human-like manner and **small loading bay** for exchanging boxes (F-R BEM)
- **L-R** is equipped with a **large loading bay** for exchanging boxes (L-R BEM)



CANOPIES Vision

A Collaborative Paradigm for Human-Multi Robot Cooperation in PA

Tight collaboration between human workers and farming robots:

- Each **farmworker** interacts with a **small team of robots** to **supervise** and **facilitate** robot activities and help with agronomic or robotic tasks.
- The human operator may:
  - **improve** agronomic task execution: e.g., during the harvesting operation by removing single ruined fruits belonging to clusters to be harvested;
  - **assist** the farming platform: e.g., with the harvest by cutting any harvest-quality bunch of fruits which the robot fails to detect or cannot cut;

CANOPIES Vision

A Collaborative Paradigm for Human-Multi Robot Cooperation in PA

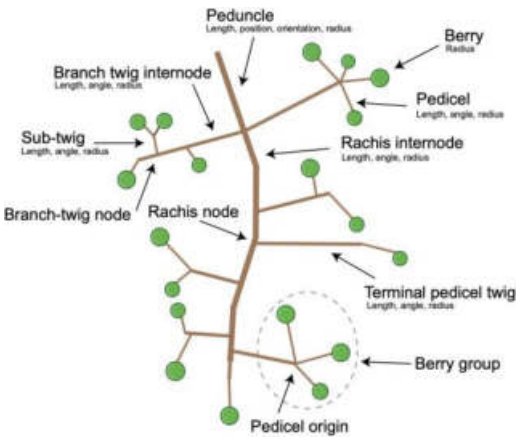
Tight cooperation between farming robots and logistic robots:

- L-R side: scheduling the **provision** of services in such a way to **minimize** the occurrence of any **peak of inactivity** for the F-Rs
- F-R side: scheduling the **request** of services in such a way to **minimize** the occurrence of any **peak of requests** for the L-Rs.

CANOPIES Case Study

Table-Grape Vineyard

- Produced for **direct consumption** while **fresh**
- **Extreme care** is required due to
  - the **fragility** of the table-grape
  - the **long productive** life of the vine



CANOPIES Case Study

Pergola Training System

Overhead shade structure usually supported with some form of columns

- **Vines** are **trained** on this overhead structure so that the **fruit** develops **under** the canopy
- In this way fruits are
  - **easy** to **reach**
  - **protected** from **sunburn**

CANOPIES Case Study

Agronomic Interventions

Task	Human	Robot
Harvesting (July-September)	• Identification of clusters • Assurance of quality control • Proper management of harvested clusters • Human positioning for optimal cutting process • Logistic organization in field • Searching for clusters hidden behind leaves • Confirming a suggested cutting point	• Localization of ripe, top quality clusters and particularly the peduncle • Generating movements to detect position of clusters • Identification of good quality clusters through image evaluation (colour, shape, size…) • Precise positioning of cutting devices • Location of optimal cutting position for multiple clusters at the same location • Accurate management of clusters to avoid damage • Careful box-filling process
Pruning (December-January)	• Define optimal position of selected buds allowed to become grape clusters • Identify optimal cutting point for branches to be removed • Evaluate the average number of remaining branches in the managed zone	• Identify branches to be removed and cutting site • Optimal placement of cutting devices • Removing process rejected buds • Identification of optimal distance between remained buds

CANOPIES Objectives

Three Macro Objectives

1. **Human-Robot Interaction**
2. **Human-Robot Collaboration and Multi-Robot Coordination**
3. **PA Integrated System**

CANOPIES Objectives

Objective-1: Human-Robot Interaction (HRI)

- Develop novel **perception** and **collaborative** techniques to promote and facilitate the **interaction** between the human workers and the robotic platforms

- Four Specific Objectives are identified:
  - **Safe HRI** in shared outdoor workspaces both with and without physical interaction
  - **Predicting future positions** of human torso and arms in motion
  - **Efficient communication** between robots and humans
  - Enable both parties to be **fully aware** of **each other intentions**

CANOPIES Objectives

Objective-2: Human-Robot Collaboration (HRC) and Multi-Robot Coordination (MRC)

- Development of **techniques** and **control strategies** for **collaborative implementation** of agronomic operations

- Four Specific Objectives are identified:
  - **Human-like bimanual** robot **manipulation** leading to intuitive HRC
  - Successful robot programming using **learning by demonstration** (LbD)
  - Learning from unexpected events with **human-in-the-loop**
  - **Multi-robot coordination** for collaborative tasks

CANOPIES Objectives

Objective-3: PA Integrated System

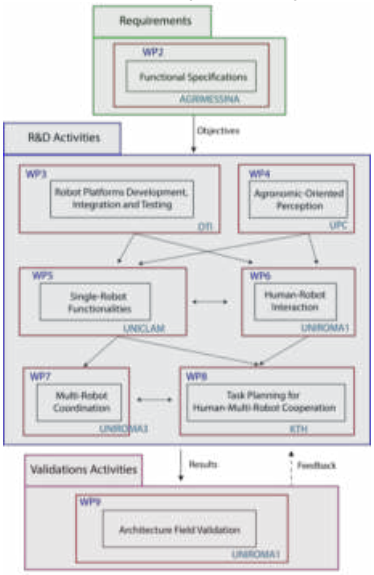
- Develop and implement the elements needed for a **physical demonstration** of the HRI, HRC, and MRC objectives in a permanent crops **piloting scenario**.

