FLEXIGROBOTS

D2.2 Requirements and platform architecture specifications

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List of Acronyms

Abbreviation / acronym	Description
AEF	Agricultural Industries Electronics Foundation
API	Application Programming Interface
AI	Artificial Intelligence
ASCII	American Standard Code For Information Interchange
BDVA	Big Data Value Association
BSD	Berkeley Software Distribution
CAP	Common Agricultural Policy
CIM	Common Information Model
CODA	Copernicus Online Data Access
CRUD	Create, Read, Update, Delete
DAPS	Dynamic Attribute Provisioning Service
DCAT	Data Catalogue Vocabulary
DGPS	Differential Global Positioning System
DIAS	Data Information Access Service
DL	Deep Learning
Dx.y	Deliverable number y belonging to WP x
DSS	Decision support system
EC	European Commission
EU	European Union
ECU	Electronic Control Unit
EFDI	Extended FMIS Data Interface
ELSEC	Ethical, Legal, Social, Economic and Cultural
ERP	Enterprise Resource Planning
ESA	European Space Agency
ETSI	European Telecommunications Standards Institute
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
FAIR	Findable, Accessible, Interoperable, and Reusable
FI-PPP	Future Internet Public-Private Partnership

Abbreviation / acronym	Description
FMIS	Farm Management Information System
FMS	Farm Management System
GCP	Google Cloud Platform
GIS	Geographic Information System
GNSS	Global Navigation Satellite System
GML	Geography Markup Language
GPS	Global Positioning System
GUI	Graphical user interface
HAE	Height Above Ellipsoid
HDOP	Horizontal dilution of precision
HLEG AI	High-Level Expert Group on Artificial Intelligence
HPC	High-Performance Computing
HTTP	Hypertext Transfer Protocol
HW	Hardware
ICT	Information and Communication Technologies
IEC	International Electrotechnical Commission
IDS	International Data Spaces
IDSA	International Data Spaces Association
IoT	Internet of Things
ISO	International Organization for Standardization
IT	Information technology
KPI	Key Performance Indicators
LAI	Leaf Area Index
LAN	Local Area Network
LC	Leaf Cover
LCC	Leaf Chlorophyll Content
MCC	Mission Control Centre
ML	Machine Learning
MLOps	Machine Learning Operations
MQTT	MQ Telemetry Transport

Abbreviation / acronym	Description
MVDS	Minimum Viable Data Space
NGSI	Next Generation Service Interfaces
NMEA	National Marine Electronics Association
NVDI	Normalized difference vegetation index
ODC	Open Data Cube
ODRL	Open Digital Rights Language
OGC	Open Geospatial Consortium
PPP	Public Private Partnership
RAM	Reference Architecture Model
RCP	Remote procedure call
REST	Representational State Transfer
RFMS	Robot Fleet Management System
RGB	Red, Green, Blue
ROS	Robot Operating System
RTK	Real-Time Kinematic
SD	Secure Digital
SDK	Software Development Kit
SEPA	SPARQL Event Processing Architecture
SLAM	Simultaneous Localization and Mapping
SVM	Support Vector Machine
TC	Task Controller
TCP	Transmission Control Protocol
UAV	Unmanned aerial vehicle
UC	Use-case
UGV	Unmanned ground vehicle
URI	Uniform resource identifier
USB	Universal Serial Bus
UT	Universal terminal
UTC	Universal Time Coordinated
W3C	World Wide Web Consortium

Abbreviation / acronym	Description
WAAS	Wide Area Augmentation System
WMS	Web Map Service
WCS	Web Catalogue Service
WFS	The Web Feature Service
WP	Work Package
XML	Extensible Markup Language
WMS	Web Map Service Interface Standard

Executive Summary

This deliverable D2.2 describes the consolidated functional and non-functional requirements, architecture and detailed technical specifications for the FlexiGroBots platform. It is the first outcome of task *T2.2 - Platform requirements and architecture*. An updated version will be released in June of 2022, which corresponds to month eighteen of the project, with the publication of D2.3.

In order to leverage the know-how, results and lessons learnt during the last years as part of both innovation and commercial activities, FlexiGroBots performed an exhaustive analysis of the state-of-the-art considering relevant reference architectures, European research projects, standards and already available products. Thus, FlexiGroBots platform is based on technologies that are the result of years of investment by the whole European Community, being interoperable with innovative agriculture digital solutions and completely aligned with some of the most promising ecosystems that are being promoted currently, e.g., GAIA-X, European Common Data Spaces or the Artificial Intelligence on-demand-platform. FlexiGroBots includes by design requirements identified by the High-level Expert Group on AI of the European Commission (HLEG AI) to ensure ethical, human-centric and trustworthy AI and robotics systems for precision agriculture, thanks to the work that is being performed within *T2.4 - ELSE factors and guidelines*, under the coordination of CEPS.

From the detailed specifications of the three pilots' use cases that were elaborated and included in D4.1, D5.1 and D6.1, the different stakeholders included in the agri-food value chain have been characterised, following a value proposition methodology that covers most common jobs, pains and gains. Then, the project functional requirements were consolidated in the form of user stories and complemented with non-functional needs.

Finally, the multiple components of the FlexiGroBots platform are described using a high-level architecture that is easy to understand and reflects the main building blocks and the interactions between them. It identifies systems and technologies that will be interoperable with the FlexiGroBots platform, along with the main technological results of the project, e.g., an Artificial Intelligence platform, the enablers for common agricultural data space, geospatial processing, common AI-powered services and the Mission Control Centre. For each one of these components, the provided features are documented following IEC 62559 standard. They are complemented with the inclusion of the rest of the views of the 4+1 architectural view model.

The list of requirements will be updated, and it will evolve along the project lifecycle until M18 when the final version of this deliverable will be submitted (D2.3). It will contain also an enhanced and fine-tuned version of the FlexiGroBots platform architecture, including also the feedback obtained during the execution of the project's pilots in WP4, WP5 and WP6.

1 Introduction

1.1 Purpose of the document

FlexiGroBots project is an Innovation Action aiming to build a platform for flexible heterogeneous multi-robot systems for intelligent automation of precision agriculture operations, providing multiple benefits to farmers around the world. In this vision, fleets of heterogeneous robots will be able to execute complex missions in an orchestrated and coordinated way overcoming some of the main barriers that currently limit the adoption of unmanned vehicles and robotics technologies in the agriculture domain.

FlexiGroBots architecture will be designed to enable the secure and sovereign exchange of information following the principles proposed by the International Data Spaces Association (IDSA), which will break the data silos and will open the door to new business models for the farmers. The embracement of IDSA vision and guidelines will allow creating more powerful robotics systems and which can interact with the rest of the digital systems deployed in the crops, having access to real-time and historic datasets.

Models powered by Artificial Intelligence techniques will be embedded in the robots for perception, navigation and decision making. They will be used also "as a service" or integrated into Farm Management Systems (FMSs) to analyse the information gathered by the robots and by other data sources and to create powerful applications and services to support the farmer needs. The store, access and analysis of geospatial information are also considered in FlexiGroBots architecture.

The project will pay special attention to comply with the requirements established by the European Commission in terms of trustworthy AI, also providing guidelines about their specification application in the agriculture domain.

FlexiGroBots AI methods will consider Ethical, Legal and Socio-Economic issues, in order to ensure scalable human oversight and intervention and compliance with trustworthy requirements.

The goal of this document is to identify the complete list of requirements that should be satisfied by the platform, considering the needs and expectations of the diverse actors that participate in the precision agriculture value chain. From them, FlexiGroBots technical architecture will be designed, describing the main functionalities that will be provided by each one of its components. The deliverable also includes the analysis of previous and ongoing projects and initiatives that are related to FlexiGroBots goal and which results will serve as a baseline or will be interoperable with the project's results.

It must be noted that FlexiGroBots architecture will be used as the main reference for the implementation of the respective WP3 modules and to guide the integration, execution and validation activities of the three pilots of WP4, WP5 and WP6.

A second and updated version of this deliverable, D2.3, will be released in M18 of the project, which corresponds to June 2023.

1.2 Relation to other project activities

A graphical representation of the relation between deliverable D2.2 and other tasks' outcomes is shown in Figure 1.

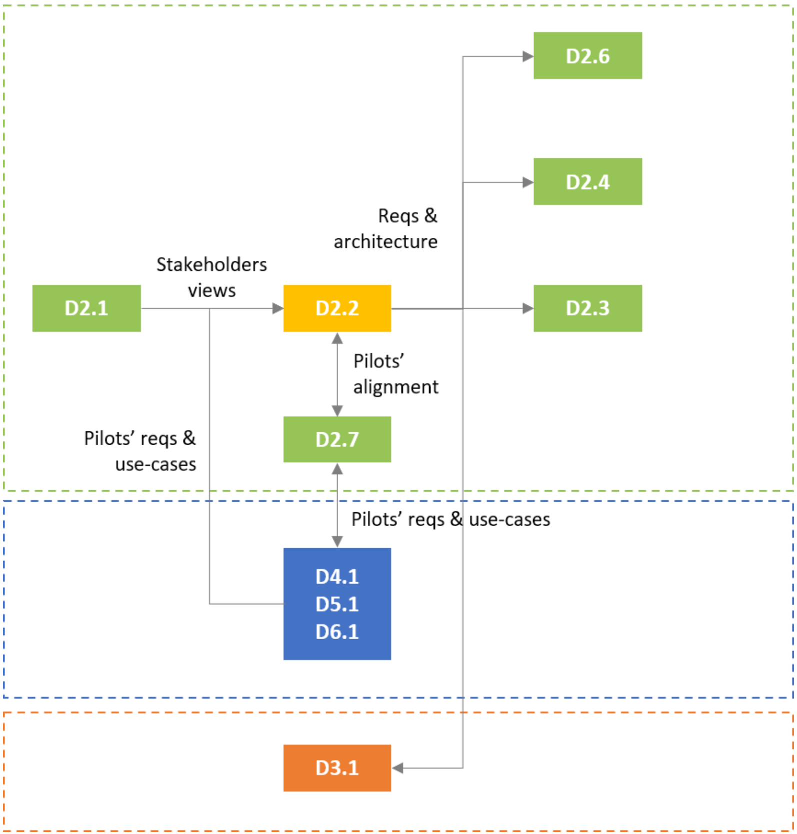


Figure 1 Deliverables linked to D2.2

Deliverable D2.2 is the first outcome of *T2.2 - Platform requirements and architecture* and the second of *WP2 - Requirements, architecture and standardization*, after the release in M9 of the project of D2.1, which was devoted to describing the stakeholders' view to FlexiGroBots system scenarios. The content of D2.2 has been generated through the analysis and consolidation of the results of D2.1 and the use-cases specifications included in D4.1, D5.1 and D6.1. This activity was coordinated as part of the efforts of *T2.5 – Pilots' methodology, follow-up and alignment*, which will have also its first outcome in M12 with D2.7. In this document, FlexiGroBots technical architecture is mapped to each one of the pilots, describing in detail the components that will be used in the different use-cases and interactions with already existing systems, devices and robots. The validation process for the KPIs is also discussed in detail. At the same time, the work done for D2.2 will be continued in several tasks of WP2: in T2.2 to update and evolve the requirements and architecture until the release of D2.3 in M18, in T2.3 to evaluate the standards that must be taken into account for the implementation activities or to which the project shall contribute, in T2.4 for the assessment of the Ethical, Legal and Socio-Economic (ELSE) issues. Finally, WP3 will be in charge of the development of the platform and all the specified functionalities.

1.3 Structure of the document

This document is structured in six major sections:

- **Section 1** introduces the purpose of the deliverable, its relation to other tasks and documents and the structure of the content.
- **Section 2** of the deliverable describes the methodology that has been proposed and followed by T2.2 in order to produce the requirements and to specify the platform technical architecture.
- **Section 3** is focused on a detailed and exhaustive analysis of standard reference architectures and European initiatives, past and ongoing research and innovation projects and relevant standards in the technological domains covered by FlexiGroBots. For each one of them, a short description is performed, also describing the relation for the project.
- The present deliverable is the instrument used by the project to document and publish the complete list of requirements that must be satisfied. Thus, **section 4** presents the characterisation of stakeholders and actors that are normally involved in the end-to-end agriculture value chain. Functional and non-functional requirements are then proposed and coded.
- In **section 5**, D2.2 presents the FlexiGroBots platform architecture in the form of a high-level diagram and IEC 62559 use-cases descriptions. The rest of the views of the 4+1 architectural view model (logical, developments, process and physical) are also included. UML diagrams have been used as modelling language.
- **Section 6** explains the conclusions of the deliverable, providing a vision for the related tasks and documents, especially for the next iteration of this document D2.3.

2 Methodology

Figure 2 below illustrated the methodology used for completing the different objectives addressed by D2.2.

FlexiGroBots requirements and platform architecture specifications			
SOTA analysis	**Analysis of stakeholders**	**User-stories & reqs.**	**FlexiGroBots architecture**
▶ Relevant projects and initiatives. ▶ Reference architectures. ▶ Standards.	▶ Analysis of stakeholders' views and scenarios (D2.1). ▶ Analysis of pilots' use-cases and requirements (D4.1, D5.1 and D6.1) ▶ Characterisation of stakeholders. – Jobs to be done. – Experienced pains. – Wanted gains.	▶ Specification of functional requirements using user stories. ▶ Specification of non-functional requirements. ▶ Analysis of ethical guidelines and requirements (T2.4). ▶ Analysis of overall list of requirements.	▶ High-level architecture. – Modules' description. – Interfaces ▶ Platform use-cases (IEC 62559-2:2015). ▶ 4+1 architectural view model.

Figure 2 Methodology followed in D2.2

First, the partners have performed the **analysis of the state-of-the-art** covering the following aspects:

- Relevant initiatives at the European level so that FlexiGroBots platform is fully aligned with the main frameworks that are being incubated so far.
- Similar research and innovation projects are already finished or that are still underway. In some cases, since some of the partners were involved in them, the expertise and technical outcomes are incorporated within FlexiGroBots background.
- Standards covering technological domains like AI, data-driven platforms, geospatial information, agricultural machinery, drones or robotics.

Second, the **stakeholders for FlexiGroBots technologies have been analysed and characterised**. Starting from the conclusions of the answers obtained as part of the survey of T2.1 and their study, the different actors and stakeholders have been characterised. A Value Proposition Canvas [1] approach was applied in order to describe for each stakeholder:

- Jobs to be done by the user and context on which they are done.
- Pains, negative situations or risks suffered by the user before, during, or after the execution of the jobs.
- Gains or positive impact that the users would like to receive from the project's outcomes.

The goals of the three different pilots and the knowledge of all the partners have been key to completing this task.

Third, **requirements are extracted** considering both functional and non-functional needs. For the former, the elicitation of user stories has been the main task, detailing for each stakeholder, the desired benefit or new capability and the reason that motivates it. For the latter, inputs from the three pilots and from all the partners have been consolidated. ELSEC and ethical requirements have been specifically included thanks to the contribution of T2.4. The complete set of requirements has been consolidated, assigning unique identifiers, categorising them and finding relationships.

A graphical representation of this approach is depicted in Figure 3 below. It was already used successfully in previous H2020 projects like INFINITECH [2] or PLEDGER [3].

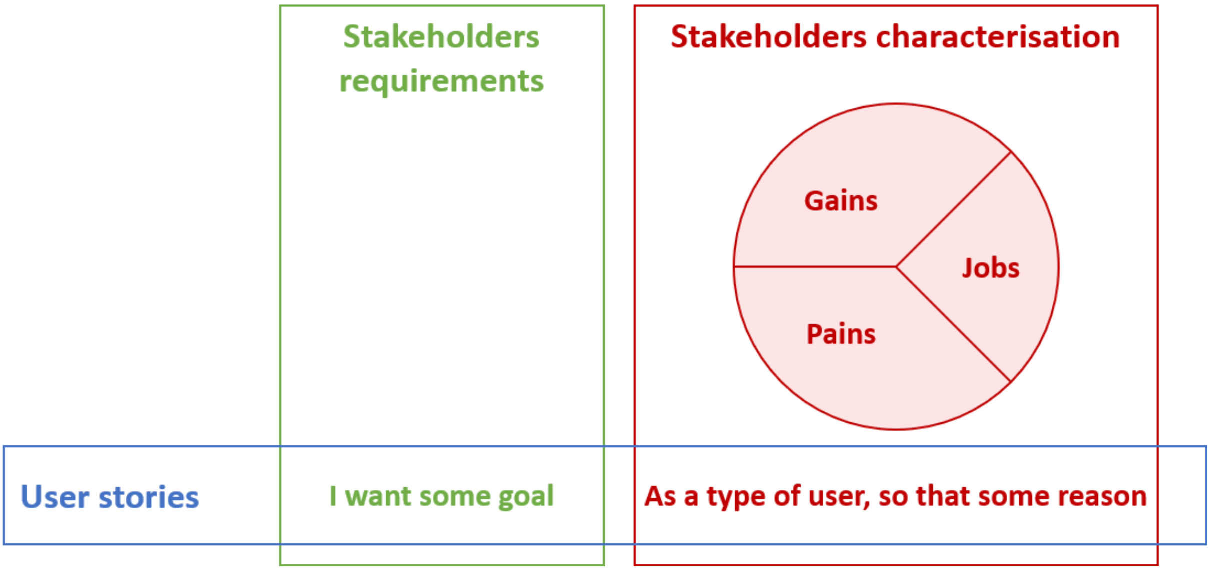


Figure 3 Value Proposition Canvas Methodology

Finally, combining the results of the previous steps, **FlexiGroBots platform technical architecture was specified.** It is provided in the form of a high-level descriptive diagram showing the different components grouped in logical groups, including the interfaces between them. A detailed description of the intended functionalities has been created following templates proposed by the standard IEC 62559 use case methodology [4]. Logical, development, process and physical views of the expected system have been proposed using UML diagrams and relying on relies on the 4+1 architectural view model [5].

3 Analysis of the state of the art

The following figure illustrates the analysis of state-of-the-art included in this chapter.

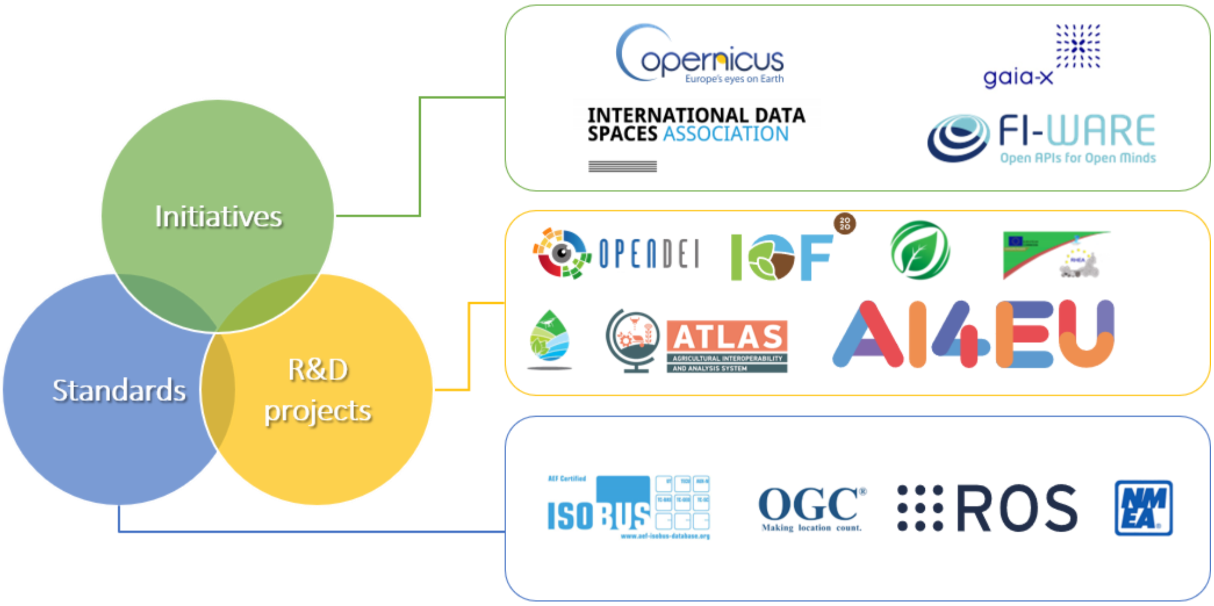


Figure 4 Summary of the analysis of the state-of-the-art in D2.2

3.1 Reference initiatives

3.1.1 International Data Spaces (IDSA)

3.1.1.1 Overview

The International Data Spaces Association (IDSA) [6] has created a technical standard that is the blueprint for data exchange based on European values of trust and self-determination of data usage by the data provider. In IDSA, it is called *data sovereignty*.

In the IDS Reference Architecture Model [7] (IDS-RAM), IDSA specifies a distributed software architecture that enables the sovereign sharing of data between participants in a data space. A data space comprises the relationships between trusted partners that are governed by the IDSA standard for secure and sovereign data exchange. In order for a data space to become operational, certain services need to be enabled, such as an identity provision system with its' certification components, a broker, a clearing house, and an app store.

The core element for data exchange is the IDS connector that gives a participant access to a trusted ecosystem and guarantees the required level of trust between the data provider and the data consumer that exchange data in a peer-to-peer network concept.

The necessary trust among the two entities (data provider and data consumer) is ensured by the implementation of the connectors according to the IDS Reference Architecture Model and the independent evaluation of the connector and the environment it operates. This evaluation process is performed by an approved evaluation facility and the certification body of IDSA is called certification.

The solution that allows for data sovereignty within the IDS-RAM is data usage control [8]. The implementation of data usage control in the IDS is done in the IDS connector and applied at the data provider connector or at the data consumer connector depending on the usage restrictions. The idea of data sovereignty is to allow the data owner to have full control over his/her data, which includes being able to control the usage of his/her data by the Data Consumer. In this way, the IDS architecture adds on top of access control concepts to support data-centric usage control by enforcing usage restrictions for data after access has been granted. So far 14 cases of usage policies have been defined by the data owner in different ways depending on the data space implementation scenario in use (usage policies can be legal contracts that have been translated into usage policies or can be defined directly during the upload process via configuration interfaces).