- Three Specific Objectives are identified:
  - **Collaborative robots** capable of carrying out the required **agronomic tasks** safely
  - **Simulated farming environments** for algorithm prototyping
  - **Table-Grape vineyard** case-study implementation

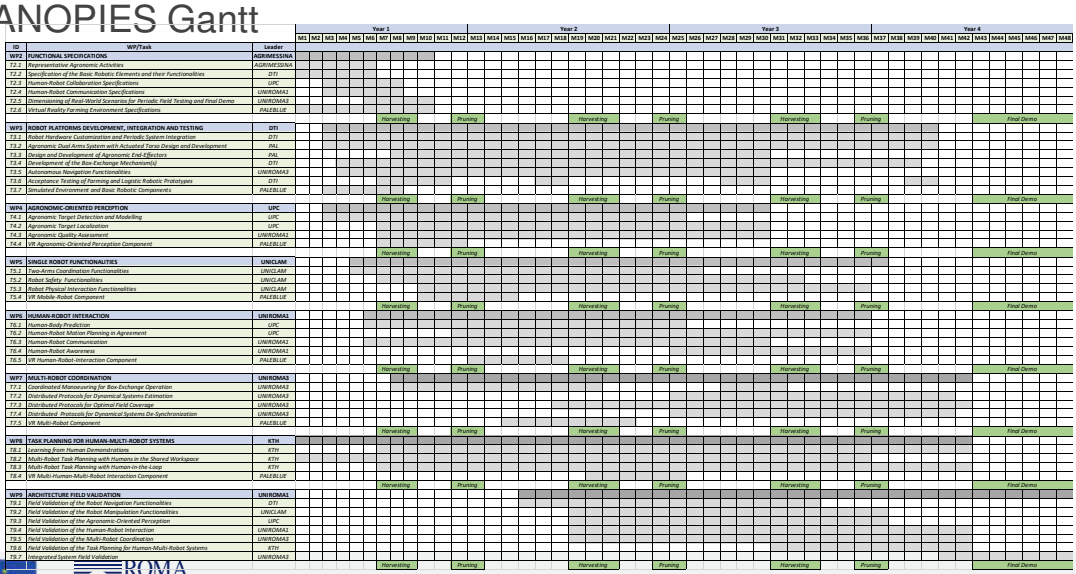
CANOPIES Implementation

Work Plan

WP No	Work Package Title	Lead Participant Short Name	Start Month	End month
1	Project Management	UNIROMA3	M1	M48
2	Functional Specifications	AGRIMESSINA	M1	M10
3	Robot Platforms Development, Integration and Testing	DTI	M3	M40
4	Agronomic-Oriented Perception	UPC	M3	M30
5	Single Robot Functionalities	UNICLAM	M5	M36
6	Human-Robot Interaction	UNIROMA1	M6	M36
7	Multi-Robot Coordination	UNIROMA3	M8	M42
8	Task Planning for Human-Multi-Robot Systems	KTH	M7	M42
9	Architecture Field Validation	UNIROMA1	M16	M48
10	Dissemination and Promotion of the Exploitation	UPC	M1	M48



CANOPIES Gantt



CANOPIES Implementation

Milestones

Milestone Number	Description	Related WP(s)	Due date	Means of verification
MS1	All technical specifications finalised	WP2	M6	Deliverable D2.1
MS2	First Release of Farming and Logistic Robot Prototypes	WP3	M14	Deliverable D3.2
MS3	Final Release of the VR Farming Environment	WP [3,4,5,6,7,8]	M25	Software Released and Validated by a User Group
MS4	Robotic Navigation and Coordination Field Validation	WP9	M33	Deliverable D9.1
MS5	Human-Robot Interaction: Safety and Communication	WP5, WP6	M36	Deliverables D5.2, D6.2
MS6	Human-Robot Collaboration: Planning in Agreement, Task Planning	WP6, WP8	M36	Deliverables D6.1, D8.1
MS7	Experimental validation of the integrated system with respect to the pilot scenario	WP9	M48	Deliverable D9.4

CANOPIES Implementation

Common Development Platform

Goal:

- To **reduce** the **risk of compatibility** issues and **speed up** the **integration** process
- **Promote** the **interaction between partners** and **facilitate interaction** between robot components
- **Facilitate** intermediate **algorithm validation** during the development stage

Requirements:

- A set of **best practices** and **guidelines** to produce code and documentation **must be discussed**

CANOPIES Implementation

Assessment

- Hardware and software components will be tested before each operational period, i.e., in **June** before harvesting and in **November** before pruning.
- Each robotic prototype will go through **full testing** and **safety assessment** under **laboratory conditions** at DTI (Factory Assessment Test - FAT).
- During the **integration weeks**, all **changes** will be **evaluated** in **in-field testing** before the in-field validations (Site Acceptance Test - SAT).

CANOPIES Implementation

Integration Weeks (IWs)

- **Full weeks** during which partners will **work together** to **integrate** the developed components and **check** for potential issues.
- **Four IWs** are envisioned over the project duration:
  - **One** at the **second year** before harvesting season,
  - **Two** at the **third year** before harvesting and pruning seasons,
  - **One** at the **fourth year** before the final demo
- IWs **costs** have been **included** in the budget of each Partner.

CANOPIES Implementation

Piloting at "Cooperativa Agricola Corsira"

- A **community** of about 20 small producers in the municipality of Aprilia, Lazio, Italy
- Vineyards trained on a **pergola** trellis system
- **Planting Pattern**: 2,60 x 2,60 m
- **Height**: 1,85 – 1,95 m
- **Varieties**: Vittoria, Matilde, Pizzutello, Italia

Thanks for your attention!!!

A Collaborative Paradigm for Human Workers and Multi-Robot Teams in Precision Agriculture Systems

Forewords by ICT Project Officer

Antonio Puente Rodero

Let's Now Enjoy the Coffee Break!!!

Don't be shy!

Let's get to know each other!

A Collaborative Paradigm for Human Workers and Multi-Robot Teams in Precision Agriculture Systems

WP8 -Task Planning for Human-Multi-Robot Systems

This project is funded by the European Union G.A No 101016906

1

Multi-Human Multi-Robot System

Heterogeneous team of robots

Logistic robots for logistic tasks, e.g., transport boxes of harvested grapes

Agricultural robots for agronomic tasks, e.g., harvesting or pruning

Humans sharing common workspace and/or controlling robots whenever needed

2

Overall Goal

- Design learning framework to teach the robot from human motion and transfer acquired knowledge to accomplish agronomic tasks
- Design of multi-robot task planning/control methods considering humans in the loop and in the shared workspace
- Integrate the multi-human multi-robot system in the **VR** farming environment

Objectives

- Objective 1 – Safe Human-Robot Interaction
- Objective 2 – Robot Programming using Learning by Demonstration
- Objective 3 – Multi-robot Task Planning with Human in Shared Workspace
- Objective 4 – Multi-robot Task Planning with Human-in-the-Loop
- Objective 5 – VR Multi-Human-Multi-Robot Interaction Component

Tasks Description

Task 8.1 – Learning by Human Demonstrations [M7-M42]

(Leader: **KTH**)

Partner	UNIROMA3	KTH	UNIROMA1	UPC	UNICLAM	DTI	PALEBLUE	PAL	AGRIM.	RSA
PM	0	22	0	0	0	0	0	0	2	0

Task 8.2 – Multi-Robot Task Planning with Humans in the Shared Workspace [M7-M37]

(Leader: **KTH**)

Partner	UNIROMA3	KTH	UNIROMA1	UPC	UNICLAM	DTI	PALEBLUE	PAL	AGRIM.	RSA
PM	0	22	0	1	0	0	0	1	0	0

Tasks Description

Task 8.3 – Multi-Robot Task Planning with Human-in-the-Loop [M7-M42]

(Leader: **KTH**)

Partner	UNIROMA3	KTH	UNIROMA1	UPC	UNICLAM	DTI	PALEBLUE	PAL	AGRIM.	RSA
PM	0	22	0	0	0	0	0	1	1	0

Task 8.4 –VR Multi-Human-Multi-Robot Interaction Component [M20-M25]

(Leader: **PALEBLUE**)

Partner	UNIROMA3	KTH	UNIROMA1	UPC	UNICLAM	DTI	PALEBLUE	PAL	AGRIM.	RSA
PM	0	2	0	0	0	0	7	0	0	0

Deliverables

D8.1: Human-in-the-loop Task Demonstration and Transfer	Leader: KTH	Delivery Month: **M42**
The learning framework to teach the robot from human motion in virtual reality environment and transfer knowledge to the real robotic setup.		
D8.2: Multi-Robot Task Planning with Humans in the Shared Workspace	Leader: KTH	Delivery Month: **M36**
The design of a temporal logic-based strategy to ensure safety of the human and multi-robot system in the shared environment.		
D8.3: Multi-Robot Task Planning with Humans-in-the-Loop	Leader: KTH	Delivery Month: **M42**
The design of planning strategies that will incorporate human preference to adapt predefined plane as needed.		
D8.4: VR Multi-Human-Multi-Robot interaction Component	Leader: PALEBLUE	Delivery Month: **M25**
The design of Multi-Human-Multi-Robot interaction software module that will allow several humans and robots to join via network.		

Milestones

# Mil.	Description	Related WP(s)	Due Date	Means of verification
MS1	All technical specifications finalised	WP2	M6	Deliverable D2.1
MS2	First Release of Farming and Logistic Robot Prototypes	WP3	M14	Deliverable D3.2
MS3	Final Release of the VR Farming Environment	WP[3,4,5,6,7,8]	M25	Software Released and Validated by a User Group
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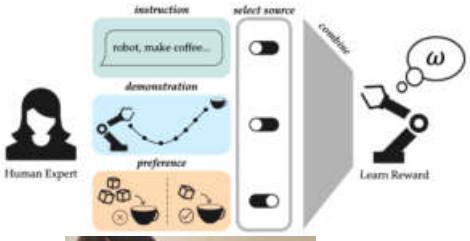
MS5	Human-Robot Interaction: Safety and Communication	WP5, WP8	M36	Deliverables D5.2, D8.2
MS6	Human-Robot Collaboration: Planning in Agreement, Task Planning	WP6, WP8	M36	Deliverables D6.2, D8.1
MS7	Experimental validation of the integrated system with respect to the pilot scenario	WP9	M48	Deliverable D9.4

Technical Discussion

- Task 8.1 Learning from Human Demonstrations ·
  - **Learning the reward function**
    - Directly learn the reward from a human teacher
    - Train RL policies to maximize the reward
  - **Meta-Learning**
    - Learn from a dataset of demonstrations of many other tasks to train the meta-learner
    - Adapt to a new task given few demonstrations

Bıyık, et al., 2020

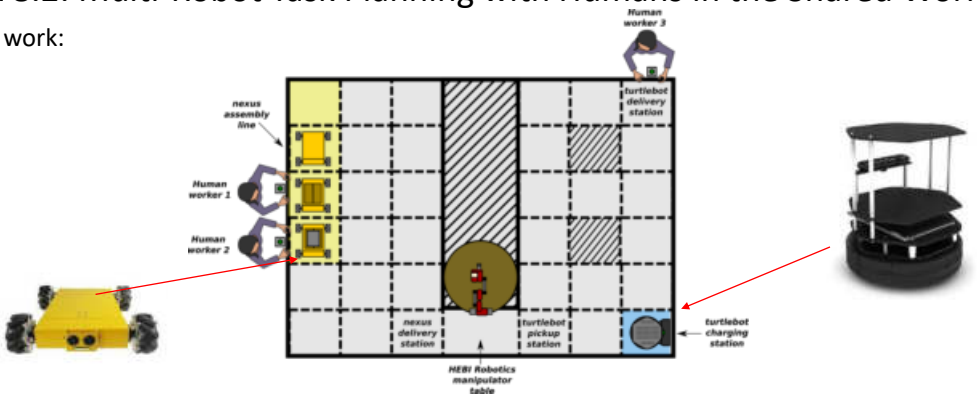


KTH's Smart Suite

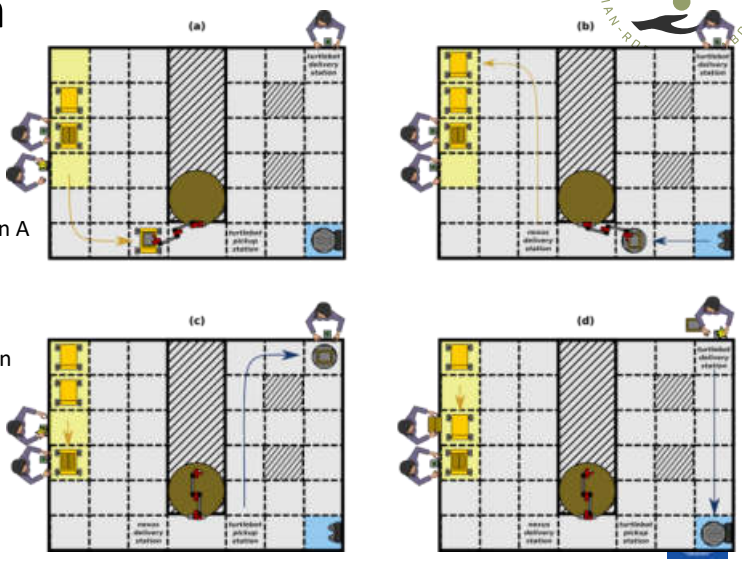
Technical Discussion

- Task 8.2: Multi-Robot Task Planning with Humans in the Shared Workspace

Existing work:



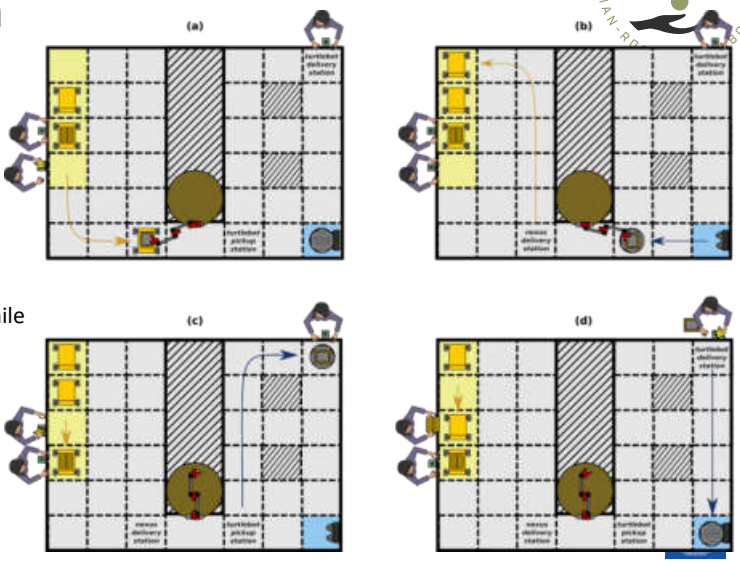
Technical Discussion



Motion Planning

- Linear Temporal Logic (LTL)
  - Defines a spatio-temporal logic task
  - E.g., ”Always eventually return to A, If in A next go to B, Never reach C and always avoid obstacles”
- Graph-based method constructs motion plan
- Human as an obstacle

Technical Discussion



Next steps:

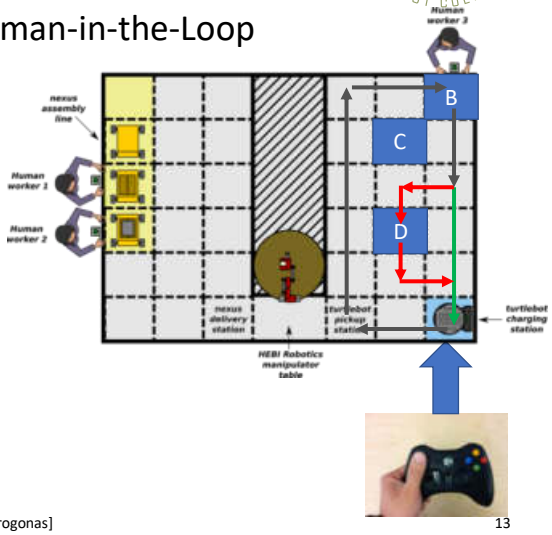
- Extend to *agronomic* applications
- Incorporate *timed* specifications, such as,
  - Mixed interval temporal logic (MITL)
  - Signal Temporal Logic (STL)
- Re-planning and least-violating solutions while considering human presence as obstacles
- Extend to multi-robot systems

Technical Discussion

- Task 8.3: Multi-Robot Task Planning with Human-in-the-Loop

  Human-in-the-Loop Existing Work:

  - Online Re-planning
    - Human adjusts LTL specfications online
  - Mixed-initiative Control
    - Human joy-stick commands
    - Human is allowed to control as long as high-level specification is always satisfied
  - Inverse Learning
    - Human-controlled path is recorded
    - High level plan is updated to satisfy human preference

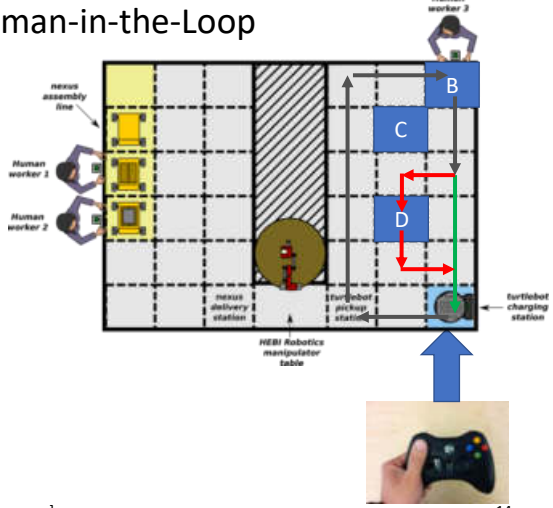


Technical Discussion

- Task 8.3: Multi-Robot Task Planning with Human-in-the-Loop

  Next Steps:

  - Multi-robot Setup
    - Humans command subgroup of robots
    - Possibly in leader-follower framework
    - Online re-planning for new human plans
  - Inverse Learning
    - Extend to more general framework
    - Multi-agent learning of human preference

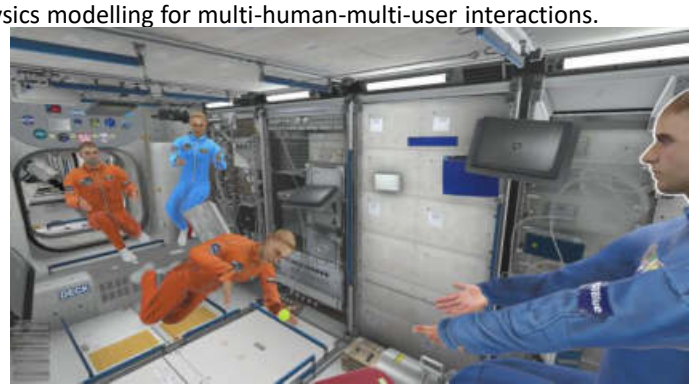


Objectives: PaleBlue

Objective 8.4 – VR Multi-Human-Multi-Robot Interaction Component

Technical Goals: PaleBlue

- Enabling 3D environment with networking multi-user functionality.
- Full body modelling + physical modeling.
- Robots added in real time in same network environment.
- Enable kinematic physics modelling for multi-human-multi-user interactions.