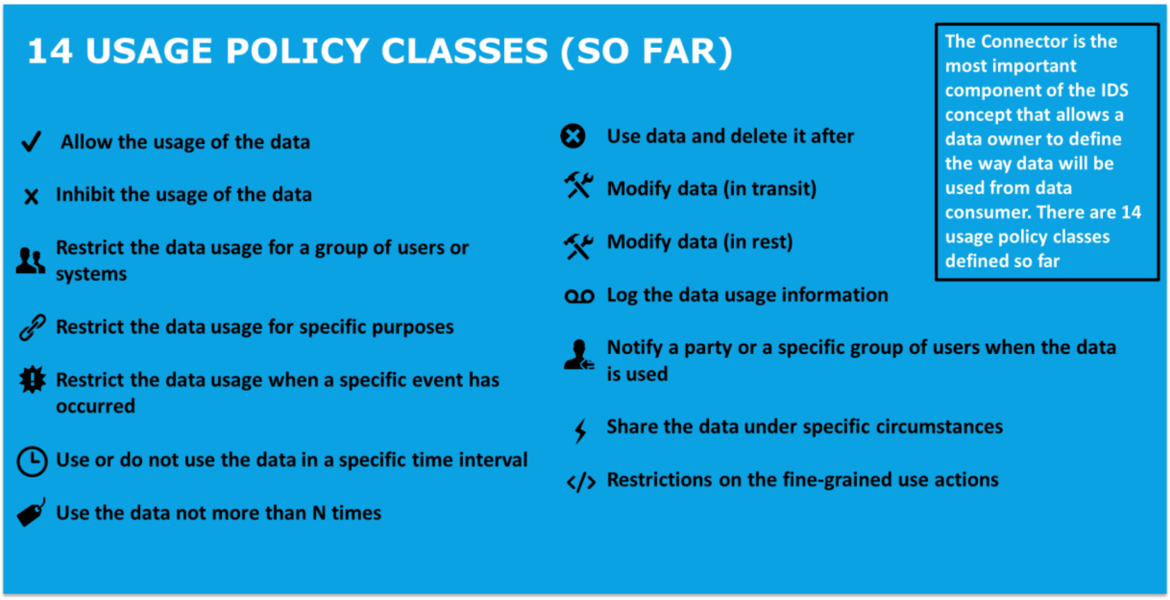


Figure 5: ***14 Usage Policy Cases in IDS based Data Spaces***

The figure below showing the different roles and interactions described in the IDS-RAM allows for a better understanding of what components create a data space. More specifically, there are 4 categories of roles defined in the IDS-RAM: Core Participant, Intermediary, Software/Service Provider and Governance Body.

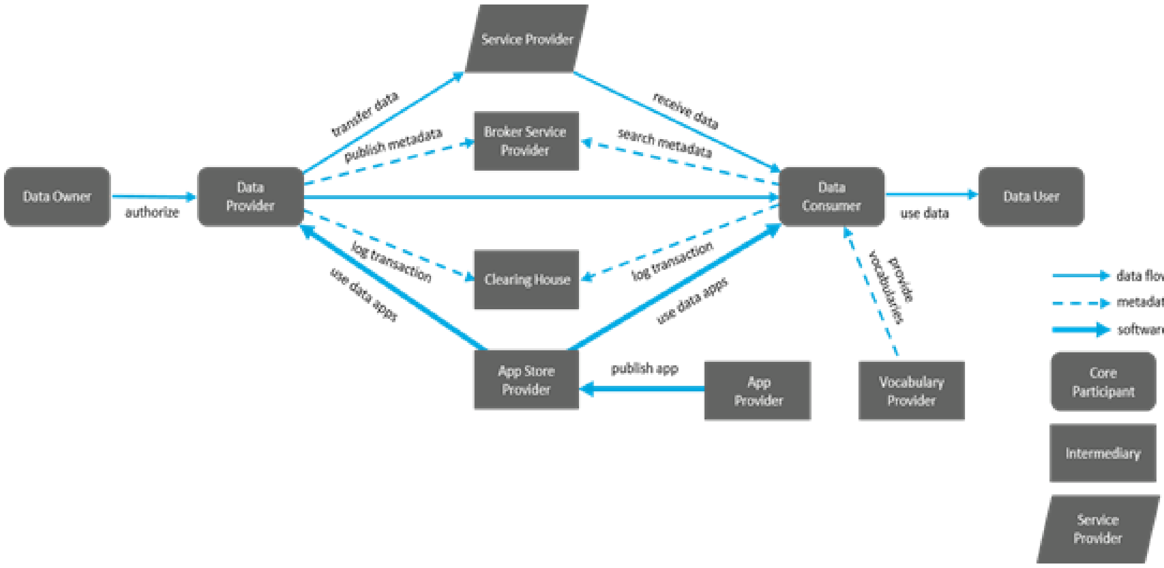


Figure 6: IDS Roles and Interactions as presented in the IDS-RAM 3.0. Source: [7]

The Core Participants are the Data Owner, Provider, Consumer and User. The owner and provider can be the same entity, which is also true for the consumer and user of the data. The core participants are involved in every IDS-based data exchange. The intermediaries act as trusted entities that offer services like the broker, acting as a place where all information about the available data sources in the data space are stored, the Clearing House that records all data exchange transactions for the purpose of financial settlements, and the Identity Provider that is a collection of components (Certification Authority, Dynamic Attribute Provisioning Service and the Participant Information Service) that creates, maintains, manages and validates identity information of and for participants in the IDS. The software/Service Provider category consists of companies that provide software and/or services to the participants of the data space. Finally, the Governance Body consists of the certification body and evaluation facilities that take care of the certification process and issue certificates, both with regards to software components that will be used and the organizations that want to participate.

The IDSA is a neutral body that does not build the above elements itself. These are built from industry partners or members of the IDSA. With the ever-increasing international and economic-political relevance of GAIA-X, it has also become possible to shift certain further developments to open-source initiatives. The Fraunhofer Institute ISST, for example, has been one of the first organizations to develop a connector [9] according to the IDS specification. Another example is the Eclipse Dataspace Connector being currently developed by a community of big industrial players and initiated by Fraunhofer, Daimler, BMW, Deutsche Telekom, Microsoft, Amazon AWS, SAP, ZF Friedrichshafen and supported by GAIA-X AISBL as well as the International Data Spaces Association.

While the description of the IDSA roles describes the Business Layer of the IDS-RAM, there are four more layers of the model, each of which expresses different concerns and viewpoints of the various stakeholders. A layer that defines the functional requirements of IDS-based data spaces and the features to be implemented based on these requirements is the functional one. In the IDS-RAM the requirements are divided into 6 groups that comply with the strategic requirements of IDSA. The six groups of software functionality to be provided by the IDS can be seen in the figure below.

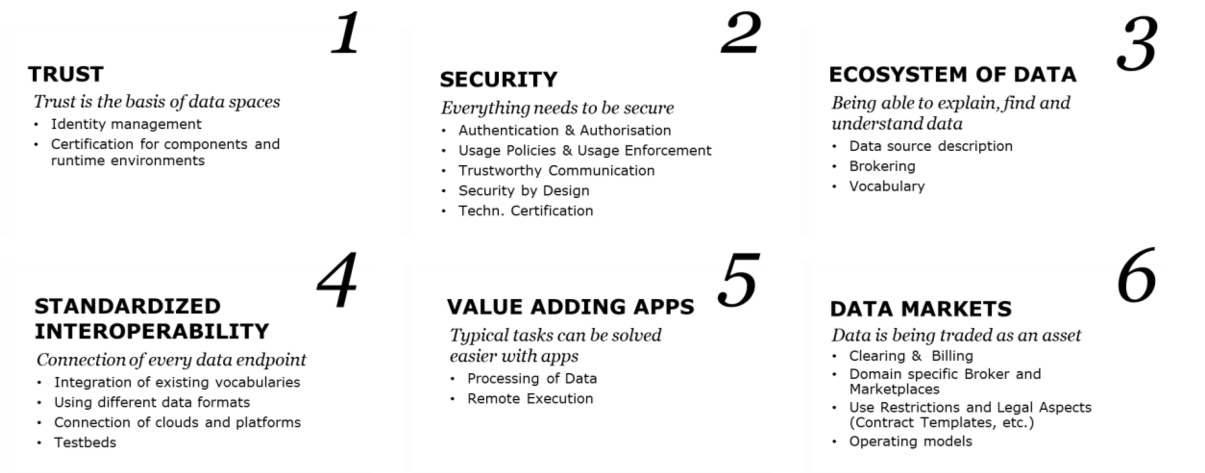


Figure 7: Functional Layer of the IDS Reference Architecture Model. Source: [7]

3.1.1.2 Relevance to FlexiGroBots

The Reference Architecture Model of IDSA will be used for the Common Data Enablers and Services component of WP3. The different IDS components that will be implemented will create a minimum viable Data space tailored to the agricultural context that will allow the sovereign data exchange across companies in the three different pilots in WP4, WP5 and WP6.

The minimum viable data space to be created will consist of the mandatory and a number of optional components defined in the IDS-RAM. The components that will be used are: Connectors for sovereign data exchange within and between the pilot, components that are necessary for the Identity Provision for the data space participants: Certificate Authority (CA), Dynamic Attribute Provisioning Service (DAPS) and the Participant Information Service (ParIS), a Broker for storing and managing information about the data sources available in the Data Space and a Vocabulary Provider for managing and offering vocabularies (ontologies, reference data models etc.) that can be used to annotate and describe datasets. The certification process for all components and the operational environments they act will add a trust layer and will ensure that the functionalities of components work in the specified conditions. An illustration of a minimum viable data space and its key components that will be instantiated for the purposes of the FlexiGroBots project is provided in Section 5.2.2, where the common data services as part of the FlexiGroBots Reference Architecture is described.

The embryonic data space that will be created in FlexiGroBots will allow farmers to keep control of the data they share without losing the benefits from the value created from the analysis of it. Farmers will have the ability to give access to certain data or insights, define how exactly this data shall be used using 14 usage policy classes and in return benefit from the added value created through AI-driven robotic operations.

3.1.2 Gaia-X

3.1.2.1 Overview

GAIA-X Foundation [10] is a non-profit organisation that has the ambition of building a secure and transparent European data and cloud framework. It is formed by multidisciplinary organisations covering stakeholders from the complete digital value chain and from the main application domains. All the information about GAIA-X can be found at https://gaia-x.eu.

The mission of GAIA-X is to facilitate sharing of data by means of designing and implementing vertical data spaces, which should enable advanced smart services to be implemented by also exploiting the possibilities of advanced data analytics and artificial intelligence. The overall high-level vision of GAIA-X is included in Figure 8 below.

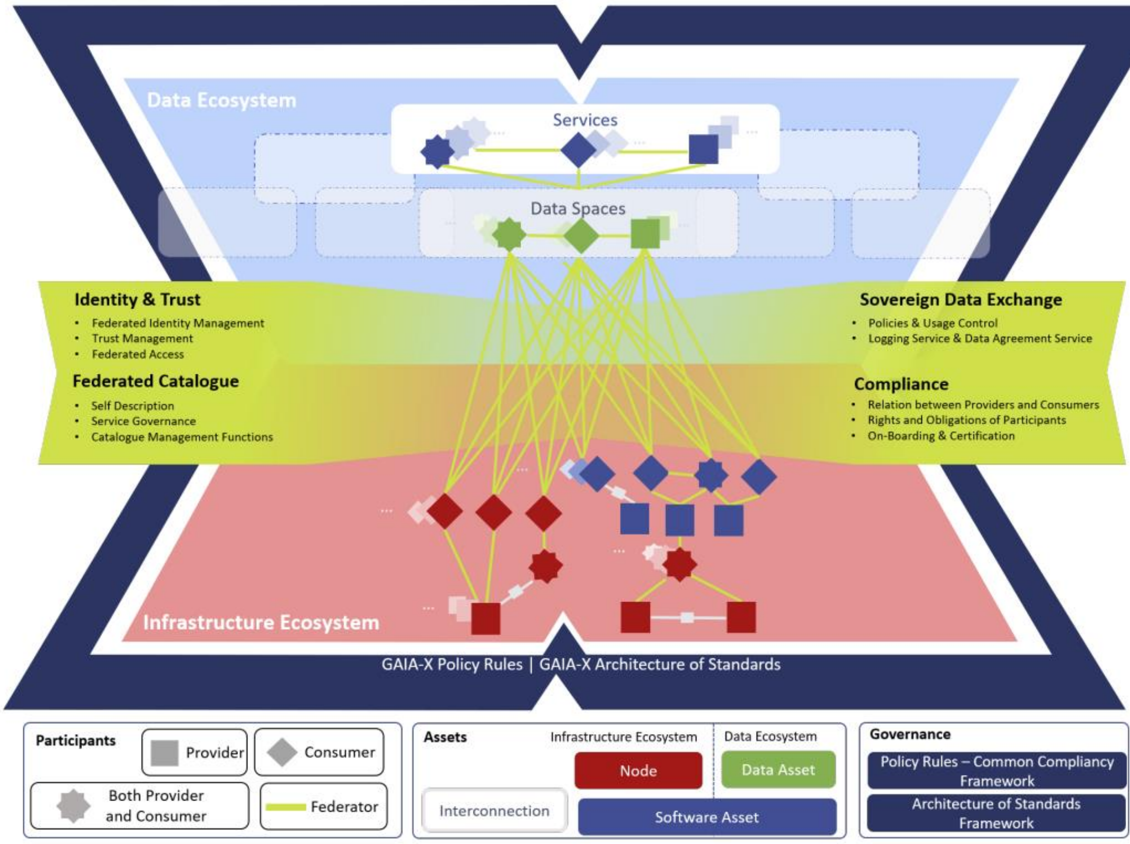


Figure 8 GAIA-X high-level overview. Source: [11]

During 2021, GAIA-X has released the first set of documents that provide technical details about its concept (i.e., architecture of standards, technical architecture). Considering the layered vision of its technical concept, the following aspects will be promoted:

- Compliance, including legal requirements, regulations and policies.
- Infrastructure ecosystem that will provide portability, interoperability and interconnectivity. It setups the technical baseline for the whole stack. At this layer, we can find the federated catalogue and compliance aspects. The main result will be GAIA-X interoperable, federated, trust and sovereign services. It also contains the hardware infrastructures of the hybrid computing continuum, from far edge IoT devices to High-Performance Computing (HPC) centres.
- Data Spaces will be built on top of the services of the Infrastructure Ecosystem, consisting of interoperable and portable cross-sectorial datasets and services. The outcomes of this layer will connect end-to-end stakeholders of the whole data-value chain, including data vendors or producers, service operators, manufacturers, data consumers, etc.
- Finally, cross-sector advanced smart services and applications will be implemented to address the requirements and needs of vertical domains.

As can be seen, there is a clear convergence between GAIA-X and IDSA visions. The mapping of IDSA into the GAIA-X high-level architecture was addressed by a dedicated position paper and it has been included in Figure 9 for the sake of the completeness of the present document.

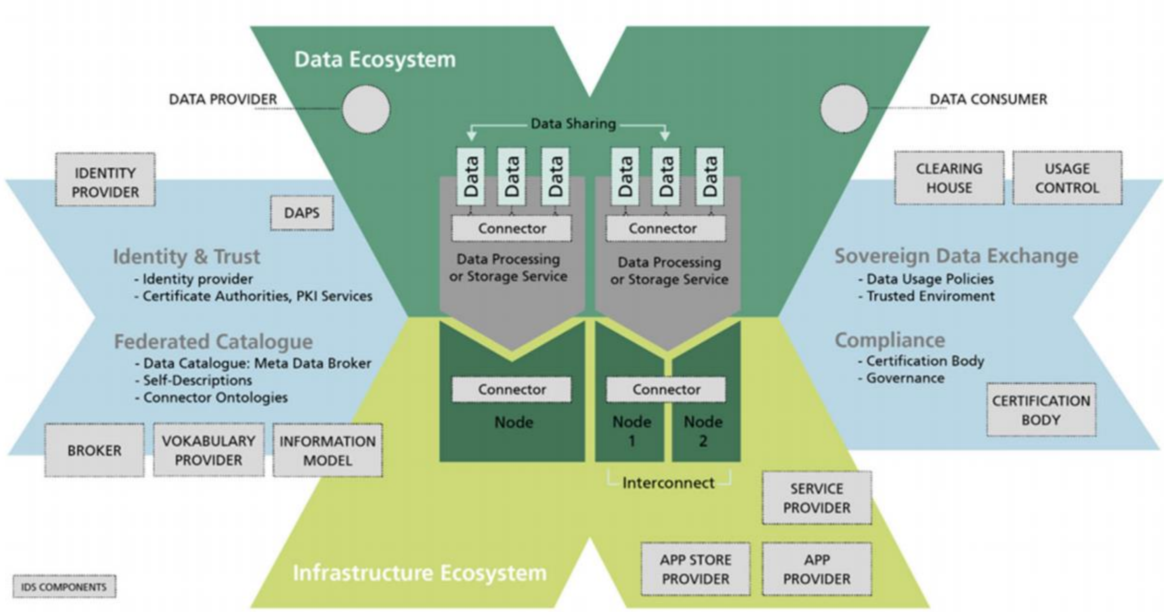


Figure 9 Mappings of IDS components to GAIA-X architecture. Source: [12]

3.1.2.2 Relevance to FlexiGroBots

Regarding the application and particularisation of GAIA-X to the agri-food domain, two main examples can be found so far: the AI-AGRAR platform and Agdatahub [13]. In the first case, the focus is how to implement a platform for the exchange of data and the usage of AI models and algorithms, using GAIA-X infrastructure as the basis for such a decentralised ecosystem. Figure 10 show the stakeholders considered by the AI-AGRAR platform and vision.

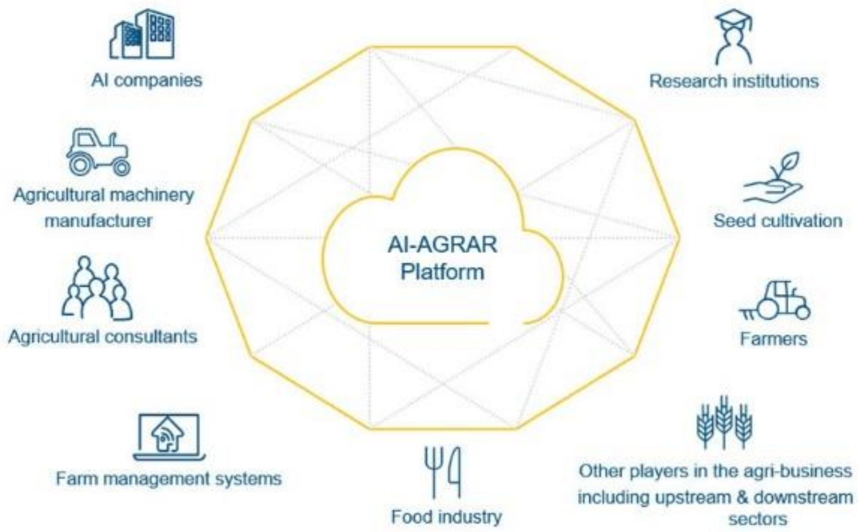


Figure 10 AI-AGRAR use-case

On the other hand, Agdatahub is much more oriented towards safe, trust and sovereign data exchange. Figure 11 presents the Agdatahub high-level approach.

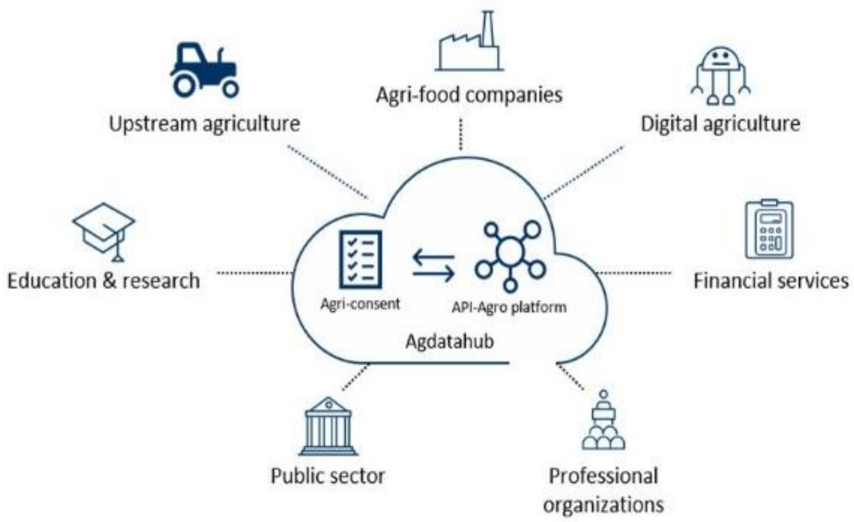


Figure 11 Agdatahub use-case

Agdatahub platform is implementing a consent router to manage consents and a dashboard for easy access to the farmers.

FlexiGroBots will define a high-level reference architecture for building mission control systems of heterogeneous multi robots systems for precision agriculture operations that will consider by design the decentralised nature that the digitalisation of the agriculture realm is adopting. In this sense, the project will follow the guidelines and recommendations of the

GAIA-X technical concept, providing one of the first pilots about the adoption of these concepts with a strong focus on robotics. The lessons learnt and the blueprints of AI-AGRAR and Agdatahub will be used as a baseline.

3.1.3 FIWARE

3.1.3.1 Overview

FIWARE [14] is a European initiative that aims to create an ecosystem and community to facilitate the creation of smart solutions for different domains, breaking the current data silos between proprietary or vertical platforms that avoid the creation of more powerful and cross-domain services. Originally it was funded and supported by European Commission through the Future Internet Public-Private Partnership (FI-PPP) [15] and the FI-WARE FP7 project led by Telefonica [16]. Currently, the initiative is led by the FIWARE Foundation, which was founded in 2016, having more than 415 members from more than 45 countries and more than 100 open-source projects and solutions based on FIWARE. Further information can be found at https://www.fiware.org/.

From a technical point of view, FIWARE consists of a set of curated and open-source components that are interoperable by relying on NGSI, a common information model and API for the exchange of context data. From the initial version, several evolutions of these models have been released by the community until its proposal as an industry-standard in the form of the ETSI CIM NGSI-LD [17].

The main and central component of a FIWARE-based implementation is the Context Broker, which implements the NGSI standard through a RESTful API to enable the exchange of context data between several components and stakeholders. Although there are several implementations of the Context Broker, the most widely used is the one developed initially by Telefonica and called Orion Context Broker [18].

In addition to the Context Broker and as part of the framework, a set of open-source components can be integrated into a FIWARE-compliant solution to cover the needs of the different layers of the stack, e.g., integration of IoT devices, authentication, authorization, data storage in specialized databases, business intelligence, analytics or information visualization.

Several reference architectures particularised to the needs and requirements of main verticals have been designed, piloted and tested during the last years thanks to the involvement of industrial partners and the whole community. An example of agri-food can be seen in Figure 12.