Technical Challenges: PaleBlue

- Multi-user networking and synchronization
- Connecting several robots with ROS in same scene
- Data exchange over network for all participants

Technical Discussion

- Task 8.4: VR Multi-Human-Multi-Robot Interaction Component
  - Establishing collaboration simulation over internet
  - Digital security concerns for data exchange?

Coordination and Planning of Activities

- **Regular meetings** to measure the status of achievement of the WP
- The **leading unit** of each task is responsible for **its timely completion**
- **The leading unit** of each task is responsible for the **drafting of the related deliverable** (all involved units must contribute)
- The **leading unit** of the WP is responsible for **communicating with the PI** in the case of difficulties

References

Learning from Demonstrations:

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Multi-Robot Task Planning with Humans in the Shared Workspace:

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M. Guo, S. Andersson and D. V. Dimarogonas. "Human-in-the-Loop Mixed-Initiative Control under Temporal Tasks", in Proceedings of the IEEE International Conference on Robotics and Automation, 2018.

Let’s move on to the next WP…

Any questions?

A Collaborative Paradigm for Human Workers and Multi-Robot Teams in Precision Agriculture Systems

WP9 - Architecture and Field Validation

This project is funded by the European Union
G.A No 101016906

WP 9 – Architecture Field validation





Overall Goal

- This work package will focus on the experimental validation on a table-grape vineyard of the integrated system capabilities resulting from the study of the main project developments
- The field validation of the system capabilities has been organized according to the seasonal arrangement of the agricultural practices (December-January for pruning and July-September for harvesting) starting from year 2.

Objectives

- i) Field Validation of the Robot Navigation Functionalities;
- ii) Field Validation of the Robot Manipulation Functionalities;
- iii) Field Validation of the Agronomic Perception Functionalities;
- iv) Field Validation of the Human-Robot Interaction;
- v) Field Validation of the Multi-Robot Cooperation;
- vi) Field Validation of the Human-Multi-Robot Task Planning;
- vii) Final Demo of the Integrated System.

Tasks Description

Task 9.1 Field Validation of the Robot Navigation Functionalities [M16-M33]

(Leader: DTI)

Partner	UNIROMA3	KTH	UNIROMA1	UPC	UNICLAM	DTI	PALEBLUE	PAL	AGRIM.	RSA
PM	5	0	1	1	0	6	0	0	0	0

Task 7.2 – Field Validation of the Robot Manipulation Functionalities [M19-M37]

(Leader: UNICLAM)

Partner	UNIROMA3	KTH	UNIROMA1	UPC	UNICLAM	DTI	PALEBLUE	PAL	AGRIM.	RSA
PM	14	0	1	1	5	0	0	0	1	0

Tasks Description

Task 9.3 Field Validation of the Agronomic-Oriented Perception [M19-M37]

(Leader: UPC)

Partner	UNIROMA3	KTH	UNIROMA1	UPC	UNICLAM	DTI	PALEBLUE	PAL	AGRIM.	RSA
PM	0	0	3	7	0	0	0	0	1	0

Task 9.4 Field Validation of the Human-Robot Interaction [M19-M42]

(Leader: UNIROMA1)

Partner	UNIROMA3	KTH	UNIROMA1	UPC	UNICLAM	DTI	PALEBLUE	PAL	AGRIM.	RSA
PM	0	0	5	8	3	0	0	0	1	0

Tasks Description

Task 9.5 – Field Validation of the Multi-Robot [M19-M42]

(Leader: **UNIROMA3**)

Partner	UNIROMA3	KTH	UNIROMA1	UPC	UNICLAM	DTI	PALEBLUE	PAL	AGRIM.	RSA
PM	5	2	0	0	3	0	0	0	1	0

Task 9.6 – Field Validation of the Task Planning for Human-Multi-Robot Systems [M31-M42]

(Leader: KTH)

Partner	UNIROMA3	KTH	UNIROMA1	UPC	UNICLAM	DTI	PALEBLUE	PAL	AGRIM.	RSA
PM	5	1	0	0	0	0	0	0	0	0

Tasks Description

Task 9.7 – Integrated System Field Validation [M41-M48]

(Leader: UNIROMA3)

Partner	UNIROMA3	KTH	UNIROMA1	UPC	UNICLAM	DTI	PALEBLUE	PAL	AGRIM.	RSA
PM	5	2	4	2	4	4	2	18	1	0

Deliverables

D9.1: Robotic Navigation and Coordination Field Validation	Delivery Month: M33
This deliverable will be composed of a report along with a video describing the validation of the robotic functionalities as per Tasks 9.1 and 9.5, including navigation, and box-exchange manoeuvring.	

D9.2: Validation of Human-Robot Interaction	Delivery Month: M42
This deliverable will be composed of a report along with a video describing the validation of the human-robot interaction functionalities during harvesting and pruning as per Tasks 9.2, 9.3 and 9.4.	

D9.3: Human-Multi-Robot Task Planning Field Validation	Delivery Month: M42
This deliverable will be composed of a report along with a video describing the validation of the human-multi-robot task planning functionalities as per Task 9.6.	

D9.4: Final Demo	Delivery Month: M48
This deliverable will be composed of a report along with a video describing the outcome of the final demo with respect to the CANOPIES objectives KPIs as per Task 9.7.	