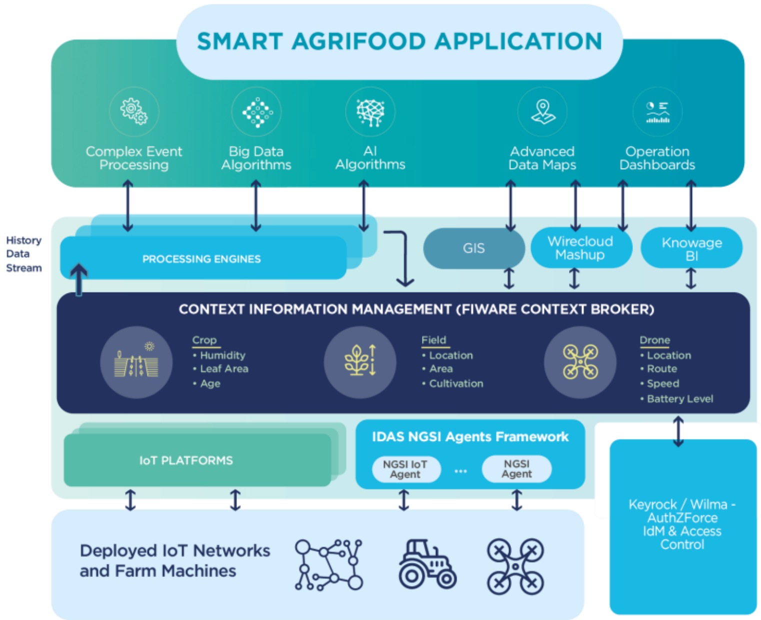


Figure 12 FIWARE reference architecture for IoT-enabled smart farming solutions

3.1.3.2 Relevance to FlexiGroBots

FIWARE is going to be used as part of the WP5 pilot and therefore interoperability between FIWARE and FlexiGroBots embryonic data space and pilot 2 services will be tested/demonstrated.

3.1.4 Copernicus Programme and Sentinel Missions

3.1.4.1 Overview

As described in its landing page [19], "*Copernicus is the European Union's Earth observation programme, looking at our planet and its environment to benefit all European citizens. It offers information services that draw from satellite Earth Observation and in-situ (non-space) data.*"

The programme provides a wealth of high-resolution data at different temporal frequencies, bringing numerous opportunities for the application and development of innovative solutions in several domains such as civil security, land, environmental, marine and atmosphere monitoring among others.

In particular, "*with its frequent and systematic coverage, Sentinel-2 makes a significant contribution to land monitoring services by providing input data for both land cover and land cover change mapping and, support the assessment of bio-geophysical parameters such as Leaf Area Index (LAI), Leaf Chlorophyll Content (LCC) and Leaf Cover (LC)*", which is of high relevance for the agriculture-related FlexiGroBots pilots.

Access to Copernicus and its services is freely and openly accessible by any organization (or individual) all over the world, being the Copernicus Open Hub Access Hub (formerly known as "Sentinels Scientific Data Hub (SciHub)" [20]) its primary and most well-known access point. It provides access to Sentinel-1, -2, -3 and -5p data by means of an interactive graphical user interface. In addition, automated query and data download can be performed by using the OpenSearch APIs it offers.

There exist other possibilities for accessing Copernicus data with their own APIs, access fees (free or pay-per-use) and nuances. That assessment was already performed by the H2020 EO4AGRI project [21], which we extract from its deliverable " [22]" (chapter 4) and briefly reproduce hereby:

"*To ease these implications for end-users, five different Data and Information Access Services (DIAS) are available. The DIAS provide access to product repositories in cloud storage. They primarily are not thought to be used as "dissemination" hubs (download bandwidth is even lower than at Open Access Hub and it is generally not free). The DIAS provide platforms for hosting processing in the vicinity of cloud storage. End-users can bring their algorithms and run them with free and fast access to the product data. Eventually, the end-user only needs to download the (typically low volume) processing results and not the (high-volume) satellite input products. Examples of existing data cube (open-source) software solutions implementations are xcube* [23], *Rasdaman* [24] *and Open Data Cube (ODC)* [25]."

3.1.4.2 Relevance to FlexiGroBots

Earth Observation datasets are a central part of the inputs consumed by the tools and software components within the FlexiGroBots platform. In order to facilitate the management and consumption of EO data (either from Sentinel 2 and Landsat 7/8 satellites and/or more detailed observations from UAVs deployed in the field study areas) the project plans to setup one of the existing open-source solutions, in this case, the Open Data Cube (ODC).

3.2 Architectures from R&D projects

3.2.1 RHEA

3.2.1.1 Overview

The RHEA project [26] aimed at the design and development of new specific and automatic agricultural tools, mobile robots (both aerial and ground) and all related equipment. The project also envisaged the holistic integration of all these equipment and systems in order to carry out inspection, decision making and treatment application to reduce the use of pesticides and improve crop efficiency.

The RHEA multi-robot system consisted of the following set of main systems:

- A Graphical User Interface (GUI) that allows the operator to interact with the entire RHEA multi-robot system.
- A Mission Manager, which defines the missions and controls the multi-robot system.
- Unmanned vehicles, consisting of hexagonal rotor UAVs and commercial tractors converted into UGVs.
- Actuation systems.
- Perception systems, consisting of sensors on the vehicles and the proper sensor data processing methods.
- Location and communications Systems, which provide each vehicle with its real position as well as make the interaction of all the systems possible.

In the case of the mission manager, it had a key role within the project, automating the working sequence that should be implemented by the multi-robot system.

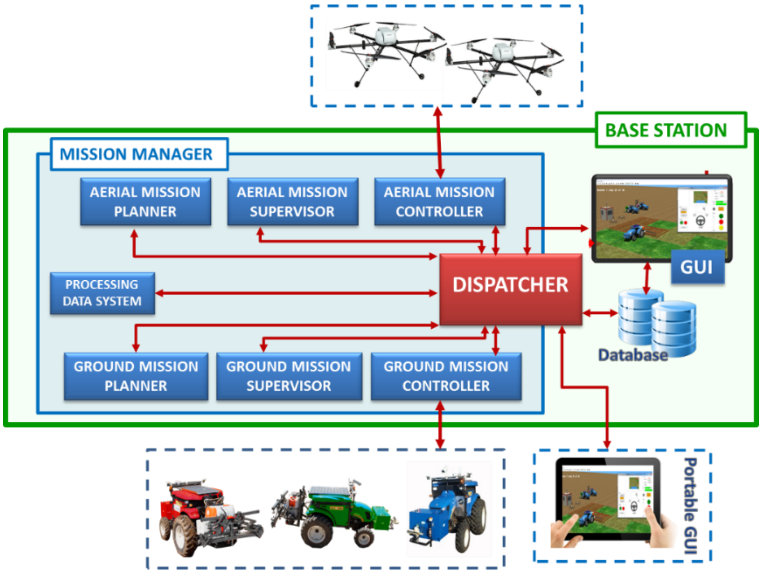


Figure 13 RHEA mission manager architecture. Source: [27]

It contained additional components for planning, controlling and supervising the missions. A more detailed view of the internal architecture of the RHEA mission manager is included in Figure 13.

3.2.1.2 Relevance to FlexiGroBots

FlexiGroBots Mission Control Centre will be designed and implemented leveraging the work done in the RHEA project. A similar architecture will be proposed including similar functionalities and components for faults recovery. Some pieces of the software developed in RHEA may be integrated and adapted in FlexiGroBots MCC.

RHEA will contribute the architecture designed and developed for the supervisors of autonomous ground vehicles, i.e., UGVs, to the FlexiGroBots project. The RHEA supervisor concepts, elements and pieces of code that will be used in the FlexiGroBots platform are described below.

3.2.2 Internet of Food and Farm 2020

3.2.2.1 Overview

Internet of Food and Farm 2020 (IoF2020) [28] is a closed project funded by Horizon 2020 (H2020) from January 2017 until March 2021. Its main objective was to accelerate the adoption of the Internet of Things (IoT) to ensure sufficient, safe and healthy food and to consolidate the European leading position in the global IoT industry by fostering a symbiotic ecosystem of farmers, food industry, technology providers and research institutes. Several goals were set to achieve the ambitious target of the project: i) harvest higher yields and with a better quality thanks to IoT technologies; ii) drop the usage of pesticides and fertilizers by optimizing their efficiency; iii) increase food safety by enabling better traceability of food.

For further details visit https://www.iof2020.eu/.

The IoF2020 consisted of over 120 partners from 22 EU countries, being Wageningen University & Research (WU) the leader of the project. An important remark was that for that project, a substantial number of farmers were involved as end-users and helped to test the applicability of the project to real farms. For IoF2020, thirty-three use cases were organised around five sectors (arable, dairy, fruits, meat, and vegetables) to develop, test, and demonstrate the importance of IoT technologies in an operational farm environment.

The main architecture deployed during this project is shown in Figure 14. It is subdivided into four layers: Physical Object Layer, Production Control Layer, Operations Execution Layer, and Management Information Layer. The Physical Object Layer contains the most important objects that will be needed in the study case. The main function of the Production Control Layer is to sense information about the crop growth and provide inputs to the Operations Execution Layer, which will analyse all the data. Next, the Management Information Layer monitors crop growth. After, the needs of fertiliser and pesticide are calculated based on the crop growth monitoring and the weather data, and the task is sent to the Operations Execution Layer, which schedules the spraying and irrigation tasks and sends this information to the Production Control Layer.

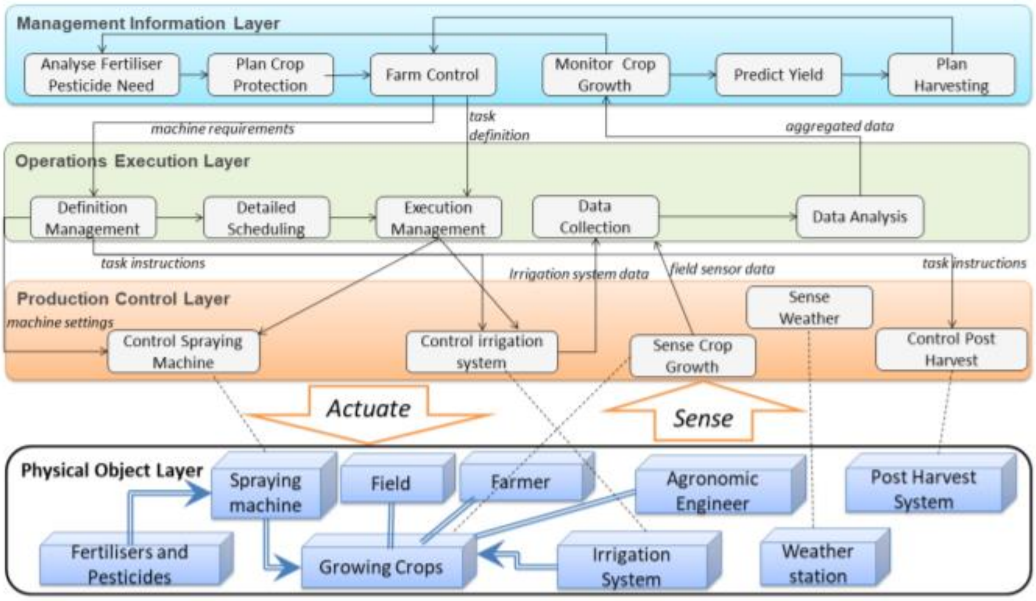


Figure 14. Internet of Food and Farm 2020's architecture.

3.2.2.2 Relevance to FlexiGroBots

Internet of Food and Farm 2020 worked on two sectors that are relevant for the three pilots of FlexiGroBots: arable and fruits. For that, FlexiGroBots will take advantage of the challenges that IoF2020 faced, and the results obtained. IoF2020 and FlexiGroBots share common objectives regarding the technification of agriculture, for instance, to ensure the production of enough and high-quality food and to produce it in a more sustainable way by reducing the amount of pesticides and fertilizers applied to the crop. Moreover, both projects have the same targeted users and use similar technologies to achieve their main goal. The reference architecture produced by IOF will be used to guide the work done in D2.2.

3.2.3 FroboMind

3.2.3.1 Overview

FroboMind [29] is an open-source software framework for robotic control systems. The goal of this project is to provide a generic platform for controlling systems of field robots and drones across different platforms. This approach aims to maximize the reuse of previous work. The standardization of robot software development is undertaken in two ways:

- Scalability: the standard needs to make robot software to be extendable a scalable so it can be used for small projects and also big ones.
- Modularity: the premise for maximizing reuse of previous work is to minimize effort in (i) development, (ii) debugging and (iii) testing.

The main contributors to this project are the researchers of the University of Southern Denmark. As for its technical requirements, the tool is implemented in ROS and runs on Ubuntu Linux.

The tasks of a field robot can be divided into three groups that must take place in the given order: (1st) perception, (2nd) decision-making and (3rd) action. The architecture of this software tool is based on an intuitive breakdown of these three tasks (see Figure 15).

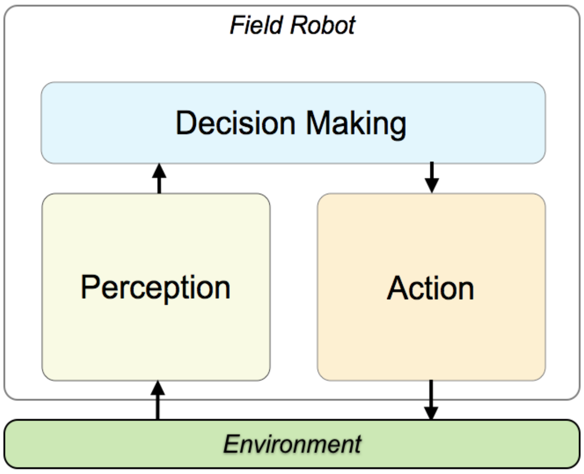


Figure 15 Decision-making agent. Source: [29]

- Perception: the goal of this task is to gather all the required inputs that are useful to obtain awareness of the robot's surroundings. For that purpose, the system combines sensors installed in the robot with already known information. As for the navigation, the robot will have as inputs the mission, the environmental knowledge and user interactions.
- Decision-making: this module will have to use as input all the information gathered by the "perception" task. Then, it will sort, categorize and interpret all this information in order to understand it. Using that processed perception intel, this agent will output the actions that optimize the mission's objectives.
- Action: the last part is to execute the orders given by the decision-making module, which are based on the awareness gained by the perception task.

Figure 16 depicts FroboMind architecture, featuring the aforementioned tasks along with several additional layers. This plot shows the interactions between the physical and software components of the robot's operations as well as the data flow, which is illustrated by arrows. The presence of an arrow tip at the end of a line indicates that the data is being used as input for the connected module, whereas the lack of an arrow tip indicates that the data are flowing out of the component. The data which is available to all the modules has not been included in Figure 16.

Along with a building block for each of the robot tasks, the figure includes two additional layers: "External" and "Safety". The external block comprises all the beforehand known information that is given to the system as input, and it does not represent the actual code of methods. The safety block features those functions that allow the robot to avoid damage and conflict. These are: (i) "internal fault diagnosis" and (ii) "system watchdog" which combined minimize potential software errors; and (iii) "incident handler" to give the robot behavioural response to internal and external interactions. This layer can activate the "emergency stop" hardware if needed.

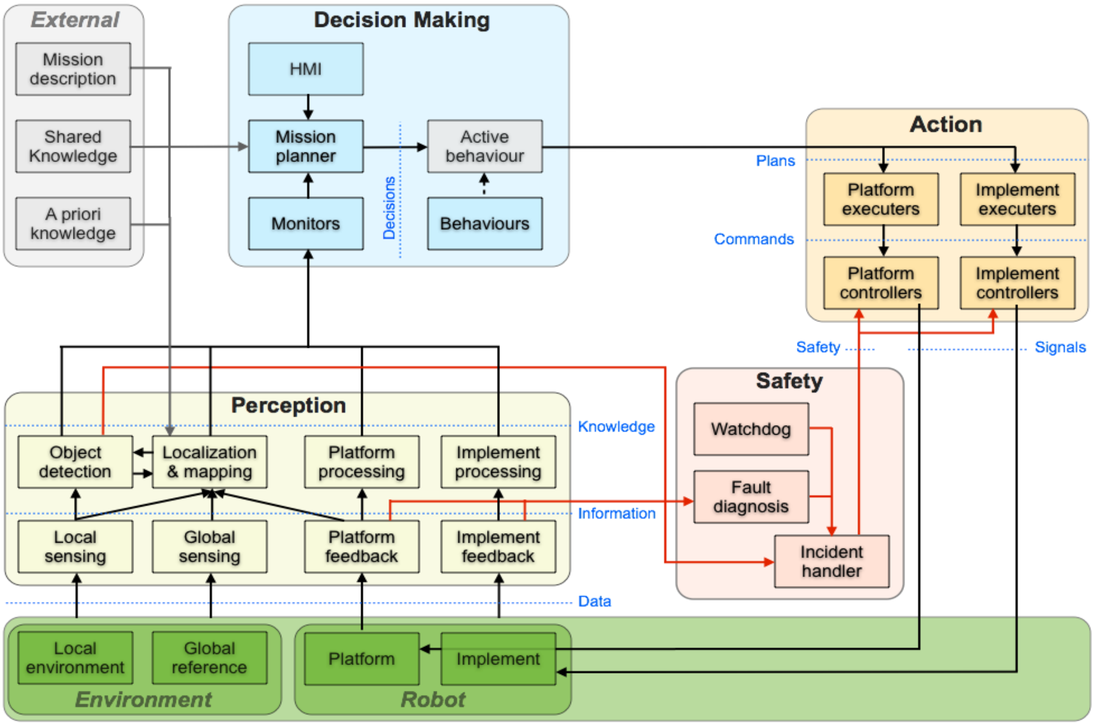


Figure 16 FroboMind conceptual architecture. Source: [29]

3.2.3.2 Relevance to FlexiGroBots

FlexiGroBots has three pilots in different locations that involve robots. Using the FroboMind platform is interesting to standardize the robot software development in order to maximize the efficiency-effort ratio. This project is a particularly suited case because different robot fleets must be deployed in different locations but with similar tasks.

3.2.4 AI4EU

3.2.4.1 Overview

AI4EU (A European AI On-Demand Platform and Ecosystem) [30] is a project funded by the European Commission under the umbrella of ICT-26-2018-2020 topic with the main objective of creating a world-reference AI community in Europe. With this very ambitious goal in mind, the project aimed to achieve several objectives: i) the development of an AI platform that connects the whole community and which facilitate access to specialised resources including datasets, models and experimentation facilities; ii) the demonstration of the platform across eight industrial and real-world pilots; iii) to produce advances with respect to the state-of-the-art in five scientific areas; iv) to establish the AI4EU ethical observatory; v) the composition of a Strategic Research Innovation Agenda for Europe. All the details of the project are available at https://www.ai4europe.eu/.

As it is a core element of the European Commission's strategy to improve the sovereignty of the old continent in the global race to dominate AI, the platform is going to be extended and complemented by several projects funded in ICT-49-2020 topic: AI4Copernicus [31], AIPlan4EU [32], BonsAPPs [33], DIH4AI [34], I-NERGY [35], StairwAI [36]. In all cases, new services will be added on top of the existing AI4EU platform with a special focus to open it to all the SMEs and startups in Europe.

Figure 17 below show the overall vision of the AI4EU project, covering all the outcomes that the project is expected to release.

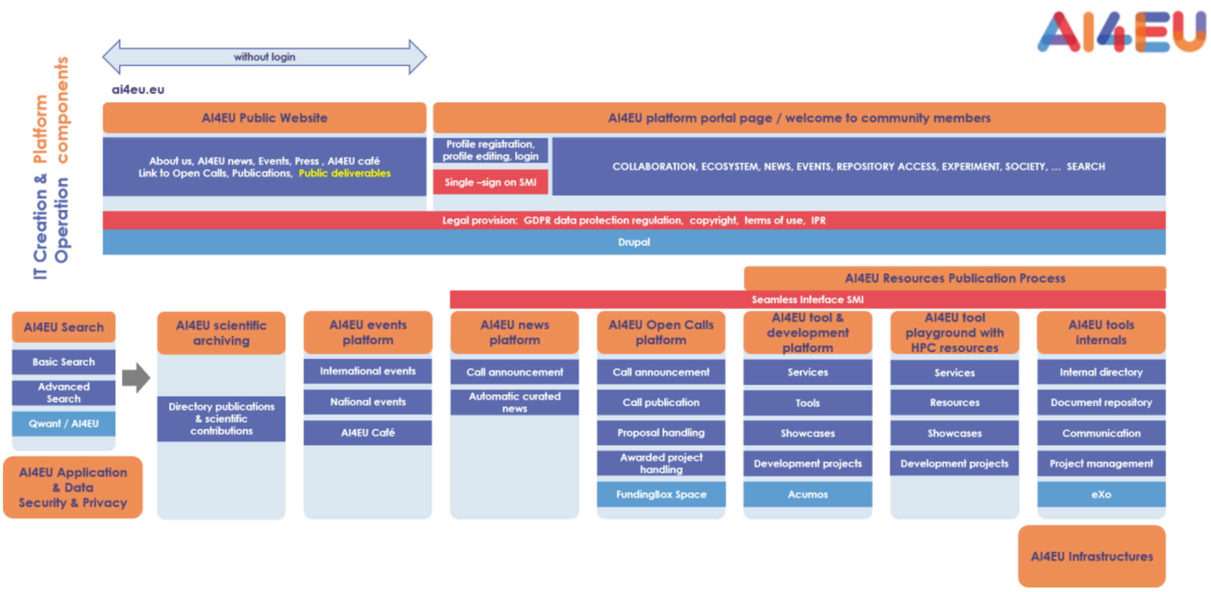


Figure 17 AI4EU project overall vision

Having a closer view of the outcomes of the project, the AI4EU development platform based on Acumos AI [37] will include a set of services to facilitate the design, implementation and deployment of AI services and a catalogue or marketplace to allow sharing them with other members of the community. A public instance of the AI4EU Experiments is available in https://www.ai4europe.eu/.

AI4EU Experiments includes functionalities for the development, training, sharing and deployment of AI models. The core is based on AcumosAI, a project promoted by the Linux Foundation supporting a continuous learning paradigm as illustrated by Figure 18.

The deployment possibilities of Acumos AI relies on the usage of Docker images and enables AI resources to be transferred to target infrastructures and environments for training or inferencing purposes. For instance, currently, it supports local deployment using Docker and Kubernetes, public and private clouds with Microsoft Azure and OpenStack. Existing clients are available for each one of these ecosystems. In the case of Kubernetes, a downloadable deployment package can be exported, and the user must upload the AI resources in the corresponding cluster using different scripts. As part of these scripts, the runtime orchestrator composes the model microservices.

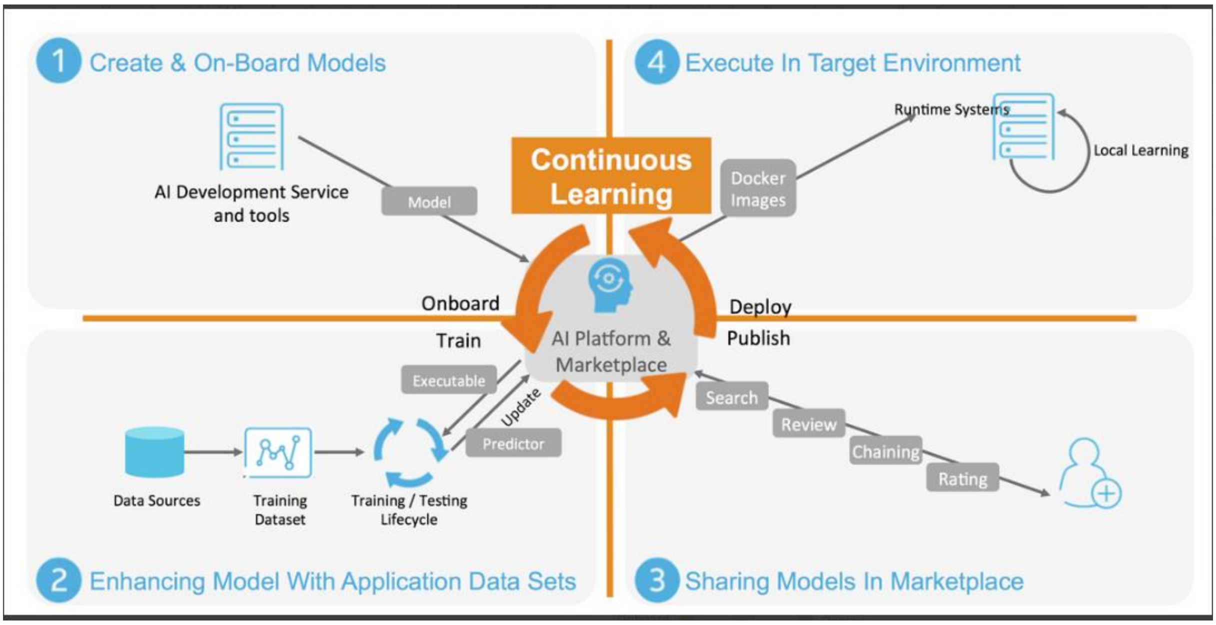


Figure 18 Acumos AI functionalities. Source: [37]

3.2.4.2 Relevance to FlexiGroBots

FlexiGroBots marketplace is intended to provide a space for managing and sharing AI resources, i.e., data sources, data transformers, specific models for prediction, regression and classification. A screenshot of the AI4EU marketplace is shown in Figure 19Figure 19. The system makes it possible to control the visibility of the resources and the onboarding can be done through an API or the user interface. The models must be dockerized and follow some guidelines as explained in Acumos documentation [38]. Protobuf [39] files must be also included in the information uploaded to the platform. They will be used to serialise the input data according to the inputs of the specific model. Data brokers will be in charge of translating data from data sources and converting the information into the Protobuf format.

FlexiGroBots project intends to contribute to the AI4EU European AI on-demand platform. For instance, several datasets are going to be produced during the execution of the three project's pilots including high-quality and labelled images gathered by drones and robots or time-series observations from IoT sensors.

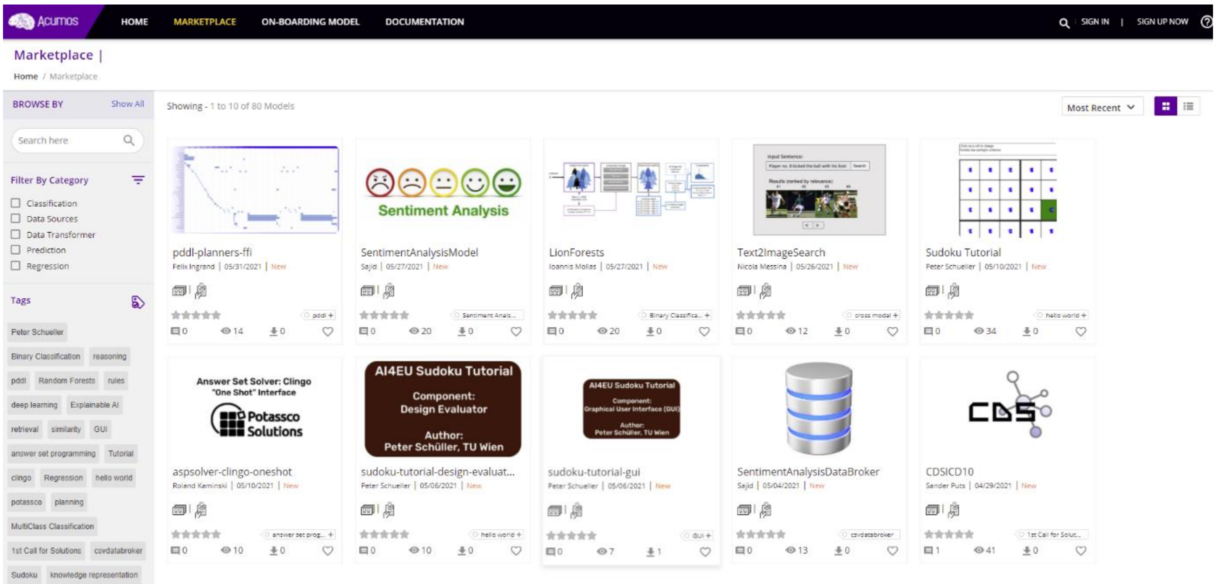


Figure 19 AI4EU AcumosAI instance marketplace. Source: [37]

The project will study that a relevant part of them can be published in the AI4EU platform. The same happens with respect to the AI models. FlexiGroBots partners are going to develop new models to detect pests, diseases or moving objects that will be embedded in the robots or used by the project advanced services. Also, other models to predict yields or some environmental conditions that are essential for the decision-making process of the farms. The project will analyse also the catalogue offered by the AI4EU platform to understand if some datasets of resources can be relevant. Figure 20 below shows the interoperability between FlexiGroBots and AI4EU that will be implemented.

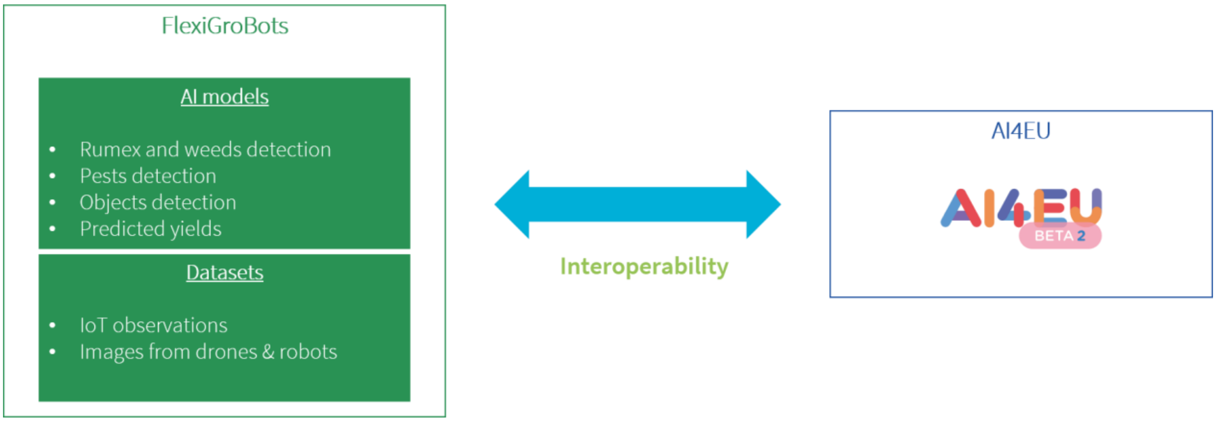


Figure 20 Interoperability between FlexiGroBots and AI4EU

3.2.5 SWAMP

The SWAMP (Smart Water Management Platform) project was an H2020 project from the EU-Brazil call between 2017-2020 [40].

3.2.5.1 Overview

The SWAMP architecture is targeted for implementing FIWARE based smart water management applications for agriculture [41]. The main focus was to enable precision irrigation at various and different conditions. The overview of the architecture is described in Figure 21. It has five main layers from which the lowest three layers are typical IoT system layers such as devices, data transport, and data management. The data management layer combines the FIWARE architecture with the SEPA approach [42]. SEPA is a SPARQL event processing architecture based on semantic web concepts. The fourth layer contains the domain-specific services that are implemented as generic enablers of FIWARE. The fifth layer is the applications such as mobile or web applications that use the services.

The SWAMP systems can combine various information sources and it can be implemented to distributed computing continuum with varying degrees of computing capacity. In farming applications, this is a necessary capability as farms in many cases are in remote locations without proper infrastructures available. SWAMP also extended the virtual entity concept of FIWARE to virtualized entities from both physical and digital domains. This allowed to implement the context of the farm in a holistic way and enabled the development of complex services relatively easily as FIWARE components.

The SWAMP project created three SWAMP architecture-based systems in three pilots. The implementations of the platform and all developed services are available online through www.swamp-project.org

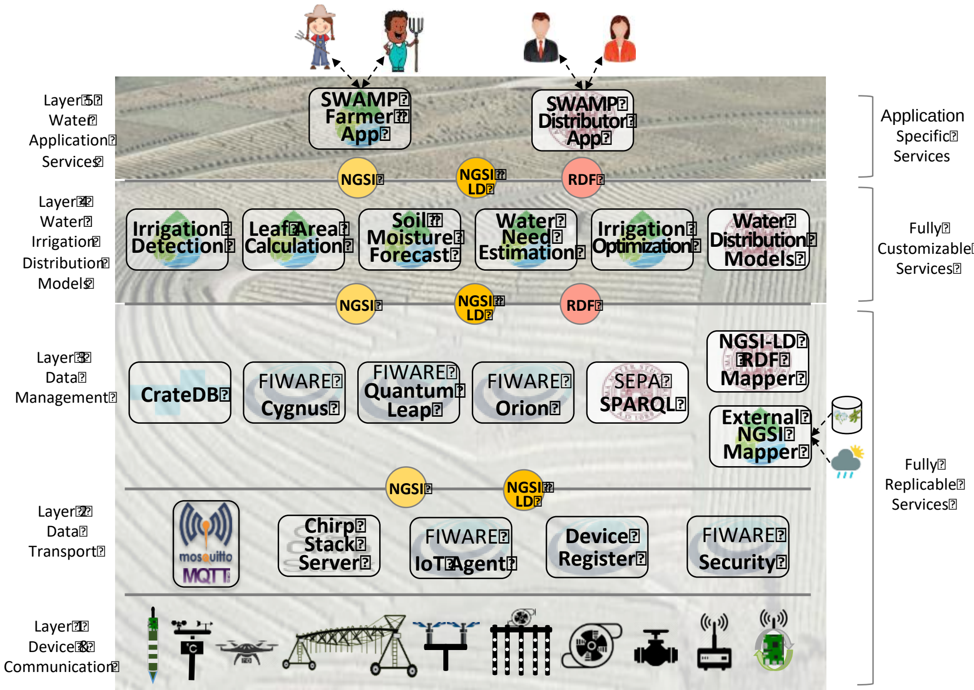


Figure 21. SWAMP smart water management architecture.

3.2.5.2 Relevance to FlexiGroBots

SWAMP project implemented an IoT platform based on FIWARE and created mechanisms to integrate AI-based services as part of the system. SWAMP data model also included the farm data and drones as virtual entities. The drone system communicated directly with the SWAMP system and applications through the platform. This is conceptually very similar to what we have in the FlexiGroBots project. Complex robots could be operated through the IoT platform as well.

Implementing pilots in the FlexiGroBots project will have a lot of alternatives on how to allocate the functionalities to system objects. When having robots collaborating with each other they need to interact with farm management, with each other, and with AI services that need also external data to be trained and operate efficiently. The SWAMP architecture demonstrates how the IoT platform can be the centralized data and service point. The context broker in the IoT platform aims to create and share the context of a location. Services in FlexiGroBots are mostly based on that context and time series based on the previous contexts. The question to be considered in FlexiGroBots is then how much farm management, IoT platforms, and robots should be integrated for supporting AI and context-based cooperation.

3.2.6 ATLAS

ATLAS project [43] is addressing the lack of data interoperability in agriculture by combining the use of agricultural machinery, with sensor systems and data-driven approaches. A platform will be developed to offer technology interoperability services that will demonstrate the benefits of digital agriculture at a larger scale.

3.2.6.1 Overview

ATLAS project is addressing the lack of data interoperability in agriculture by combining the use of agricultural machinery, with sensor systems and data-driven approaches. A platform will be developed to offer technology interoperability services that will enable the exchange of information between different existing systems (e.g., different agricultural software systems and equipment). Each participating system is independent and built upon its own technical infrastructure, this leads to a distributed, non-centralized network of systems (see Figure 22).

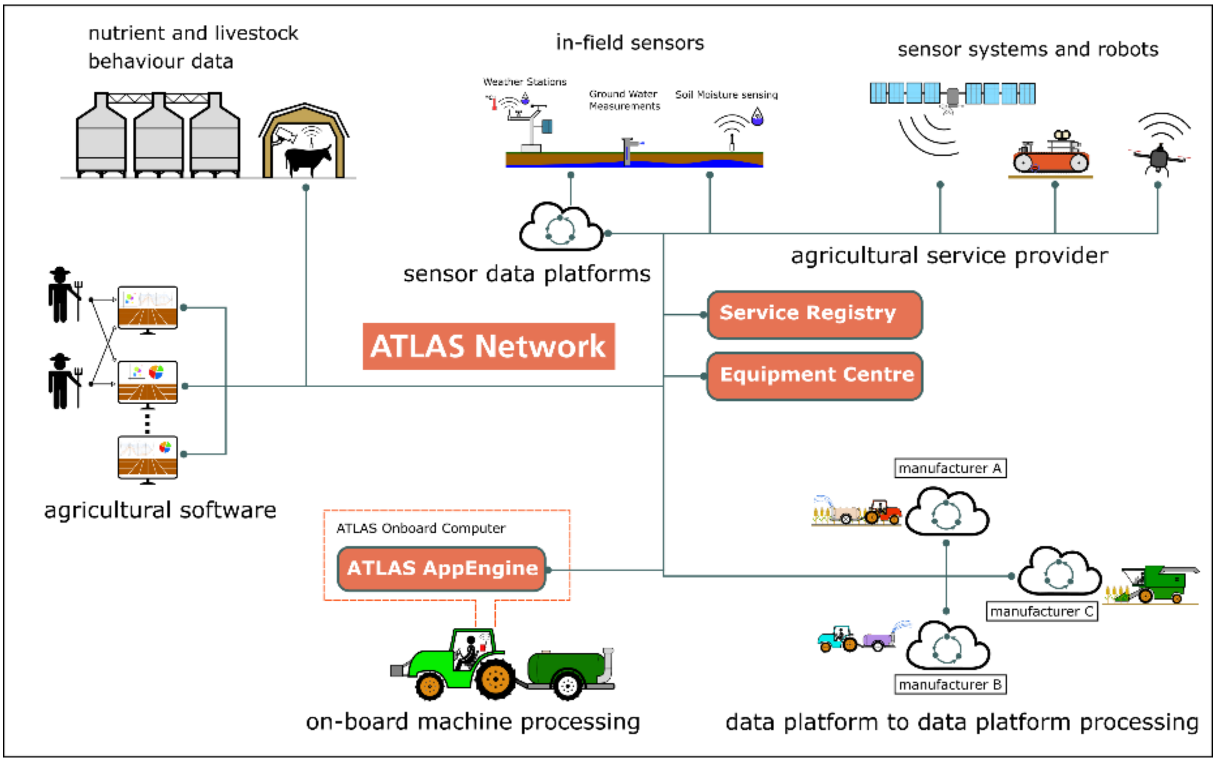


Figure 22 ATLAS high-level architecture and principal participants. Source: [43]

The architecture core components are ATLAS services offered by each participant in a standardized fashion, ATLAS SERVICE REGISTRY, which works as a service discover and register certified networks, and finally, the ATLAS AppEngine, which enable edge-computing capabilities.

3.2.6.2 Relevance to FlexiGroBots

ATLAS will explore the benefits of digital agriculture within different pilot studies and target groups, addressing architecture for interoperability and data exchange. In this line, FlexiGroBots also aim to improve interoperability through standards such as ISOBUS and OGC (Open Geospatial Consortium), reference architectures from initiatives such as IDSA (International Data Spaces Association5) and OPEN DEI (for digital solution pilots), and guidelines such as Trustworthy AI. It is essential that the foreseen platform enables communication with any type of agricultural robot / HW robotic platform from any vendor.

FlexiGroBots platform sits on top of vendor-specific platforms and provides a layer of abstraction which enable the integration, interoperability and platform independence of multi-robot applications and systems. This means that different agricultural technology providers, platforms and systems could collaborate and be integrated into heterogeneous multi-platform (e.g., multi-robot) solutions. Also, third-party robotics application developers will be able to create solutions for farmers through the robotics platform-independent APIs and SDKs provided by the FlexiGroBots.

3.2.7 FOODIE

3.2.7.1 Overview

FOODIE project [44] aimed at building an open and interoperable agricultural specialized platform hub on the cloud for:

- The management of spatial and non-spatial data relevant for farming production.
- Discovery of spatial and non-spatial agriculture-related data from heterogeneous sources.
- Integration of existing and valuable European open datasets related to agriculture.
- Data publication and data linking of external agriculture data sources contributed by different public and private stakeholders.

The development and refinement of the following FOODIE data models represent the most remarkable standardization results carried out by the project in order to achieve exchangeable information between heterogeneous information systems with respect to the agriculture domain.

FOODIE Core Data Model, as described in its architecture deliverable (and further developed in the context of H2020 DataBio project [45], deliverable D4.4 Service Documentation) [46] [47], is "*a stable standardization framework for the management of economically and ecologically related agricultural information. It comprises unified definitions for collecting data about yield, reference materials for subsidies, evidence of environmental burden (e.g., phosphates, nitrates, pesticides, etc.). To ensure the maximum degree of data interoperability, the FOODIE data model follows INSPIRE generic data models, in particular, the INSPIRE data model* [48] *for Agricultural and Aquaculture Facilities, by extending and specializing them*."

3.2.7.2 Relevance to FlexiGroBots

The FOODIE & FlexiGroBots Projects have some common objectives related to the agricultural sector, such as the development of open data platforms and offering different services to the stakeholders. Both projects share targeted users and aim to improve the sector by means of new high-valued applications and services. FlexiGroBots plans to leverage on FOODIE Data Model (and possibly extend it) in order to exchange information from (and back to) the pilots' farming systems in a common and interoperable manner with the other components (e.g., AI algorithms, geoprocessing modules, etc.) in FlexiGroBots agricultural data space.

The three pilots of the FOODIE project will also give good examples, experiences and guidelines, special Pilot 1, focused on precision agriculture for vineyards.

In addition, it is important to note that there are three FOODIE partners involved in FlexiGroBots (ATOS, Terras Gauda and SERESCO), and this will ensure the use of knowledge and experiences, as well as taking advantage of other improvements detected in the previous project.

3.2.8 Open Dei

3.2.8.1 Overview

OPEN DEI [49] is a Horizon 2020 project for aligning reference architectures, open platforms, and large-scale pilots in digitising European Industry. Task Force 1 led by International Data Spaces Association has made the first approach to define the design principles for data spaces through bringing together data space and industrial domain experts. The key outcomes of this first definition are described in the position paper "Design Principles for Data Spaces v1.0" [50] that underlines the importance of data spaces and through the sovereign sharing of data in creating the future data economy.

The motivation behind the work of OPEN DEI in Task Force 1 is the fact that nowadays all individuals and organizations act in data ecosystems and usually in many at the same time and they are not limited to sharing data within a single data silo or data domain [51]. The first version of the position paper included an analysis of the different relevant data sharing stakeholders and their concerns. This analysis resulted in the definition of four main design principles for data spaces, which are data sovereignty, a level playing field for data sharing and exchange, decentralised soft infrastructure, and public-private governance.

Based on the IDS-RAM, a data space is a federated data ecosystem that within a certain application domain governs data sharing via shared policies and rules allowing users to access data in a secure, transparent, trusted, easy and unified fashion. Such a federated data ecosystem needs also to be overlapping with data spaces from other domains to avoid the fragmentation of the ecosystems into multiple isolated domains. OPEN DEI defined the appropriate condition for setting up such an open data ecosystem that will be based on mutual trust between all participants with the term “soft infrastructure”. This infrastructure is supposed to enable thousands of data spaces and will prevent the European data spaces from becoming a monolithic, centralised IT infrastructure. Instead, the European data spaces will consist of the totality of interoperable implementation of data spaces complying with a set of agreements in terms of functional, technical, operation and legal aspects. The soft infrastructure will be invisible to data space participants and will entail functional and non-functional requirements regarding interoperability, portability, findability, security, privacy, and trustworthiness. The 4 different categories of agreements that the general soft infrastructure stack is made up of specify how organisations and individuals can participate in the data economy and how they need to act and behave in compliance with commonly agreed rules and directives. These solutions neutral and sector-agnostic agreements are represented by 12 building blocks that fall under two types: i) Technical building blocks that enable the implementation of the technical architecture of a data space, and ii) Governance building blocks that refer to the business, operational and organizational agreements among data space participants.

Even though the agriculture sector has the reputation for being slow in adopting digital and data-driven technologies, there are many efforts in the last years that show that agriculture is going under a big change through digital transformation. For instance, the code of conduct [52] has been the first attempt within an industry sector to define a framework for data sharing. What the code of conduct actually specifies is the conditions for defining the soft infrastructure for data spaces based on a set of agreements and guidance on fair and transparent use of data.

3.2.8.2 Relevance to FlexiGroBots

The embryonic data space that will be created in FlexiGroBots will be implemented and operated according to the design principles defined in Open DEI Project. The goal of the project in terms of data sovereignty is to guarantee that farmers and other agriculture ecosystem players are in full control of the various data they make available for creating new services and added value in the pilots of the project.

The data space design principles defined in the Open DEI Project will be instantiated in FlexiGroBots. More specifically, in terms of the decentralised soft infrastructure, the use of the IDS standard will ensure the standardized interoperability for data exchange, as the connector, being the central component of the Reference Architecture is able to communicate with any other Connector (or another technical component) owned by another participant of the data space. Regarding data sovereignty, this will be enabled by IDS connectors that will be used for the exchange of sensitive agriculture data.

FlexiGroBots will follow the activities of Open DEI towards the second version of design principles for data spaces to make sure that the embryonic data space to be created will become part of the European agri-food data space that the EU Commission plans to come up with for the implementation of the European Data Strategy.

3.3 Standards

3.3.1 ISOBUS

3.3.1.1 Overview

ISO 11783 [53] standard series defines a control and communications data network between a tractor and an implement as well as a precision farming information model between the machinery and FMIS. It is commonly known by the trade name ISOBUS, which is maintained by AEF (Agricultural Electronics Industry Foundation). The standard is the most accepted machine-to-machine communication standard in the agricultural industry and all major agricultural machinery and component manufacturers are committed to the standard. There are no other competing standards available or under development at the moment.