Milestones

# Mil.	Description	Related WP(s)	Due Date	Means of verification
MS1	All technical specifications finalised	WP2	M6	Deliverable D2.1
MS2	First Release of Farming and Logistic Robot Prototypes	WP3	M14	Deliverable D3.2
MS3	Final Release of the VR Farming Environment	WP[3,4,5,6,7,8]	M25	Software Released and Validated by a User Group
MS4	Robotic Navigation and Coordination Field Validation	WP9	M33	Deliverable D9.1
MS5	Human-Robot Interaction: Safety and Communication	WP5, WP6	M36	Deliverables D5.2, D6.2
MS6	Human-Robot Collaboration: Planning in Agreement, Task Planning	WP6, WP8	M36	Deliverables D6.1, D8.1
MS7	Experimental validation of the integrated system with respect to the pilot scenario	WP9	M48	Deliverable D9.4

Critical Activities (next 12 Months)

- Farm site set-up
- Data Acquisition Campaigns

Technical Discussion

- Farm site set-up:
  - Arrange a working area indoor and wireless network connectivity
  - Equipment storage
  - Determine CANOPIES experimental area
  - Finalize logistics for site visits: food and accommodation details …
- Availability of sensors and mobile base for the Data Acquisition Campaigns

Coordination and Planning of Activites

- **Meetings in connection with WP3 and 4, late spring to plan data acquisition campaigns**

- **Monthly meetings** to measure the status of achievement of the WP
- The **leading unit** of each task is responsible for **its timely completion**
- **The leading unit** of each task is responsible for the **drafting of the related deliverable** (all involved units must contribute)
- The **leading unit** of the WP is responsible for **communicating with the PI** in the case of difficulties

Let's move on to the next WP…

Any questions?

A Collaborative Paradigm for Human Workers and Multi-Robot Teams in Precision Agriculture Systems

WP10 - Dissemination and Promotion of the Exploitation

This project is funded by the European Union G.A No 101016906

UNIVERSITAT POLITÈCNICA DE CATALUNYA BARCELONATECH

1

WP10 - Dissemination and Promotion of the Exploitation. Objectives

- Create **visibility** of the project and provoke **dissemination** to the general public and other relevant stake holders affected by the outcome of the project.
- Ensure **technical and scientific dissemination** of the results towards research institutions, public and private health entities and public and private companies.
- Set up a web platform for **communication**. This site and connections to social media will be the basis for disseminating and sharing knowledge between as well as among project partners and external participants.
- **Promote the results of project**.
- Review the innovations within the project and if necessary, protect the information.
- **Advise the target industries of the achievements** and ensure the direction of the project is likely to lead to commercially relevant results within the areas of application.

2

Tasks' structure[M1-M48]

Task 10.1 – Website Construction and Updates (Leader: **UPC**)

Task 10.2 – Dissemination (Leader: **UPC**)

a) Dissemination in the scientific community

b) Industry and end users

c) Academic Dissemination

Task 10.3 – Dissemination and Synergies with DIH-agROBOfood (Leader: **UNIROMA3**)

Task 10.4 – Communication Activities and Event (Leader: **UPC**)

Task 10.5 – Exploitation and Management of Knowledge (Leader: **PAL**)

Tasks' PMs.

Partner	UNIROMA3	KTH	UNIROMA1	UPC	UNICLAM	DTI	PALEBLUE	PAL	AGRIM.	RSA
PM	12	2	4	12	4	2	2	8	3	0

Deliverables

D10.1: Project Website	Leader: UPC	Delivery Month: **M2**
This deliverable will consist in the publication of a website describing CANOPIES. The website will be regularly updated with the progress and achievements of the project.		
D10.2: Data Management Plan	Leader: UPC	Delivery Month: **M6**
A Data Management Plan (DMP) will be produced detailing what data the project will generate, whether and how it will be exploited or made accessible for verification and re-use, and how it will be curated and preserved. A first version of the DMP will be issued at M0+6, and the plan will evolve during the lifetime of the project in order to present the status of the project's reflections on data management.		
D10.3: Communication, Dissemination and Exploitation Plan	Leader: UPC	Delivery Month: **M3**
This deliverable will consist in the project plan for the communication, exploitation and dissemination activities, including: i) the setting of the strategy and objectives of both the dissemination and exploitation activities; ii) the designing of the relevant policy and rules; iii) the management of these activities; iv) the identification of the target user groups as well as the media and means to be used; v) Exploitation activities for paving the way to GISCADOV solution Business Development. D10.3 has been designed according to the European Commission guidelines applying to H2020 projects.		

Task 10.1 – Website Construction and Updates (UPC)

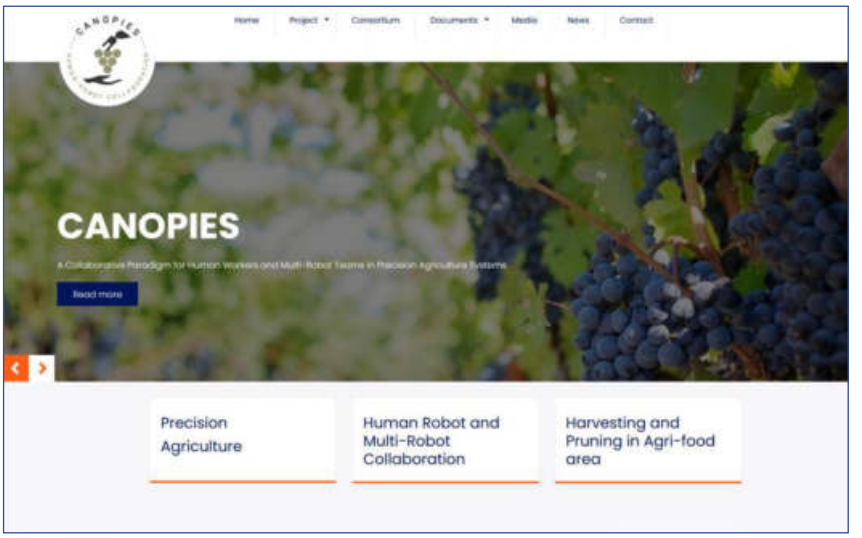
Objectives:

- Project domains
  - canopies-project.eu
  - project-canopies.eu

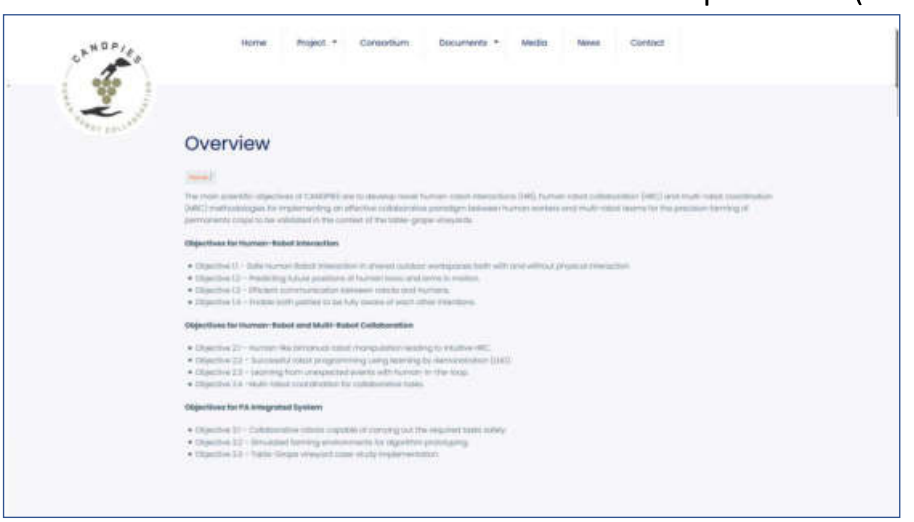
- Website construction
  - External site for general public (Drupal)
  - Internal site for consortium members (NextCloud)

- Website updates. CANOPIES partners will prepare the information about their activities. UNIROMA3 and UPC will be in charge of the website and social media updates

Task 10.1 – Website Construction and Updates (UPC)



Task 10.1 – Website Construction and Updates (UPC)



Task 10.2 – Dissemination (UPC)

Objectives:

a) Dissemination in the scientific community

b) Industry and end users

c) Academic Dissemination

Important issues:

All the partners are strongly involved in the dissemination and communication activities in the local, national and international context.

Dissemination and Communication Instruments

– Website - Social networks (YouTube, Twitter, Linkedin, Facebook, Instagram) - Flyers and brochures - Mass media -

Participation to Fairs / Events / Open days – Industrial and End User partners, EU booth

Professional video – Supported by all the partners

Task 10.3 – Dissemination and Synergies with DIH-agROBOfood (UNIROMA3)

- We have already established a communication channel through DTI, who is also part of the agROBOfood consortium.
- We have been planning on the following actions:
  - Participation and presentation of CANOPIES on the annual agROBOfood summit, currently planned as an online event in April.
  - Potential presentation of CANOPIES on the European Robotics Forum (ERF) workshop proposed by agROBOfood partners.
  - Companies in our consortium can become business members of agROBOfood.
  - The consortium will also try to connect with DIH Smart Agri Hubs.
  - Once a communication channel is created, we will also try to achieve similar actions.

Task 10.4 – Communication Activities and Event

	OBJECTIVES	TARJETED PUBLIC	ABOUT	INSTRUMENTS
COMMUNICATION + DISSEMINATION	**TO COMMUNICATE TO INFORM TO PROMOTE INCREASE VISIBILITY INCREASE AWARENESS on how robotics and IT technology has the potential to improve agricultural operation while being at the same time more sustainable and environmentally friendly**			***WEBSITE &*SOCIAL MEDIA**
		SCIENTIFIC COMMUNITY	CONSORTIUM ACTIVITIES PROJECT SCIENTIFIC RESULTS	*PEER REVIEW PAPERS ACCEPT *SCIENTIFIC WORKSHOPS ORG.
		FARMERS, FORUMS AND ASSOCIATIONS: TABLE-GRAPE & PERMENENT CROPS	THE POTENTIAL TO IMPROVE AGRICULTURAL OPERATIONS BY ROBOTICS	*PRESS RELEASE *ARTICLES *ENTRY IN ASSOC.MAILING LISTS *INT. PUBLIC MEETINGS
		AGRICULTURAL HIGH SCHOOLS AND UNIVERSITIES		*SEMINARS HELD (AGR.SCHOOLS)
		INDUSTRY IN NATIONAL TECH /INN CLUSTERS	PROJECT INDUSTRIAL RESULTS	BRANDING, FLYERS, BROCHURES EC-SUPPORTED MECHANISM
		NATIONAL ORGANIZATION FOR IND/RES DEVELOPM.		MASS MEDIA: LOCAL, REGIONAL AND NATIONAL *PRESS RELEASE
INTERNAL COMMUNICATION	MAILING LIST NETWORKING ACTIVITIES > INTEGRATION WEEKS	GOV. BODIES – ENV. ORG – GENERAL UNIVERSITY AND HIGH SCHOOLS – GEN. PUBLIC		POPULAR SCIENCE AND TECH *PARTICIPATION TO FAIRS/EVENTS/OPENDAYS

***KPIs**

Task 10.4 – Communication Activities and Event (UPC). *Key Performance Indicators -KPIs

Venue	Indicator	Poor	Good	Excellent
Website	#of visits	<1000	1000-5000	>5000
Social media	#of followers	<50	50-100	>100
Scientific publications	#of peer reviewed papers accepted	<15	15-25	>25
Scientific workshops	#of scientific workshops organized	<1	1-2	>3
Agricultural schools	#of seminars held	<3	3-6	>6
Table-Grape Farmer's associations	# of press release + # of article in bulletin/magazines + #entry in associations mailing lists + #of intervention to public meetings	<5	5-10	>10
Permanent Crops Farmer's Association	# of press releases + # of articles in bulletins/magazine + #entries in associations mailing lists + #of interventions in public meetings	<2	2-4	>4
Mass Media	#of appearance on mass media of regional or national relevance	<2	2-5	>5
Popular Science	#of appearance on popular science media	<1	1-3	>3

Task 10.5 – Exploitation and Management of Knowledge (PAL) [M1-M48]

Contributors: all (**Industrial partners** are the main contributors)

- The exploitation of the knowledge generated in this project will be carried out along three lines:
  - Scientific Exploitation (**academic partners**): re-use of the methodological outcomes for future research and projects, advancement in the visibility
  - Economic Exploitation (**industrial partners**): creating new opportunities to expand its own business
    - **PAL**: to develop robots for outdoor applications and to develop new services for the agricultural field.
    - **PALEBLUE**: to move into the new business segment within agriculture using the simulation tools.
  - Societal Exploitation: the Consortium will contribute to promote, especially in the new generations of agricultural operators, a positive vision of the role of automation in agriculture.