ISO 11783 defines the communication protocol used between different components of the tractor-implement system. In addition, ISO 11783 defines a set of functionalities and devices required from the machinery. As it is explained in [54]: "*The simplest system consists of a tractor Electronic Control Unit (ECU) (T-ECU), an implement ECU (I-ECU) and a universal user interface called universal terminal (UT) or virtual terminal (VT). These devices form the basic structure used to control the tractor and implement combinations. There can be additional devices attached to the system, such as a positioning device (GNSS), or a task controller (TC). The task controller can be used to control the implementation, as well as to store the data logged in an executed field operation. A TC that is capable of location-specific control and logging is called TC-GEO and a TC that is capable only of data logging is called TC-LOG*".

3.3.1.2 Relevance to FlexiGroBots

ISO 11783-10 describes an interface between agricultural machinery (a device called Task Controller) and FMIS. The standard defines the Task file to describe the operations. Into the Task file, it is also possible to include the machine allocation, scheduling and routes in the field in addition to the information needed by PF. The ISO 11783 Task file is also used to document the work that has been done in the field. Therefore, the ISO 11783-10 Task file can be used also to give all the instructions that are needed for the autonomous operation to robots.

At the moment, the standard does not define how the Task file is transferred to the tractor and the TC. The de-facto standard is to use a USB stick to transfer the file. However, many commercial Task Controllers also supports data transfer through a cloud service. Online telemetry is also possible through cloud services. AEF and ISO are working to standardize the cloud connection. The proposed definition is called Extended FMIS Data Interface (EFDI) and is based on the MQTT/Protobuf protocols. The same structure that is used in the ISO 11783-10 Task file (XML) is used in the Protobuf definitions, so the conversion from XML format to Protobuf doesn't lose any information and is straightforward.

In this project, the PF operations can be planned in the FMIS and transferred through the EFDI to the robots. The same Task files can be used also in the tractors that are operated by the human driver.

3.3.2 OGC

3.3.2.1 Overview

The Open Geospatial Consortium (OGC) [55] is an international consortium of more than 500 businesses, government agencies, research organizations, and universities driven to make geospatial (location) information and services FAIR - Findable, Accessible, Interoperable, and Reusable.

3.3.2.2 Relevance to FlexiGroBots

FlexiGroBots geospatial components rely upon several OGC standards – such as Web Map Service (WMS), Web Coverage Service (WCS), Web Feature Service (WFS), GML and GeoJSON among others – as well as open-source implementations (e.g., GeoServer, Mapserver, Open Data Cube) of these standard specifications in order to manage and make available in an interoperable manner the different data sources used within the pilots.

3.3.3 ROS

3.3.3.1 Overview

Robot Operating System [56] is a framework for robot software development that provides the functionality of an operating system in a heterogeneous cluster. ROS can also be defined as a metasystem, since it is an OS installed on top of another OS, most commonly, an UNIX system (Ubuntu, Debian), although it is also being adapted to other operating systems including Microsoft Windows. ROS is based on a graph architecture where processing takes place at nodes that can receive, send and multiplex messages from sensors, control, status, planners and actuators, among others.

ROS is a flexible and open-source framework, with a wide variety of tools, libraries and packages that aim to create complex software for robust robots with varied behaviour.

Some of the main characteristics of ROS are:

- It is committed to modularity (different areas that come together in a project).
- In ROS each module is autonomous (like computers in a LAN network).
- Each module interacts with each other by means of messages (XML-RCP protocol), which makes it possible to program in different C++, Python, Java languages.
- It makes use of the TCP/IP protocol for a client-server scheme. The main server is the core of ROS.

3.3.3.2 Relevance to FlexiGroBots

ROS has two basic parts: the operating system part, *ros*, as described above, and *ros-pkg*, a suite of user-contributed packages (organised into stacks) that implement functionality such as simultaneous localisation and mapping, planning, perception, simulation, etc. ROS is free software under the terms of the BSD licence. This licence allows freedom for commercial and research use. The package contributions in ros-pkg are under a variety of different licences. Thus, ROS provides a significant number of resources aimed at helping developers to generate increasingly complex behaviours in their robots. Since 2007, this has led to the creation of an important community that shares the knowledge acquired. Finally, the use of this operating system as a basis for programming the various FlexiGroBots robots will help to increase the interoperability and portability of the technologies to be developed.

3.3.4 National Marine Electronics Association (NMEA)

3.3.4.1 Overview

NMEA [57] is a standard data format supported by all GNSS equipment manufacturers and is the measurement output-data format of this kind of sensors in a predefined ASCII format. NMEA is the acronym for the National Marine Electronics Association, an association formed in 1957 by a group of electronics distributors with the aim of establishing better communication with manufacturers.

3.3.4.2 Relevance to FlexiGroBots

The purpose of NMEA is to provide the possibility to mix and match hardware and software. In addition, having a standard format also makes it easier for software developers to generate software for a multitude of equipment, which increases the portability of the developed software. For example, the VisualGPS [58] software (free of charge) accepts NMEA formatted data from any GNSS receiver and displays it graphically. Without a standard such as NMEA, writing and maintaining such software is time-consuming and expensive.

4 Requirements from stakeholders and pilots

4.1 Analysis of stakeholders’ requirements survey

As part of the activities of T2.1, the project created a stakeholder survey using the Google Forms questionnaire. The questionnaire was distributed to project partners and their contacts. We got a set of replies that were analysed and reported in Deliverable D2.1. The main focus of the survey was to understand the general attitudes of replicants and to analyse what planned features are considered most important.

The main conclusions that were extracted from the survey can be summarised in the following points:

- The main obstacles for the wider adoption of AI and robotics technologies in precision agriculture scenarios are related to costs and complexity. Appropriate training, intuitive and friendly interfaces and evolutionary development are proposed as potential solutions.
- The importance of data is highlighted but there are concerns with respect to the technical mechanisms and governance principles to ensure fairness and trustworthiness.
- FlexiGroBots development activities should prioritise services that address the principal pains of farmers, providing a direct benefit for them.

The complete content of the survey and the subsequent analysis and discussion can be found in D2.1 [59].

4.2 Stakeholders’ characterization

4.2.1 Farmers

Job ID	Job to be done
JOB_FARMER_01	They must detect and treat pests and diseases in the crops. In general, to map problematic areas.
JOB_FARMER_02	They must make decisions about the management of the crops (e.g., irrigation, fertilizers, harvesting, weeding).
JOB_FARMER_03	They must analyse laboratory results and data (historic and real-time) about the soli, crops yield, productivity, and quality to make a decision and plan the next seasons.
JOB_FARMER_04	They must plan and organise resources, e.g., supplies, machinery, workers, etc.
JOB_FARMER_05	Depending on the size of the farm, they must market crops’ products, which implies negotiating with distributors or with the agri-food industry.

Job ID	Job to be done
JOB_FARMER_06	In some cases, they must process and transform raw harvested agricultural products into high-added-value marketable products. This is the case of vineyards, but it is extending since direct sales from farms is an emerging trend.
JOB_FARMER_07	They must guarantee the security and safety of their workers and physical infrastructures.
JOB_FARMER_08	They must find private or public funding opportunities to modernise and improve their farms. In the latter case, they may use regional, national or European mechanisms including the Common Agricultural Policy (CAP).
JOB_FARMER_09	They must show evidence on how the crop was cultivated, what actions were done, when they were done, and what fertilizers, pesticides, herbicides, seeds etc. were used. This must be done for both crop buyers (to be used in marketing to consumers) and public authorities (for public support).

Table 1 Description of jobs for farmers

Pain ID	Pain description
PAIN_FARMER_01	Traditional approaches for pests' detection based on human surveillance are expensive and inefficient. Treatments require excess pesticide control.
PAIN_FARMER_02	Remote sensing with UAVs and/or satellite images is not appropriate for all types of crops and may not provide enough accuracy.
PAIN_FARMER_03	IoT sensors and smart traps are expensive to cover large fields, they require complex communication infrastructures and do not allow applying treatments.
PAIN_FARMER_04	Costs related to UAVs are proportional to the total flight time and the number of flight missions.
PAIN_FARMER_05	Closed interfaces and proprietary technologies from main agriculture machinery providers limits the freedom to select different technology providers.
PAIN_FARMER_06	Lack of control about the usage that agricultural machinery providers do of collected data.
PAIN_FARMER_07	Many farms, especially the smallest, are not digitalized and do not have modern communication networks and IT infrastructures.
PAIN_FARMER_08	New digital technologies, machinery and robotics systems are not interoperable. This requires handling different tools and interfaces.

Pain ID	Pain description
PAIN_FARMER_09	Uncertainty around emerging regulations and requirements for AI-based systems.
PAIN_FARMER_10	Traditional agricultural machinery incorporating autonomous functionalities has high fixed and variable costs. For small farms, it is only possible to acquire a few units and their failure implies stopping the production. It also has a strong impact on the soil, and it is not appropriate for certain types of farms and crops.
PAIN_FARMER_11	Pesticides application has an additional cost for the farms and negatively impacts the environment. Nowadays, it may also reduce the level of acceptance of the products by the industry or the final consumers.
PAIN_FARMER_12	Some tasks are resource-demanding and must be done in a very short and concrete period of time. The work must be done in parallel in multiple fields.
PAIN_FARMER_13	The decision-making process for certain activities (e.g., the optimal time for silage harvesting) is done using expensive and non-automated processes (e.g., manually collected samples that are analysed in the laboratory).
PAIN_FARMER_14	Uncertainty about the global economic, political and societal situation, that may affect the profitability of their businesses.

Table 2 Description of pains for farmers

Gain ID	Gain description
GAIN_FARMER_01	Higher profitability thanks to the reduction of costs related to pests and diseases, higher efficiency, and productivity.
GAIN_FARMER_02	Higher quality in the resulting products.
GAIN_FARMER_03	More sustainable and environmentally friendly farms and agricultural practices.
GAIN_FARMER_04	Better decision-making capabilities for short-term and long-term.
GAIN_FARMER_05	Autonomy and independence to select the most suitable providers, including machinery, robotics solutions, IT infrastructures and services.
GAIN_FARMER_06	Resilient farming systems to failures or losses.
GAIN_FARMER_07	Find new revenue streams through the commercialization of data.
GAIN_FARMER_08	Lower costs and complexity for the deployment and usage of AI and robotics systems.
GAIN_FARMER_09	Capacity to predict events for better planning of resources and activities.

Gain ID	Gain description
GAIN_FARMER_10	New carbon-aware farming methods need a new type of machinery, i.e., lighter machines that do not manipulate the soil unnecessarily.
GAIN_FARMER_11	Better awareness of the production can lead to increase transparency and capability to create higher revenues through adding data to the product.

Table 3 Description of gains for farmers

4.2.2 Farm workers

Job ID	Job to be done
JOB_WORKER_01	They must perform harvesting tasks, collecting fruits and vegetables manually and putting them into baskets or containers without causing damages. During the process, they must select the products according to their size and ripeness, discarding those which are rotted or over-ripped.
JOB_WORKER_02	They must transport collected products to warehouses.
JOB_WORKER_03	They must plant seeds and plants manually or using specialised machinery.
JOB_WORKER_04	They must take care of the crops manually or with the support of machines, e.g., applying fertilisers or pesticides, irrigation, thinning, weeding, pruning.
JOB_WORKER_05	They must visually inspect crops to detect the presence of pests or diseases. Also, to inform the farmer about the status of the crop.
JOB_WORKER_06	They must take soil samples for laboratory analysis.

Table 4 Description of jobs for farm workers

Pain ID	Pain description
PAIN_WORKER_01	Demanding labour conditions that require bending, crouching, lifting and transporting crops and tools.
PAIN_WORKER_02	Exposure to hard weather conditions.
PAIN_WORKER_03	Exposure to pesticides and chemical products could be potentially hazardous for health.
PAIN_WORKER_04	Low wages and precarious contractual conditions.
PAIN_WORKER_05	Inappropriate skills and knowledge for interacting or using new digital technologies.
PAIN_WORKER_06	Safety risks and accidents are caused by dangerous machines, robots and equipment.

Pain ID	Pain description
PAIN_WORKER_07	New digital technologies and autonomous systems may replace some human workers.
PAIN_WORKER_08	Soil sampling is tedious work that requires digging and spending time to get the laboratory results.
PAIN_WORKER_09	Work is very seasonal. Harvesting season is short and at that time workers are needed to do it 24/7.

Table 5 Description of pains for farm workers

Gain ID	Gain description
GAIN_WORKER_01	Improve labour conditions by introducing automation in the hardest and more repetitive tasks.
GAIN_WORKER_02	New high-added-value opportunities and jobs for the management, operation and supervision of IT systems, robots and intelligent machines.
GAIN_WORKER_03	Better salaries and contracts.

Table 6 Description of gains for farm workers

4.2.3 Manufacturers of robots and machinery

Job ID	Job to be done
JOB_ROB_MAN_01	Design, produce and commercialise agricultural machinery (including autonomous systems), aerial and ground robots. This includes activities related to mechanics, hardware, electronics, sensors, actuators, communications, embedded software, cloud platforms and applications.
JOB_ROB_MAN_02	They develop software components (mostly to be embedded within the robots) for sensing, perception, cognition, decision-making, planning and actuation. Some of these functionalities are based on Machine Learning and Deep Learning techniques.
JOB_ROB_MAN_03	They integrate third-party supplies and parts, including software libraries, algorithms and models.
JOB_ROB_MAN_04	They must implement hardware and software components to ensure trustworthy, safe and resilient operation.
JOB_ROB_MAN_05	They may analyse the correct behaviour of the systems in production.
JOB_ROB_MAN_06	They provide maintenance, support and repairs.
JOB_ROB_MAN_07	They offer specialised training for distributors, partners and end-users.

Job ID	Job to be done
JOB_ROB_MAN_08	They offer additional or complementary services, e.g., tasks planification, automated guidance, digital worksheets, real-time data monitoring and analytics, mobile applications, fleets management, etc.

Table 7 Description of jobs for manufacturers of robots and machinery

Pain ID	Pain description
PAIN_ROB_MAN_01	Conservative mentality and inappropriate skills of farmers and farm workers.
PAIN_ROB_MAN_02	High costs of robotics technologies and modern machinery.
PAIN_ROB_MAN_03	Uncertainty with respect to the emerging regulation and requirements for AI, robotics and autonomous systems that are being developed by the European Commission.
PAIN_ROB_MAN_04	Lack of standard interfaces to exchange data between different technologies and platforms.
PAIN_ROB_MAN_05	Many farms, especially the smallest, are not digitalized and do not have modern communication networks and IT infrastructures.
PAIN_ROB_MAN_06	Farms are dynamic, complex and unstructured environments where robots and automated machinery must co-exist with human workers, livestock, vehicles, infrastructures, etc.
PAIN_ROB_MAN_07	SMEs and startups may not have the resources (knowledge, infrastructures, data) to cover the complete stack of technologies, especially with respect to AI.
PAIN_ROB_MAN_08	Rapid evolution of technologies requires continuous adaption and improvement of systems.

Table 8 Description of pains for manufacturers of robots and machinery

Gain ID	Gain description
GAIN_ROB_MAN_01	Specific guidelines for the usage of AI technologies in the agriculture domain.
GAIN_ROB_MAN_02	Interoperable data-driven solutions that enforce secure and sovereign sharing of information.
GAIN_ROB_MAN_03	Improved software components for general use-cases of agriculture robotics solutions.
GAIN_ROB_MAN_04	Reduction in the time and effort needed to develop, adapt or integrate AI solutions in robotics products.

Table 9 Description of gains for manufacturers of robots and machinery

4.2.4 Robot operators

Job ID	Job to be done
JOB_ROB_OP_01	In manual mode, they pilot or control aerial and ground robots using remote or onboard control systems.
JOB_ROB_OP_02	In automatic mode, they define the missions (routes and actions) that the robots must execute but manual intervention is required in case there are unforeseen events.
JOB_ROB_OP_03	In autonomous mode, they define the missions (routes and actions) that the robots must execute. They are able to perform them safely, facing unexpected situations thanks to the usage of AI functionalities.
JOB_ROB_OP_04	They must check compliance with respect to existing regulations (e.g., licensing, forbidden zones, insurance, operational procedures).
JOB_ROB_OP_05	They must ascertain that robots' status is appropriate periodically and before starting a mission.
JOB_ROB_OP_06	They must plan robots' missions so that they are executed according to the expected goals and constraints.
JOB_ROB_OP_07	They must supervise and monitor robots' status and missions' execution.
JOB_ROB_OP_08	They must make real-time decisions to modify the original mission plan depending on the current context or events.
JOB_ROB_OP_09	Depending on the type of robot, they have to extract collected data and do needed actions to allow analysing or processing the information.
JOB_ROB_OP_10	If needed, they load treatments or fertilisers in the robots.
JOB_ROB_OP_11	They are responsible for maintenance and troubleshooting actions. They need support from manufacturers.
JOB_ROB_OP_12	They must ensure that weather conditions are suitable for the mission, considering the types of robots involved.
JOB_ROB_OP_13	They calibrate cameras and sensors to obtain results with enough accuracy and quality.

Table 10 Description of jobs for robots' operators

Pain ID	Pain description
PAIN_ROB_OP_01	There are no available open tools for mission planning and control covering aerial and ground robots.

Pain ID	Pain description
PAIN_ROB_OP_02	There are no available open tools for mission planning and control tailored to the specific needs of precision agriculture tasks.
PAIN_ROB_OP_03	There are no available open tools for mission planning and control for robots' fleets.
PAIN_ROB_OP_04	There are no available open tools for mission planning and control that allow orchestrating and coordinating tasks between several heterogeneous robots.
PAIN_ROB_OP_05	Automatic uploading of collected images and data is not completely available and, in many cases, requires using SD cards.
PAIN_ROB_OP_06	Automatic generation of high-resolution orthophotos from collected images is not possible.
PAIN_ROB_OP_07	Generation of missions must be done manually by the robot operator.
PAIN_ROB_OP_08	Complex integration with other digital systems (e.g., FMS, AI services) developed by third parties.

Table 11 Description of pains for robots' operators

Gain ID	Gain description
GAIN_ROB_OP_01	Possibility to supervise multiple heterogenous robots working together through a single graphical user interface.
GAIN_ROB_OP_02	Reduction of the level of attention required to supervise every single robot.
GAIN_ROB_OP_03	Seamless and automatic analysis of collected information.
GAIN_ROB_OP_04	Intelligent support to create missions considering historic information and context data from the crop.
GAIN_ROB_OP_05	Automatic recording of information from missions' execution.
GAIN_ROB_OP_06	Automatic detection of potential problems and failures.
GAIN_ROB_OP_07	Functionalities to define workflows involving several robots and reacting to events, conditions and sensors' values.
GAIN_ROB_OP_08	Seamless adaption to farmers needs and farms' conditions. interfacing with farms systems and possible interoperation with farmers devices and implementations.

Table 12 Description of gains for robots' operators

4.2.5 AI developers

Job ID	Job to be done
JOB_AI_01	They pre-process and clean datasets. Also, the labelling must be done for subsequently supervised training.
JOB_AI_02	They analyse datasets with statistical techniques, trying to extract the most relevant features for the type of functionality to be developed.
JOB_AI_03	They train Machine Learning (and Deep Learning) models for multiple applications and services, e.g., computer vision tasks, anomaly detection, classification, prediction.
JOB_AI_04	They explore different types of features, algorithms, architectures and hyperparameters to obtain the best results.
JOB_AI_05	They optimised, packaged and publish the resulting models.
JOB_AI_06	They improve the models considering the results obtained upon deployment.
JOB_AI_07	They adapt already existing models through the usage of Transfer Learning.
JOB_AI_08	They implement mechanisms to comply with guidelines and regulations with respect to the usage of AI technologies.

Table 13 Description of jobs for AI developers

Pain ID	Pain description
PAIN_AI_01	They may not have access to datasets with enough volume, quality and variety. This may happen also in particular agriculture use-cases that are not so common and therefore open datasets are not available.
PAIN_AI_02	AI experimentation required handling complex digital infrastructures spanning from hardware resources to diverse software libraries and frameworks.
PAIN_AI_03	FMS and AI platforms are not interoperable.
PAIN_AI_04	The execution of the tasks involved in a complete AI workflow requires many iterations, consuming time and resources.
PAIN_AI_05	Machine Learning and Deep Learning models addressing specific needs of agriculture use-cases cannot be found in open marketplace and repositories.
PAIN_AI_06	Creating Machine Learning models for robotics systems supposes to consider multiple hardware processor architectures and accelerators.

Pain ID	Pain description
PAIN_AI_07	Uncertainty with respect to the emerging regulation and requirements for AI, robotics and autonomous systems that are being developed by the European Commission.

Table 14 Description of pains for AI developers

Gain ID	Gain description
GAIN_AI_01	Seamless data ingestion from FMS, machinery, sensors and digital technologies for precision agriculture.
GAIN_AI_02	Intelligent automation of MLOps.
GAIN_AI_03	Abstraction of the underlying infrastructure and frameworks needed to execute MLOps.
GAIN_AI_04	Existence of common, general and open models that can be easily reused across multiple scenarios and use-cases.
GAIN_AI_05	Existence of services to facilitate the application of Transfer Learning techniques.
GAIN_AI_06	Automatic optimisation of ML models for multiple hardware architectures.
GAIN_AI_07	Possibility to offer ML models following “as a service” paradigm to open new revenue streams.

Table 15 Description of gains for AI developers

4.2.6 Farm Management Systems (FMS) developers

Job ID	Job to be done
JOB_FMS_01	Development, maintenance and commercialisation of digital solutions to collect, process, store and visualise information needed to carry out farm operations.
JOB_FMS_02	They integrate or connect to third-party supplies and parts, including: • IoT sensors and smart objects. • Robotics systems. • Actuators. • Agriculture machinery. • Geospatial information. • Software libraries, algorithms and models.
JOB_FMS_03	They may analyse the correct behaviour of the systems in production.
JOB_FMS_04	They provide maintenance and support.

Job ID	Job to be done
JOB_FMS_05	They offer specialised training for distributors, partners and end-users.

Table 16 Description of jobs for Farm Management Systems (FMS) developers

Pain ID	Pain description
PAIN_FMS_01	Interoperability issues due to proprietary solutions and APIs, lack of standards, privacy concerns, etc.
PAIN_FMS_02	Conservative mentality and inappropriate skills of farmers and farm workers.
PAIN_FMS_03	Many farms, especially the smallest, are not digitalized and do not have modern communication networks and IT infrastructures.
PAIN_FMS_04	SMEs and startups may not have the resources (knowledge, infrastructures, data) to cover the complete stack of technologies, especially with respect to AI.
PAIN_FMS_05	Rapid evolution of technologies requires continuous adaption and improvement of systems.
PAIN_FMS_06	Diversity of use-cases, requirements and farmers' characteristics.

Table 17 Description of pains for Farm Management Systems (FMS) developers

Gain ID	Gain description
GAIN_FMS_01	Creation of a common data space that enables the secure and sovereign exchange of data between multiple interoperable data platforms and technologies, including AI and robotics.
GAIN_FMS_2	Availability of off-the-shelf AI or "AI as a Service" platform that allows easily producing new models with data managed by FMS. It should include the possibility to directly call AI models and services through standard APIs or to download them in a standard format.
GAIN_FMS_3	Seamless interconnection between the FMS and solutions to plan robots' missions to that this can be included as additional functionality.

Table 18 Description of gains for Farm Management Systems (FMS) developers

4.2.7 Agri-food industry

Job ID	Job to be done
JOB_IND_01	It includes actors like input providers, farm associations, logistics companies, primary and secondary processing, packaging, logistics, supermarkets and foods/beverage companies.

Table 19 Description of jobs for the agri-food industry

Pain ID	Pain description
PAIN_IND_01	Low visibility about the farming processes, conditions and status. This may affect the quality, price or availability of products.

Table 20 Description of pains for the agri-food industry

Gain ID	Gain description
GAIN_IND_01	Creation of a common data space that enables the secure and sovereign exchange of data between multiple interoperable data platforms and technologies, including AI and robotics.

Table 21 Description of gains for the agri-food industry

4.2.8 Consumers

Job ID	Job to be done
JOB_CONSUMERS_01	Consumers are the last stage of the food chain. Their requirements and preferences have a strong influence on all the previous processes and stakeholders. For instance, from some years ago, market segments willing to pay for sustainable or organic products are growing. Also, consumers want to understand the composition and traceability of the products they buy.

Table 22 Description of jobs for consumers

Pain ID	Pain description
PAIN_CONSUMERS_01	Low visibility about the farming processes and conditions due to the steps and intermediaries that participate in farm to fork journeys.

Table 23 Description of pains for consumers

Gain ID	Gain description
GAIN_CONSUMERS_01	Increase the knowledge about the product so that they can opt for more efficient crops and possibly reduce waste.

Table 24 Description of gains for consumers

4.3 Functional requirements

ID	As a «type of user»	I want «some goal»	so that «some reason»	Pilot(s)
US_01	Farmers	Automatically detect pests and/or diseases from UAVs and/or UGVs images	Costs associated with the human inspection are reduced and	1, 2, 3

ID	As a «type of user»	I want «some goal»	so that «some reason»	Pilot(s)
			appropriate treatments can be applied early	
US_02	Farmers	Visualise occurrences and intensity of pests and/or diseases in an interactive map	Facilitate analysis and decision-making	1,2
US_03	Farmers	Automatically apply pesticides using UAVs and/or UGVs with high accuracy	Costs associated with the human application are reduced and environmental impact is minimised	1, 2
US_04	Farmers / Farm workers	UGVs carry out detailed explorations of risk areas	Farm workers do not have to perform a visual inspection	1
US_05	Farmers	Have an estimation of my crops production	I can have better preparation for the harvest and the next processes	1
US_06	Farm workers	UGVs follow safely farm workers	Products can be deposited, and the efficiency of the process is maximised	1
US_07	Farmers / Farm workers	UGVs automatically transport products to the winery, warehouse or to the nearest tractor	Workers will be more comfortable and faster The efficiency of the harvesting process is maximised	1
US_08	Farmers	UGVs control the weight of the products that are transporting	Yield information for each area can be automatically obtained	1
US_09	Farmers	Obtain maps with digestibility values from satellite imagery	Perform digestibility analysis	2
US_10	Farmers	Obtain ranking of fields according to relevant indexes using satellite images and information from robots	Plan harvesting operations	2

ID	As a «type of user»	I want «some goal»	so that «some reason»	Pilot(s)
US_11	Farmers	To define tasks in the FMS that can be translated to goals and constraints for the MCC	Robotics missions are aligned with farms operations	1, 2
US_12	Robot operators	Plan UAVs and/or UGVs missions considering field maps and the type of mission	The mission file can be uploaded to the UAVs and/or UGVs	2
US_13	Robot operators	Create missions' plans that include control of cameras and/or sprayers	UAVs and/or UGVs require a low level of supervision by the operator	1, 2
US_14	Robot operators	Execute and monitor missions without intervention	Reduce the complexity and skills needed to operate robotics missions Allow controlling several missions simultaneously	2
US_15	Robot operators	Receive alerts about incidents and unexpected events during the mission execution	Ensure that the mission is executed safely and successfully	1, 2, 3
US_16	Robot operators	Manually control robots in case of exceptional situations	Ensure that the mission is executed safely and successfully	1, 2, 3
US_17	Robot operators	Images and data collected by the robots are automatically transferred to the FMS and FlexiGroBots platform	Automatise the process and reduce the time/effort needed for data transference Reduce the complexity and skills needed to operate robotics missions	1, 2
US_18	Robot operators	Updated dynamically missions	Robots may need to adjust their routes according to real-time data or to the positions and actions of other robots.	2

ID	As a «type of user»	I want «some goal»	so that «some reason»	Pilot(s)
US_19	Farmers / robot operators	UGV are able to autonomously locate weeds or areas infected by pests or diseases in the surroundings of the area covered by the mission plan	Appropriate treatment or action can be executed efficiently without manual intervention	1, 2
US_20	Farmers/farm workers	UGVs are able to perform weeding and to do the transportation	Increase the efficiency of weeding tasks	2
US_21	Farmers / farm workers / robot operators	UGVs are able to detect obstacles and people using onboard cameras and sensors	Safety requirements are satisfied	1, 2, 3
US_22	Farmers/robot operators	Supervise and coordinate several missions simultaneously	Increase the efficiency of robotics operations	2
US_23	Farmers/robot operators	Detect in real-time hazards and possible collisions	Ensure that the mission is executed safely and successfully	1, 2, 3
US_24	Farmers / robot operators	Implement appropriate actions in case of hazards, e.g., to stop all robots.	Ensure that the mission is executed safely and successfully	1, 2, 3
US_25	Robot operators	Visualise in a map classified anomalies	Mission situation can be easily understood and evaluated	1, 2, 3
US_26	Farmers	Control the usage of the data collected by intelligent machinery and robots by digital companies	Preserve private or confidential information and avoid data exploitation or commercialisation without consent	1, 2, 3
US_27	Farmers	Publish and commercialise data so that it can be consumed by third parties, receiving some incentives.	Find alternative business models thanks to high-quality data	1, 2, 3
US_28	Farmers	Have the freedom to select digital services providers while keeping historic data (data portability)	Avoid situations of unfair negotiation with big digital companies	1, 2, 3

ID	As a «type of user»	I want «some goal»	so that «some reason»	Pilot(s)
US_29	Robots manufacturers / FMS developers / AI developers	Develop systems that are interoperable by design without spending high effort to develop custom interfaces.	Open new business opportunities through the creation of digital agriculture systems composed of heterogeneous components.	1, 2, 3

Table 25 FlexiGroBots functional requirements in the form of user stories

4.4 Non-functional requirements

ID	Description	Source
NFR.01	FlexiGroBots components must expose well documented and standard REST interfaces	State of the art / best practices
NFR.02	FlexiGroBots components must implement IDSA connector	Data Spaces reference architectures
NFR.03	FlexiGroBots components must be designed for high availability scenarios, relying on Docker container and Kubernetes manifest for the deployment.	State of the art / best practices
NFR.04	FlexiGroBots components must support deployment on main cloud platforms and on-premises infrastructures	State of the art / best practices
NFR.05	FlexiGroBots common applications services must be deployable on robotics systems and edge computing devices.	State of the art / best practices
NFR.06	FlexiGroBots platform must adopt secure by design principles, integrating authentication, authorization and access control.	State of the art / best practices
NFR.07	FlexiGroBots platform must support multi-tenant scenarios.	State of the art / best practices
NFR.08	FlexiGroBots platform must consider hardware infrastructures including GPUs and HPC resources.	State of the art / best practices
NFR.09	FlexiGroBots data space must support structured and non-structured data formats. Data space components are data agnostic, except regarding metadata.	State of the art / best practices

ID	Description	Source
NFR.10	FlexiGroBots data space must support the exchange of big data between involved systems.	Domain expertise
NFR.11	FlexiGroBots AI platform must support the development of AI models in TensorFlow, PyTorch and Scikit-learn.	Domain expertise
NFR.12	FlexiGroBots AI platform must package and optimise ML models for heterogeneous architectures such as x86 and ARM	Domain expertise
NFR.13	FlexiGroBots AI platform should maintain essential information about the models and datasets for informative purposes, including accuracy metrics and training descriptions.	Ethical, legal, trust (T2.4)
NFR.14	FlexiGroBots Data Space must be able to work with streaming data.	Domain expertise
NFR.15	FlexiGroBots MCC must provide an easy-to-use graphical user interface	Domain expertise
NFR.16	FlexiGroBots MCC must be extensible to support easily new robots and RFMS.	Domain expertise
NFR.17	FlexiGroBots MCC must be compatible with ROS operating system.	State of the art / best practices
NFR.18	FlexiGroBots platform must be applicable to a wide range of use-cases and types of crops beyond the project's pilots. This applies specifically to common application services.	Domain expertise
NFR.19	FlexiGroBots platform should be compliant with the terms of the GDRPS.	Ethical, legal, trust (T2.4)
NFR.20	FlexiGroBots platform, especially the MCC, should be compliant with applicable legal frameworks regarding autonomous vehicles	Ethical, legal, trust (T2.4)
NFR.21	FlexiGroBots platform should guarantee the safety of human workers by performing a risk assessment. For instance, a stop-button should be implemented in the MCC.	Ethical, legal, trust (T2.4)
NFR.22	FlexiGroBots platform should establish a mechanism for users to flag issues related to technical problems, data protection, biases, etc.	Ethical, legal, trust (T2.4)
NFR.23	FlexiGroBots platform should incorporate advanced logging capabilities. Logs should be stored and preserved for later analysis.	Ethical, legal, trust (T2.4)

ID	Description	Source
NFR.24	FlexiGroBots platform should log robots' activities for traceability and auditability in case of incidents or external audits.	Ethical, legal, trust (T2.4)
NFR.25	Common application services should be developed to avoid potential biases and discrimination. For instance, services based on computer vision should work independently of the colour of the worker's skin.	Ethical, legal, trust (T2.4)
NFR.26	FlexiGroBots platform should incorporate mechanisms to track the energy consumption and equivalent CO2 footprint.	Ethical, legal, trust (T2.4)
NFR.27	Training materials should be implemented. Also, documentation for components destinated to end-users.	Ethical, legal, trust (T2.4)

Table 26 FlexiGroBots non-functional requirements

5 FlexiGroBots Reference Architecture

5.1 Overview

The progressive adoption of emerging technologies during the last decades is pushing the progressive digitalization of agricultural tasks. Currently, it is quite common that farmers have access to high-quality and detailed information from their crops thanks to the installation of IoT devices and sensors or through satellite images and observations. As part of this transition. the role of Farm Management Systems (FMS) or Farm Management Information Systems (FIMS) has become absolutely essential in order to shorten the gap between end-users (mainly farmers or farm owners) and the complexity of these technologies. Also, to support the exploitation of available information for more intelligent management of the farm and to make informed decisions. Following this trend, multiple areal and ground robots are starting to be commercialized and integrated into different agricultural tasks, relieving the hard labour conditions of human workers and increasing the competitiveness of the farms. This is also the case of traditional agricultural machinery that is being digitalized, strongly augmenting their capabilities. A very relevant example is the case of autonomous robots.

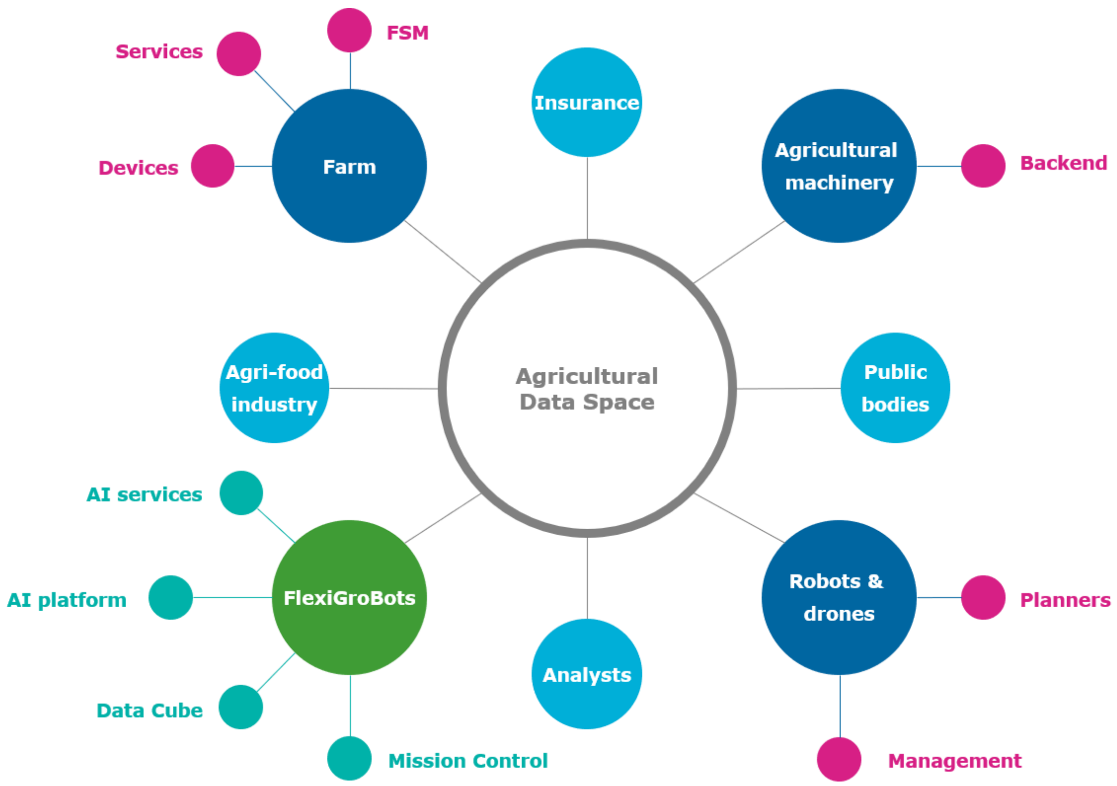


Figure 23 FlexiGroBots vision

Nevertheless, as Figure 23 shows, the current landscape of Agriculture 4.0 is not dominated by a single company or by a small group of them. Although some big providers have a very relevant part of some markets' sizes, especially in the case of heavy machinery, it is quite common that farmers must rely on multiple systems provided by different entities. Currently, in most cases, all these systems are completely isolated between them and possible integration is required to reach bilateral agreements and the implementation of ad-hoc connectors, which strongly limits the complete potential of the resulting systems and at the same time, hinders some of the benefits that farmers could have.

FlexiGroBots envisions the creation of an embryonic data space focused on the enablement of missions of fleets of heterogeneous robots for precision agricultural tasks, where any technology provider that implements an IDSA compliant connector could participate and where farmers will have full control of the data collected from their fields.

5.2 Description of the use cases for FlexiGroBots platform

5.2.1 AI platform

5.2.1.1 Data management

Name of use-case

Use case identification		
ID	Area / Domain (s) / Zone (s)	Name of use case
AI_UC1	Artificial Intelligence / Machine Learning / Machine Learning Operations (MLOps)	Data management

Scope and objectives of use case

Scope and objectives of use case	
Scope	Management of structured and unstructured datasets collected from diverse data sources.
Objective (s)	Knowledge extraction through the application of analytics or to train ML models that will be used to develop precision agriculture services, complying with trustworthy requirements.

Narrative of the use case

Narrative of use case
Short description

Datasets are loaded and managed through the platform functionalities using Command Line Interfaces (CLIs), Application Programming Interfaces (APIs) or Graphical User Interfaces (GUIs).
Complete description
Machine Learning engineers, data scientists or robots' operators have the possibility to perform CRUD operations (Create, Read, Update and Delete) for datasets, which are stored in the FlexiGroBots AI platform to enable subsequent MLOps workflows. Digital systems (e.g., FMSs, Robot Fleets Management Systems) autonomously upload information by means of IDSA connectors according to the policies defined by data owners (e.g., farmers, robots' manufacturers).

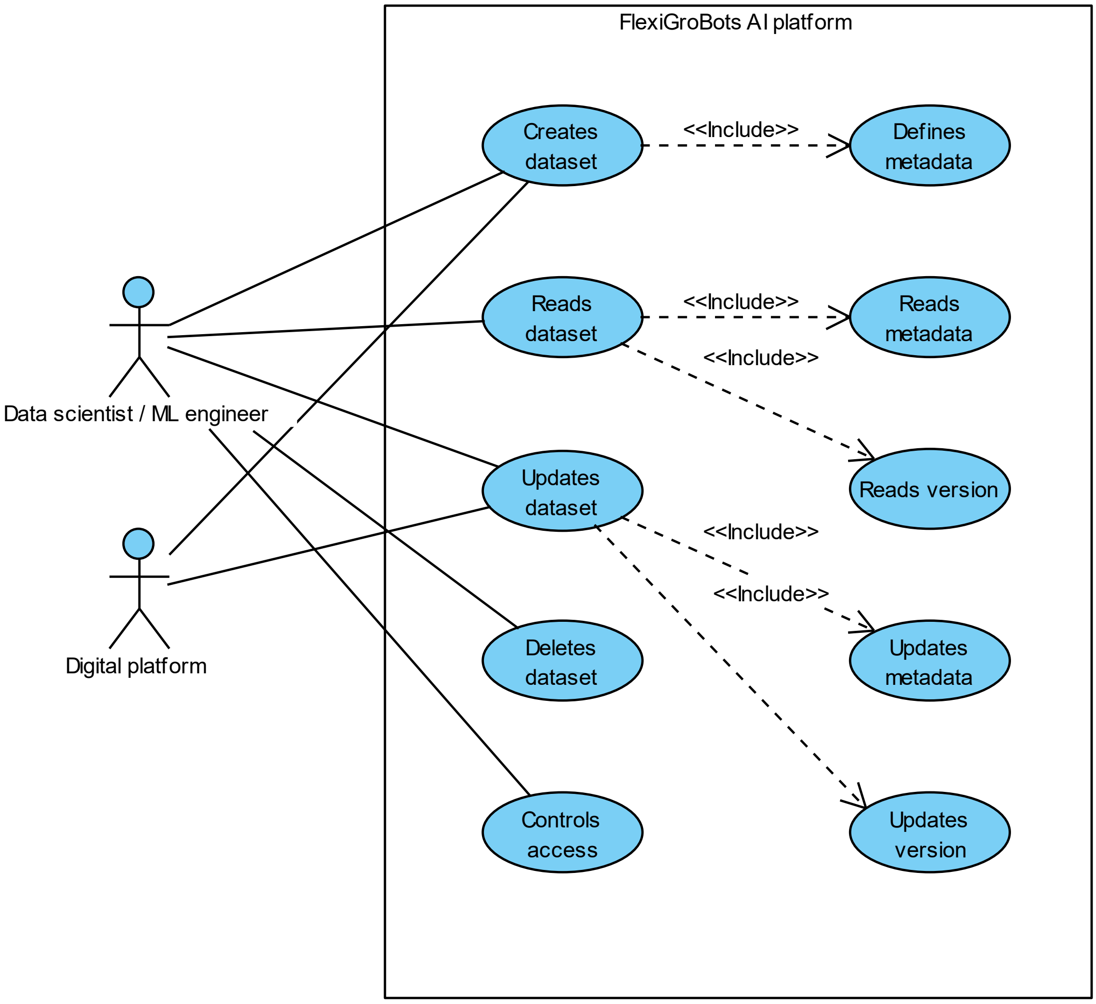
Use case conditions

Use case conditions
Assumptions
An account is created in the AI platform for the ML engineer or data scientist.
Prerequisites
Digital platforms have implemented an IDSA connector and belong to the FlexiGroBots Data Space.

Further information to the use case for classification / mapping

Classification information
Relation to other use cases
Data management is required for the rest of the use-cases proposed for the AI platform
Data uploading will follow the use-cases for common data services specified in 5.2.2.
Level of depth
Detailed Use Case
Prioritisation
Mandatory
Generic, regional or national relation
Generic
Nature of the use case
Technical

Diagrams of use case

Diagram(s) of use case


Actors

Actors			
Grouping		Group description	
N/A		N/A	
Actor name	Actor type	Actor description	Further information specific to this use case
Data scientist / ML engineer	Human	Person in charge of the development of ML models	N/A

Digital platform	Software	System that produces data to be potentially used to train ML models, e.g., FMS, Robot Fleets Management System.	N/A

Overview of scenarios

Scenario conditions						
No.	Scenario name	Scenario description	Primary actor	Triggering event	Pre-condition	Post-condition
1	Creates dataset	Structured or unstructured data is uploaded to the AI platform	Data scientist / ML engineer, Digital platform	Data is available	None	A dataset is created in the AI platform
2	Reads dataset	The dataset is read or used	Data scientist / ML engineer	N/A	A dataset is created	Dataset information is obtained
3	Updates dataset	Information for a dataset is updated	Data scientist / ML engineer, Digital platform	New data is available	A dataset is created	Dataset information is updated
4	Deletes dataset	A dataset is removed from the AI platform	Data scientist / ML engineer	N/A	A dataset is created	Dataset is not available anymore
5	Controls access	Access or visibility of other users of the platform to the dataset is managed	Data scientist / ML engineer	N/A	A dataset is created	Dataset access rights are updated

Steps – Scenarios

Scenario							
Scenario name:	No. 1 - Creates dataset						
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)
01	Dataset available to be uploaded	Defines metadata	Name, description and other metadata is defined,	POST	Data scientist / ML engineer,	AI platform	Dataset metadata

					Digital platform		
02	Step 01 completed	Uploads dataset	Data is uploaded to the AI platform	POST	Data scientist / ML engineer, Digital platform	AI platform	Dataset information
03	Step 02 completed (or data is streamed)	Stores dataset	AI platform stores dataset	EXECUTE	AI platform	Data scientist / ML engineer, Digital platform	Dataset identifier

Scenario							
Scenario name:	No. 2 - Reads dataset						
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)
01	User needs to check datasets	Lists datasets	Available datasets are listed	GET	AI platform	Data scientist / ML engineer	List of datasets with metadata
02	Step 01 completed	Reads dataset	Metadata for a specific dataset is obtained	GET	AI platform	Data scientist / ML engineer	Dataset ID, Dataset metadata and version
03	User wants to have further details about a dataset	Downloads metadata	A specific dataset is downloaded	GET	AI platform	Data scientist / ML engineer	Dataset ID, Dataset

Scenario							
Scenario name:	No. 3 - Updates dataset						
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)
01	Dataset metadata has changed	Updates metadata	Metadata for a specific dataset is updated	POST	Data scientist / ML engineer	AI platform	Dataset ID, Dataset metadata
02	More information is added to the dataset	Updates version	Dataset version is controlled	POST	Data scientist / ML engineer	AI platform	Dataset ID, Dataset version
03	Steps 01 and/or 02 are completed	Adds information	New information is added to the dataset	POST	Data scientist / ML engineer, Digital platform	AI platform	Dataset ID, New information

Scenario							
Scenario name:	No. 4 - Deletes dataset						
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)
01	User wants to remove a dataset	Deletes dataset	Deletes dataset	DELETE	Data scientist / ML engineer	AI platform	Dataset ID, Dataset is removed

Scenario	
Scenario name:	No. 5 – Controls access

Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)
01	User wants to check or modify access rights to a dataset	Lists users	List users	GET	AI platform	Data scientist / ML engineer	Users' list
02	Access rights of a dataset must be changed	Changes permissions	Changes permissions	POST	Data scientist / ML engineer	AI platform	Dataset ID, new permissions

5.2.1.2 Experiments management

Name of use-case

Use case identification		
ID	Area / Domain (s) / Zone (s)	Name of use case
AI_UC2	Artificial Intelligence / Machine Learning / Machine Learning Operations (MLOps)	Experiments management

Scope and objectives of use case

Scope and objectives of use case	
Scope	Management of AI experiments to support precision agriculture services.
Objective (s)	Experiments are used to define the steps needed as part of the workflows to create Machine Learning models. They cover the selection of the model, the configuration of the neural network architecture and potentially the usage of AutoML.