→ **Plan for Using and Disseminating Foreground (PUDF)** that will generate the guidelines for the future use of the project's results, included on **D10.3: Communication, Dissemination and Exploitation Plan** (M3)

Task 10.4 – Communication Activities and Event

WP10 OVERVIEW (Draft February 4th)		2021				2022			
	WP10 TASKS	1-3	4-6	7-9	10-12	13-15	16-18	19-21	22-24
T. 10.1	Website Construction and Updates	**CANOPIES WEB**	AFTER EACH DELIVERABLE THE RESPONSIBLE WILL PREPARE A SHORT NOTE ABOUT IT. UNIROMA3 AND UPC WILL UPDATE THE WEB SITE WITH THIS INFORMATION.						
T. 10.2	Dissemination **Scientific community** /UNIROMA3-UPC Participation in scientific conferences		**ERF** 13/04 ICRA Xi'An, China	**IROS** Prague, Czech Republic		**ERF WORKSHOP**	**ICRA**		**IROS**
	Industry /PAL-PALEBLUE-DTI 1 ACTIVITY/YEAR		**ALMERIA SMART AGRIHUB**	**INTERNATIONAL FORUM OF AGRICULTURE ROBOTICS**					
	End users / AGRIMESSINA 1 ACTIVITY/YEAR		**agROBOfood summit** April Virtual						
	Academic dissemination. Web and Press notes	**ACADEMIC PUBLICATIONS DURING THE PROJECT. PLEASE INFORM UNIROMA3 AND UPC This dissemination will include presentations in seminars, summer schools and academic events**							
	General Public /Popular science / Open days			**Science Fest**					
T. 10.3	**Dissemination and Synergies with DIH-agROBOfood**	**Companies in our consortium can become business members of agROBOfood. Contacts with DIH Smart Agri Hubs**							
T. 10.4	**Communication Activities and Events**	COORDINATION UNIROMA3 AND UPC. PARTICIPATION ALL PARTNERS							
	Corporative image, Press releases, Social media	SM ACCOUNTS	FLYERS POSTERS						
T. 10.5	Exploitation & management of knowledge								

Task 10.4 – Communication Activities and Event (UPC)

WP10 OVERVIEW (Draft February 4th)		2021				2022			
	SCIENTIFIC AND INNOVATIVE CONTRIBUTIONS	1-3	4-6	7-9	10-12	13-15	16-18	19-21	22-24
WP1	**Project Management**	**KoM D1.1 - D1.2**	D1.4					**1st REVIEW**	
WP2	**Functional Specifications**		D2.1 - **D 2.2**		D2.3 - **D2.4**				
WP3	**Robot Platforms Development, Integration & Test**			**D3.4**	**D3.1**	**D3.2**			
WP4	**Agronomic-Oriented Perception**				**D4.3**				
WP5	**Single Robot Functionalities**					**D5.4**			
WP6	**Human-Robot Interaction**						**D6.4**		
WP7	**Multi-Robot Coordination**							**D7.1**	**D7.3**
WP8	**Task Planning for Human-Multi-Robot Systems**								
WP9	**Architecture Field Validation**	**Integration weeks and Field validation Tasks: 9.1-9.7**						**INT WEEK**	
WP10	**Dissemination and Promotion of the Exploitation**	**D.10.1 - 10.3**	**D10.2**						
WP11	**Ethics**								

Task 10.4 – Communication Activities and Event

WP10 OVERVIEW (Draft February 4th)		2021				2022			
	PARTNERS CONSTRIBUTION	1-3	4-6	7-9	10-12	13-15	16-18	19-21	22-24
	Università degli Studi Roma Tre	KoM PRESS RELEASE	D1.1 NOTE					1st REVIEW	
	KTH Royal Institute of Technology				D2.3 - D2.4 NOTE				
	Sapienza Università di Roma			D3.4 NOTE	D3.1 NOTE	D3.2 NOTE			
	Universitat Politècnica de Catalunya		D10.1 NOTE		D4.3 NOTE	ERF 90' Workshop All Partners			
	Università degli studi di Cassino e del Lazio Meridionale					D5.4 NOTE			
	Danish Technological Institute	D**2.2** agROBOfood Summit & ERF Workshop **Presentations**					D6.4 NOTE		
	PaleBlue AS							D7.1 NOTE	D7.3
	Pal Robotics SL	ASA-**Presentation Agri food & robotics** ERF **Workshop coordination Robotics & Agri Food**							
	Agrimessina Srl	validation Tasks: 9.1-9.7						INT WEEK	
	RSA Srl								

Task 10.4 – Communication Activities and Event

WP10 OVERVIEW (Draft February 4th)		2021				2022			
	PARTNERS CONSTRIBUTION	1-3	4-6	7-9	10-12	13-15	16-18	19-21	22-24
	Università degli Studi Roma Tre	KoM PRESS RELEASE	D1.1 NOTE					1st REVIEW	
	KTH Royal Institute of Technology				D2.3 - D2.4 NOTE				
	Sapienza Università di Roma			D3.4 NOTE	D3.1 NOTE	D3.2 NOTE			
	Universitat Politècnica de Catalunya		D10.1 NOTE		D4.3 NOTE	ERF 90' Workshop All Partners			
	Università degli studi di Cassino e del Lazio Meridionale					D5.4 NOTE			
	Danish Technological Institute	D**2.2** agROBOfood Summit & ERF Workshop **Presentations**					D6.4 NOTE		
	PaleBlue AS							D7.1 NOTE	D7.3
	Pal Robotics SL	ASA-**Presentation Agri food & robotics** ERF **Workshop coordination Robotics & Agri Food**							
	Agrimessina Srl	validation Tasks: 9.1-9.7						INT WEEK	
	RSA Srl								

Coordination and Planning of Activities

- Communication and dissemination plan overview 2021-2024.

  D10.3 (M3)

  Contact with your communication responsible during next WEEK

- The partners are encouraged to actively contribute to the communication and dissemination plan with their own teams and share information with UNIROMA3 and UPC. >1 contribution / three months/partner
- UPC will coordinate a virtual meeting each three months looking to monitor, update, increase and improve the previous plan.

Let’s move on to the next WP…

Any questions?