Narrative of the use case

Narrative of use case
Short description

AI Experiments are loaded and managed through the platform functionalities using Command Line Interfaces (CLIs), Application Programming Interfaces (APIs) or Graphical User Interfaces (GUIs). The experiments include scripts created by Machine Learning engineers or Data Scientists applying libraries like TensorFlow, PyTorch or Scikit-learn.
Complete description
Machine Learning engineers, data scientists or robots' operators have the possibility to perform CRUD operations (Create, Read, Update and Delete) for experiments, which are stored in the FlexiGroBots AI platform to enable subsequent MLOps workflows. The experiments cover the definition of the complete workflows and the corresponding ML models. They have associated metadata and version information so that it is possible to update them over time. The experiments include the possibility to apply two advanced learning techniques: • AutoML to automate the execution of the different steps involved in the MLOps workflows. • Transfer Learning to allow building new ML models by reusing and retraining previously existing ones.

Use case conditions

Use case conditions
Assumptions
An account is created in the AI platform for the ML engineer or data scientist.
Prerequisites

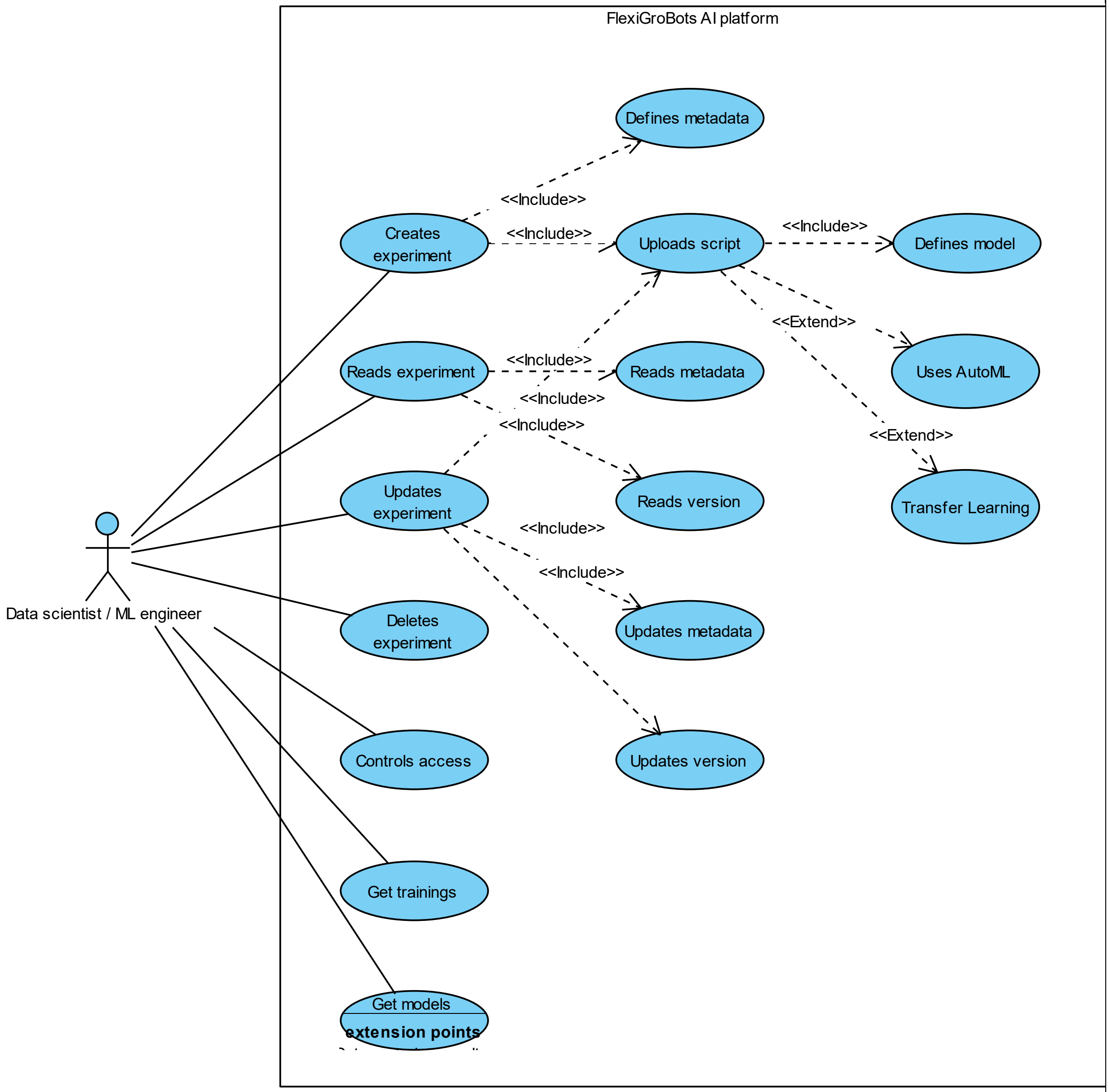
Further information to the use case for classification / mapping

Classification information
Relation to other use cases
Experiments management is required for training models on the AI platform.
Level of depth
Detailed Use Case
Prioritisation
Mandatory
Generic, regional or national relation
Generic
Nature of the use case

Technical

Diagrams of use case

Diagram(s) of use case



Actors

Actors			
Grouping		Group description	
N/A		N/A	
Actor name	Actor type	Actor description	Further information specific to

			this use case
Data scientist / ML engineer	Human	Person in charge of the development of ML model. He/she manages the experiments.	N/A

Overview of scenarios

Scenario conditions						
No.	Scenario name	Scenario description	Primary actor	Triggering event	Pre-condition	Post-condition
1	Creates experiment	A new experiment is uploaded to the AI platform.	Data scientist	N/A	None	A new experiment is created
2	Reads experiment	The experiment is read or used.	Data scientist / ML engineer	N/A	An experiment is created	Experiment information is obtained
3	Updates experiment	Information for an experiment is updated.	Data scientist / ML engineer	A better model is defined.	An experiment is created	Experiment information is updated
4	Deletes experiment	An experiment is removed from the AI platform.	Data scientist / ML engineer	N/A	An experiment is created	Experiment is not available anymore
5	Controls access	Access or visibility of other users of the platform to the experiment is managed.	Data scientist / ML engineer	N/A	An experiment is created	Experiment access rights are updated.
6	Get trainings	Information is queried about the training run for the experiment.	Data scientist / ML engineer	N/A	An experiment is created	Information of the trainings is obtained.
7	Get models	Information is queried about the models produced by the experiment.	Data scientist / ML engineer	N/A	An experiment is created	Information on the models is obtained.

Steps – Scenarios

Scenario

Scenario name:	No. 1 - Creates experiment						
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)
01	User has defined an ML experiment	Metadata definition	Name, description and other metadata are defined.	POST	Data scientist	AI platform	Experiment metadata
02	Step 01 completed	ML workflow creation	Creates an ML workflow, including required steps and model description. It can be done offline or using the platform services.	POST	Data scientist	AI platform	Experiment described
03	User has defined an ML experiment using AutoML libraries	Uses AutoML	AutoML libraries are applied to introduce automation.		Data scientist	AI platform	Experiment described including AutoML functionalities
04	User has defined an ML experiment re-using an existing model	Uses Transfer Learning	The workflow is based on a previous model already existing.		Data scientist	AI platform	Experiment described including Transfer Learning

05	Steps 02 completed	Uploads experiment	If the experiment is defined offline, it is uploaded to the platform.	POST	Data scientist	AI platform	Experiment uploaded
06	Step 05 completed	Stores experiment	AI platform stores experiment	EXECUTE	AI platform	Data scientist	Experiment identifier

Scenario							
Scenario name:	No. 2 - Reads experiment						
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)
01	User wants to check the information of available experiments	Lists experiments	Available experiments are listed	GET	AI platform	Data scientist	List of experiments with metadata
02	User wants to check information for an experiment	Reads experiment	Metadata for a specific experiment is obtained	GET	AI platform	Data scientist	Experiment ID, Experiment metadata and version
03	User wants to check further information for an experiment	Downloads metadata	A specific experiment is downloaded	GET	AI platform	Data scientist	Experiment ID, Experiment

Scenario							
Scenario name:	No. 3 - Updates experiment						
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)
01	Metadata for an experiment has changed	Updates metadata	Metadata for a specific experiment is updated	POST	Data scientist	AI platform	Experiment ID, Experiment metadata
02	User has done a new version of the experiment	Updates version	Experiment version is controlled	POST	Data scientist	AI platform	Experiment ID, Experiment version
03	Steps 01 and 02 completed	Adds information	New information is added to the experiment	POST	Data scientist	AI platform	Experiment ID, New information

Scenario							
Scenario name:	No. 4 - Deletes experiment						
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)
01	An experiment must be deleted	Deletes experiment	Deletes experiment	DELETE	Data scientist	AI platform	Experiment ID, Experiment is removed

Scenario							
Scenario name:	No. 5 – Controls access						
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)
01	User wants to modify access rights to a certain experiment	Lists users	List users	GET	AI platform	Data scientist / ML engineer	Users' list
02	User wants to modify access rights to a certain experiment	Changes permissions	Changes permissions	POST	Data scientist	AI platform	Experiment ID, new permissions

Scenario							
Scenario name:	No. 6 – Get trainings						
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)
01	User wants to check available trainings	Lists experiments	Available experiments are listed	GET	AI platform	Data scientist	List of experiments with metadata
02	User wants to check informatio	Reads experiment	Metadata for a specific	GET	AI platform	Data scientist	Experiment ID, Experiment

	n for a certain experiment		experiment is obtained				metadata and version
03	User wants to check the trainings for a specific experiment	Get trainings	Retrieves the list of training for an experiment	GET	AI platform	Data scientist	List of trainings with metadata
04	User wants to check the information for a specific training	Get training	Retrieves a specific training	GET	AI platform	Data scientist	Training ID, Training metadata and results

Scenario							
Scenario name:	No. 7 – Get models						
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)
01	User wants to get the list of available models	Lists experiments	Available experiments are listed	GET	AI platform	Data scientist	List of experiments with metadata
02	User wants to get information for an experiment	Reads experiment	Metadata for a specific experiment is obtained	GET	AI platform	Data scientist	Experiment ID, Experiment metadata and version

03	User wants to get the list of available models for an experiment	Get models	Retrieves the list of models produced by an experiment	GET	AI platform	Data scientist	List of models with metadata
04	User wants to get a specific model	Get model	Retrieves a specific model	GET	AI platform	Data scientist	Model ID, Model metadata and results

5.2.1.3 Trainings management

Name of use-case

Use case identification		
ID	Area / Domain (s) / Zone (s)	Name of use case
AI_UC2	Artificial Intelligence / Machine Learning / Machine Learning Operations (MLOps)	Trainings management

Scope and objectives of use case

Scope and objectives of use case	
Scope	Management of trainings that will produce ML models by applying experiments to datasets
Objective (s)	Data Scientists or Machine Learning engineers will be able to execute MLOps workflows including the training phase in order to produce models. The datasets and experiments available in the platform will be referenced to trigger this use case.

Narrative of the use case

Narrative of use case
Short description
Trainings and MLOps workflows are launched and managed through the platform functionalities using Command Line Interfaces (CLIs), Application Programming Interfaces (APIs) or Graphical User Interfaces (GUIs).
Complete description

Machine Learning engineers or data scientists have the possibility to perform CRUD operations (Create, Read, Update and Delete) for training and MLOps workflows, which are stored in the FlexiGroBots AI platform.

Use case conditions

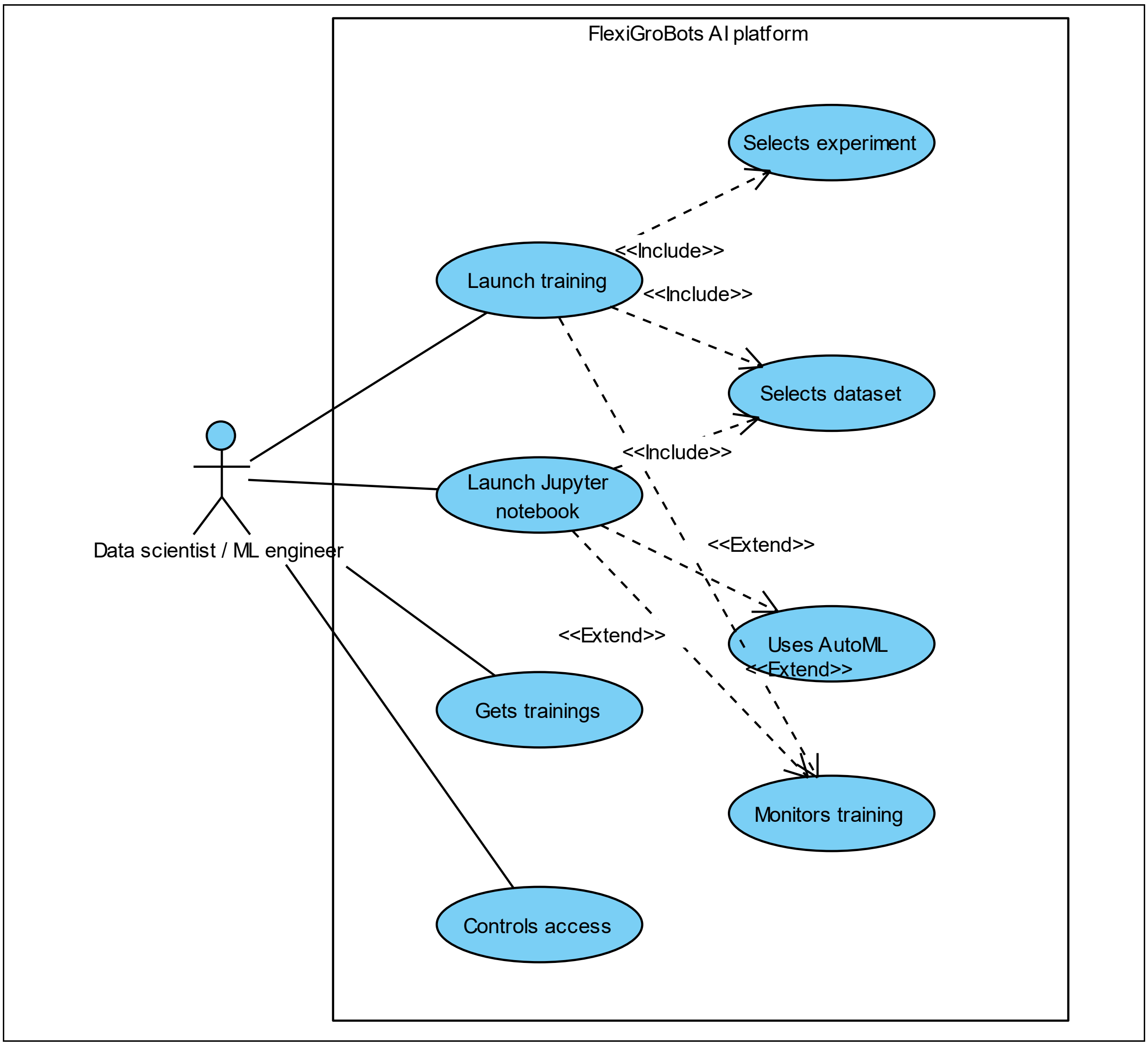
Use case conditions
Assumptions
An account is created in the AI platform for the ML engineer or data scientist.
The AI platform has access to hardware resources suitable for running ML training workloads.
Prerequisites
Datasets and experiments are available in the AI platform.

Further information to the use case for classification / mapping

Classification information
Relation to other use cases
Trainings management is required for producing the models which are managed in AI_UC3.
Level of depth
Detailed Use Case
Prioritisation
Mandatory
Generic, regional or national relation
Generic
Nature of the use case
Technical

Diagrams of use case

Diagram(s) of use case



Actors

Actors			
Grouping		Group description	
N/A		N/A	
Actor name	Actor type	Actor description	Further information specific to this use case
Data scientist / ML engineer	Human	Person in charge of the development of ML models	N/A

Overview of scenarios

Scenario conditions						
No.	Scenario name	Scenario description	Primary actor	Triggering event	Pre-condition	Post-condition
1	Launch training	A training process is launched in the AI platform.	Data scientist	N/A	Dataset is created Experiment is created	A new training is launched
2	Launch Jupyter notebook	A new session on Jupyter notebooks is opened for interactive experimentation which includes training a model.	Data scientist	N/A	None	A new Jupyter notebook session is launched
3	Gets trainings	Retrieves information about the trainings available on the platform.	Data scientist	N/A	A training is created	Trainings' information is retrieved
4	Controls access	Access or visibility of other users of the platform to the training is managed	Data scientist	N/A	A training is created	Training access rights are updated

Steps – Scenarios

Scenario							
Scenario name:	No. 1 – Launch training						
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)
01	User wants to launch a training process over a specific dataset	Dataset selection	The data scientist selects on which dataset the model will be trained.	POST	Data scientist	AI platform	Dataset ID

02	User wants to launch a training process over a specific experiment	Experiment selection	The data scientist selects which experiment will be used to train the model.	POST	Data scientist	AI platform	Experiment ID
03	User wants to define hardware resources used for the training	Resources selection	Considering available hardware and quotas, resources are allocated to run the training.	POST	Data scientist	AI platform	Hardware resources data
04	Steps 01, 02 and 03 completed	Training launch	The training process is executed.	POST	Data scientist	AI platform	Training process ID
05	Users want to get detailed information about the training process	Training monitoring	The platform obtains logs and metrics during the training process.	EXECUTE	AI platform	AI platform	Training metrics and parameters
06	The training process has finished	Gets monitoring information	Monitoring metrics are queried.	GET	AI platform	Data scientist	Training metrics and parameters

Scenario

Scenario name:	No. 2 – Launch Jupyter notebook						
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)
01	The user wants to create the training interactively	Launch Jupyter notebook	A new notebook is created on the platform.	Jupyter Hub	Data scientist	AI platform	
02	Step 01 completed	Interactive development	The data scientist uses Jupyter notebooks to interactively create an ML model.	Jupyter Hub	Data scientist	AI platform	
03	User executes fairing instructions using the AI platform library	Fairing	The training process is delegated to the AI platform HW from the notebook.	POST	Data scientist	AI platform	
04	User executes AutoML instructions using the AI platform library	AutoML	AutoML libraries are used to automatically explore several architectures and configurations.	Library	Data scientist	AI platform	
05	Users want to get detailed informatio	Training monitoring	The platform obtains logs and metrics during the	EXECUTE	AI platform	AI platform	Training metrics and

	n about the training process		training process.				parameters
06	The training process has finished	Gets monitoring information	Monitoring metrics are queried.	GET	AI platform	Data scientist	Training metrics and parameters

Scenario							
Scenario name:	No. 3 – Get trainings						
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)
01	User wants to get information about trainings one by the platform	Lists trainings	Available trainings are listed	GET	AI platform	Data scientist	List of trainings with metadata
02	User wants to get information about a specific training	Reads training	Metadata for specific training is obtained	GET	AI platform	Data scientist	Training ID, Training metadata.
03	User wants to get the model	Downloads model	The model produced by the training is downloaded.	GET	AI platform	Data scientist	Model
04	Users want to get monitoring metrics	Gets monitoring information	Monitoring metrics are queried.	GET	AI platform	Data scientist	Training metrics and

	associated with the training						parameters

Scenario							
Scenario name:	No. 4 – Controls access						
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)
01	User wants to change access rights to a training	Lists users	List users	GET	AI platform	Data scientist / ML engineer	Users' list
02	User wants to change access rights to a training	Changes permissions	Changes permissions for a certain training	POST	Data scientist	AI platform	Training ID, new permissions

5.2.1.4 Models management

Name of use-case

Use case identification		
ID	Area / Domain (s) / Zone (s)	Name of use case
AI_UC4	Artificial Intelligence / Machine Learning / Machine Learning Operations (MLOps)	Models management

Scope and objectives of use case

Scope and objectives of use case	
Scope	Management of AI models supporting precision agriculture tasks.

Objective (s)	Machine Learning models generated during MLOps workflows using the FlexiGroBots AI platform will be integrated and used to build new applications and services supporting precision-agriculture tasks based on robotics systems.

Narrative of the use case

Narrative of use case
Short description
AI Models are managed through the platform functionalities using Command Line Interfaces (CLIs), Application Programming Interfaces (APIs) or Graphical User Interfaces (GUIs). The models can be downloaded in order to be integrated on-premises or consumed as a service through an API.
Complete description
The FlexiGroBots AI platform will contain a repository with the Machin Learning models produced by the trainings executed following AI_UC3. Data scientists will be able to handle their models from this repository and to obtain detailed information about all the steps, resources and datasets which have been required to create each model, guaranteeing the traceability and reproducibility of the experiments. Two approaches are considered for the serving phase: • The models will be downloadable in several formats (i.e., original binary files, Docker images, Kubernetes manifests) for easy deployment and integration with FMS or other platforms. • It will be possible to launch an instance of the model directly on the platform and to consume the offered functionality following the “as a service” paradigm.

Use case conditions

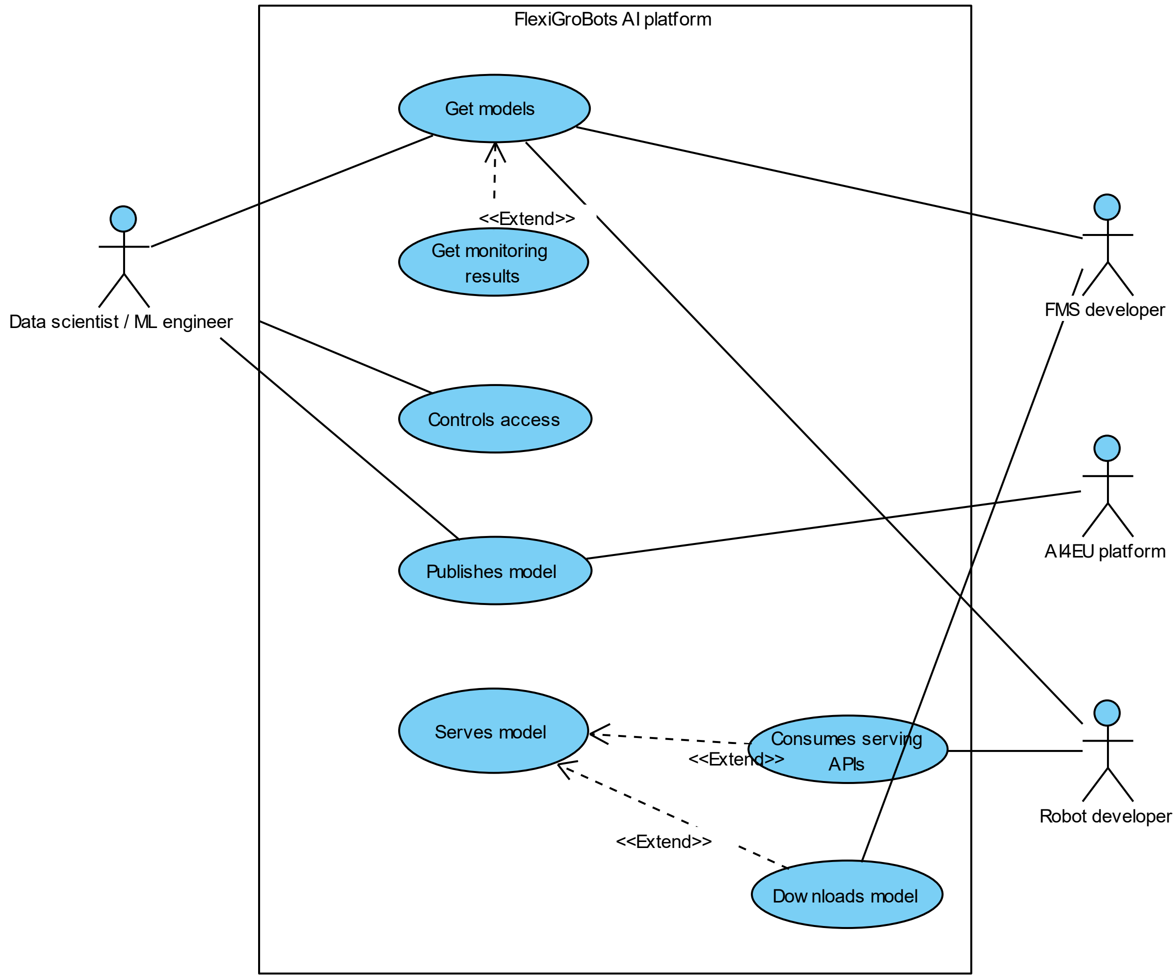
Use case conditions
Assumptions
An account is created in the AI platform for the ML engineer or data scientist.
Prerequisites
An ML model has been generated using trainings, experiments and datasets according to AI_UC1, AI_UC2 and AI_UC3.

Further information to the use case for classification / mapping

Classification information
Relation to other use cases
Models management requires the previous execution of AI_UC1, AI_UC2 and AI_UC3.
Level of depth
Detailed Use Case

Prioritisation
Mandatory
Generic, regional or national relation
Generic
Nature of the use case
Technical

Diagrams of use case

Diagram(s) of use case


Actors

Actors	
Grouping	Group description
N/A	N/A

Actor name	Actor type	Actor description	Further information specific to this use case
Data scientist / ML engineer	Human	Person in charge of the development of ML models.	N/A
Robot developer	Human	Person in charge of the development and integration of components for aerial and ground robots.	N/A
FMS developer	Human	Person in charge of the development and integration of components for FMSs.	N/A
Digital platform	Software	Digital platforms or systems that must interact with the ML models.	N/A
AI4EU platform	Software	European Artificial Intelligence on-demand platform	

Overview of scenarios

Scenario conditions						
No.	Scenario name	Scenario description	Primary actor	Triggering event	Pre-condition	Post-condition
1	Get models	Retrieves the list of models available on the platform. Also available information, metadata, etc.	Data scientist / ML engineer	N/A	A model is created	List of models and information is obtained.
2	Controls access	Access or visibility of other users of the platform to the model is managed.	Data scientist / ML engineer	N/A	A model is created	Model access rights are updated.
3	Publishes model	The model is uploaded to the AI4EU repository.	Data scientist / ML engineer	N/A	A model is created	Model is published.
4	Serves model	The model is served in order to perform the inferencing.	Data scientist / ML engineer	N/A	A model is created	Model is

Steps – Scenarios

Scenario

Scenario name:	No. 1 - Get models						
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)
01	User wants to check information about available models	Lists models	Available models are listed	GET	AI platform	Data scientist	List of models with metadata
02	User wants to check information about a specific model	Reads models	Metadata for a specific model is obtained	GET	AI platform	Data scientist	Model ID, Model metadata.
03	User wants to get the model	Downloads model	The model binary file is downloaded.	GET	AI platform	Data scientist	Model
04	User wants to get monitoring information about the model	Get monitoring results	Obtains information and metrics from the training process.	GET	AI platform	Data scientist	Model
05	User wants to get further information about a model	Get metadata	Retrieves information about the corresponding dataset, experiment and training for a model.	GET	AI platform	Data scientist	Model's metadata

Scenario

Scenario name:	No. 2 - Controls access						
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)
01	User wants to change access rights for a model	Lists users	List users	GET	AI platform	Data scientist / ML engineer	Users' list
02	User wants to change access rights for a model	Changes permissions	Changes permissions for a certain model	POST	Data scientist	AI platform	Model ID, new permissions

Scenario							
Scenario name:	No. 3 - Publishes model						
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)
01	User wants to publish a model and has identified a license	License definition	Specifies license and conditions for usage.	POST	Data scientist / ML engineer	AI platform	License
02	Step 01 completed	Model publication	Information from the model and the model itself is	POST	AI platform	AI4EU platform	Model name, model description, model

			sent to the AI4EU platform catalogue				license, model tags, model file.

Scenario							
Scenario name:	No. 4 - Serves model						
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)
01	Developers of robots or FSMs want to serve the model directly on their embedded systems or from their own infrastructure	Serves model	The model is deployed and served to perform inferencing. In some cases,	POST	Data scientist	AI platform	Model ID, version
02	User wants to consume the model from the AI platform	Consumers serving API	Applications use the model through the corresponding API.	POST	Robots, FSMs or other digital platforms and systems.	AI model	Input data required by the model, results of the processing.

5.2.2 Common data services

Common data services are based on the IDSA data space concept and the use of components that implement it. The Data Space based on the International Data Spaces Standard [7] defined by the International Data Spaces Association (IDSA) consists of connectors via which data providers and data consumers are connected and exchange data in the data space and a number of infrastructure components that allow the sovereign data sharing between trusted partners. From a technical perspective, some of these components are mandatory, which means that they are necessary for the developed software architecture to be characterized as minimum viable data space. Some other components are considered optional, even though they provide significant functionality without which a data space would not be as useful and attractive for participants, e.g., a broker for searching for data endpoints or applications.

The data space that will be created for FlexiGroBots will make use of all components, both the ones that create the minimum viable data space and the ones offering the dataspace extended functional infrastructure. The components that will be developed and implemented for the FlexiGroBots minimum viable data space, as well as the concrete development plans, are detailed in deliverable "D3.1 FlexiGroBots Platform v1" [60].

More specifically:

- The **Connector** component will be used to allow sovereign data sharing between data providers and data consumers as well as governance of the stored information.
  The sovereign data sharing is achieved through the definition of rules and conditions from the data provider for the usage of the data (usage policies) under which data is shared with a data consumer. These rules include scenarios like the restriction of data usage for a specific group of participants, restriction of usage for specific purposes, usage of data for a limited number of times, etc.
  After a data consumer requests a data set to be shared from the provider, a contract negotiation process is started during which the usage policies are negotiated. There are two ways the usage policies can be applied, either via legal or technical enforcement. In the first scenario, the connector of the data consumer is connected with a system (can be any information management system, such as an ERP or a Farm Management System) that is not deployed in the connector. Therefore, the data provider needs to agree that data will be processed outside the connector. Here, a digital contract between the two parties is established that is legally binding for both parties, even though, technical control is lost for the data provider. In the case of technical enforcement, the data consumer's data system is deployed inside the connector (dockerized). In this way, in addition to the digital contract, technical enforcement of the usage policies can be ensured.
- The **Identity Provider** is a component that consists of 3 sub-components and is responsible for offering services to create, maintain, manage, monitor, and validate identity information of and for participants in a data space. The identity forms the basis for establishing trusted communication in the International Data Space and is provided by an independent Certification Body and an Evaluation Facility in the form of a certificate issued by an Identity Provider.

  - The **Certificate Authority (CA)** grants X.509, which makes sure that the connector installed in a system of a data space participant complies with IDS specifications and requirements.
  - The **Dynamic Attributes Provisioning Service (DAPS)** is used to provide dynamic, up-to-date attribute information about the participants and the connectors.
  - Finally, the **Participants Information Service (ParIS)** holds generic information of all data space participants.
- The **IDS Certification** is the process that builds trust in unknown communication partners in data spaces, and it is related to both IDS components and the Operational environment of them. The evaluation and certification of IDS core components is based on whether they provide the required functionality, interoperability and security regarding the security profiles. The evaluation and certification of the operational environment include the physical environment, defined processes and organizational rules.
- The **Metadata Broker** is the component that allows data providers to register their data sets and make them discoverable by other participants of the data space. As the data space will be used from all three pilots but will be also opened to be connected to interested organizations outside the consortium, the broker will allow data consumers to easily search for data sets they need for their use case-specific purposes.
- The **App Store** is the infrastructure component where participants can search and discover applications for data transformations that are deployable in their connections. As different types of participants (from pilots or outside the consortium) might be interested in this functionality, the App Store will allow users to search for an app and deploy it in his/her connector.
- The **Clearing House** will be used for logging the different financial data exchange transactions. The Clearing House logs all activities performed in the course of data exchange and based on this logging information, the transaction can then be billed or used to resolve conflicts (e.g., to clarify whether a data package has been received by the Data Consumer or not).
- The **Vocabulary Provider** is the component where domain-specific vocabularies (ontologies, reference data models, or metadata elements) can be provided to the participants of the data space allowing them to understand each other in terms of the datasets that they are sharing.

Below the data space, key components in minimum viable data space are demonstrated. In the example, there are three companies that are enabled to exchange data in a peer-to-peer network concept.

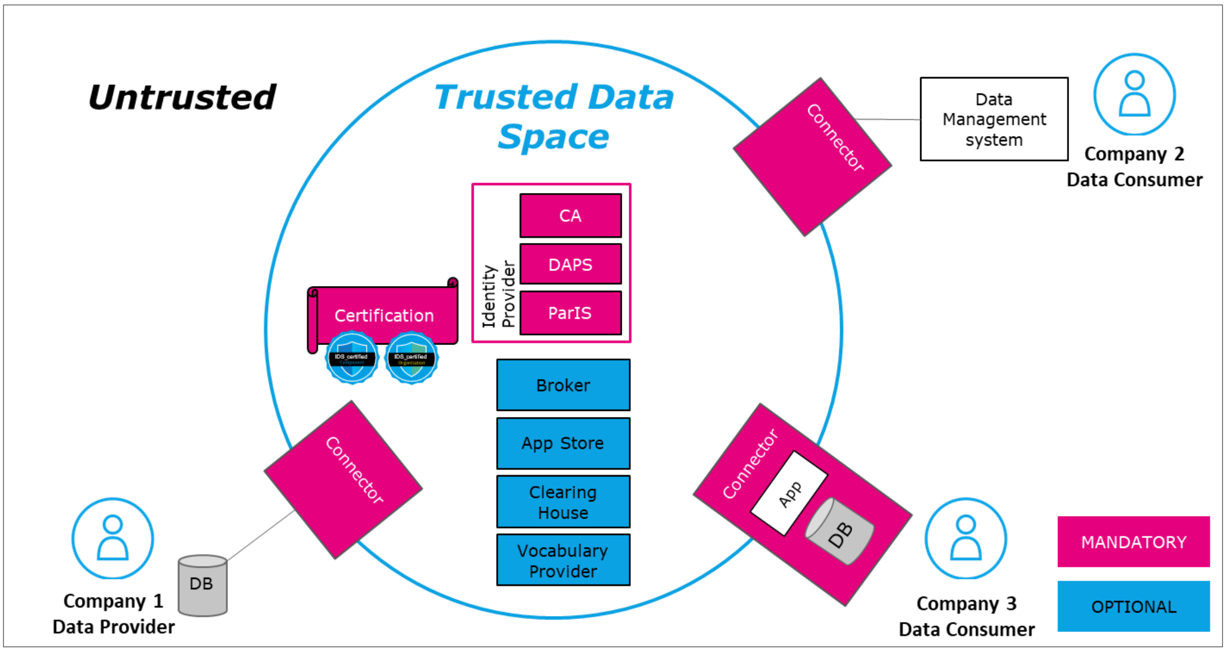


Figure 24: Example of a minimum viable data space (MVDS) and its key infrastructure components

Figure 24 presents the data space interface and the interactions between the data space infrastructure components, i.e., Certification Authority, Dynamic Attribute Provisioning Service (DAPS), broker and validation authority. The operations between these services are automatically launched by the Connector component.

In the following use cases, the focus is on how the data space operates with the back-end system that is in this case the data management system and services of the company that hosts the FlexiGroBots platform. This use case is an instance of a general use case of having a data space connection in an organization's data platform/system.

The data space interface has three main use cases: joining to data space, publishing data, and accessing shared data. Joining of data space is not covered as it happens only once in the installation phase.

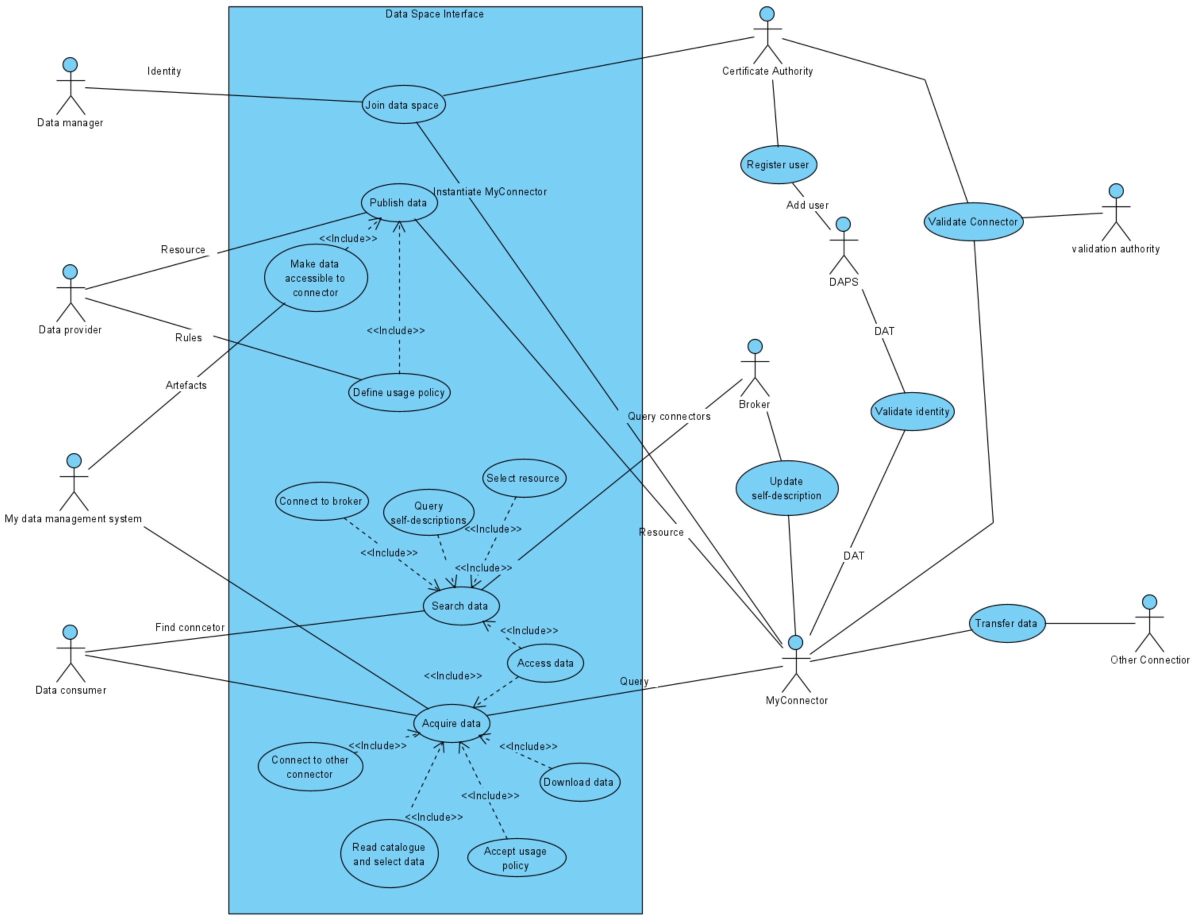


Figure 25. Top-level view to data space interface.

5.2.2.1 Publishing data

Name of use-case

Use case identification		
ID	Area / Domain (s) / Zone (s)	Name of use case
IDS_UC1	Agricultural data sharing	Publishing data

Scope and objectives of use case

Scope and objectives of use case	
Scope	Publishing data to agriculture data space for controlled use.
Objective (s)	To enable flexible and sovereignty preserving data exchange between the partners of the agriculture data space. To describe how communication between data space connector and platform owner's employees and data systems should work on the logical level.

Narrative of the use case

Narrative of use case
Short description
The company hosting the FlexiGroBots platform publishes data artefacts with specified usage policies into data space for other companies to access.
Complete description
Data provider creates data space resources from the data assets it has in their data management system. The provider defines its usage policies and publishes the resources in its data space connector.

Use case conditions

Use case conditions
Assumptions
Data provider and data consumer use the same data transfer protocols and same data models (ontologies)
Prerequisites
There is an existing data space infrastructure.
The company and its connectors are registered to the current data space.

Further information to the use case for classification / mapping

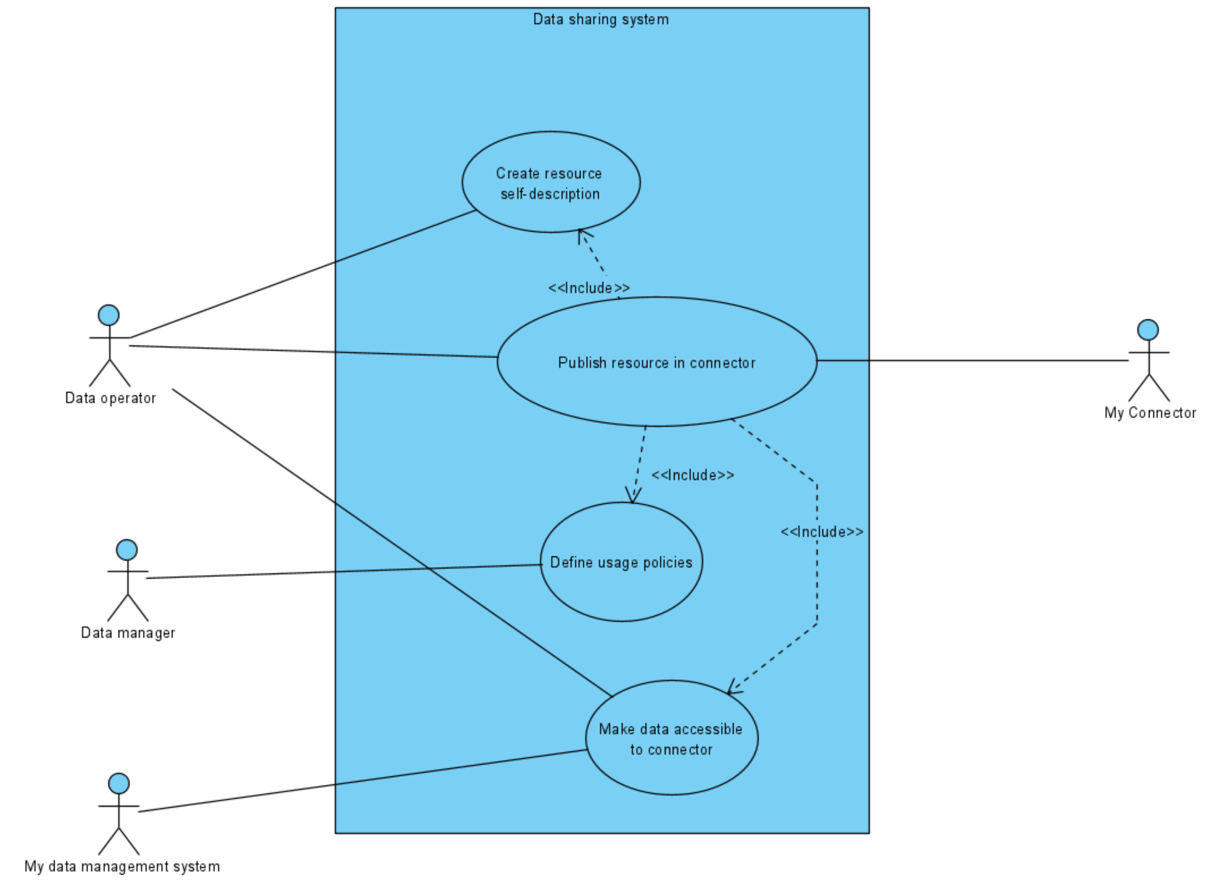
Classification information
Relation to other use cases
Publishing data is a prerequisite of all data sharing between companies in other use cases.
Level of depth
Functional description of the interface operation
Prioritisation
Mandatory
Generic, regional or national relation
Generic
Nature of the use case
Technical

General remarks

General remarks
Communication between the data space interface and IDS Connector uses the Connector API. Connector components are still evolving, so the plan is to make the interface flexible so that it can adapt to API changes. This model does not include scenario steps and information tables as they depend on selected data space connectors API and message definitions.

Diagrams of use case

Diagram(s) of use case



Actors

Actors			
Grouping		Group description	
Actor name	Actor type	Actor description	Further information specific to this use case

Data operator	Human	Performs the creation of data resource	
Data manager	Human	Defines acceptable data usage policies	May also be involved in agreement negotiation if automated solutions are not adequate.
My data management system	Software	Storage system for data to be shared	
My connector	Software	Performs the operations needed in data space	

Overview of scenarios

Scenario conditions						
No.	Scenario name	Scenario description	Primary actor	Triggering event	Pre-condition	Post-condition
1	Publish resource in connector	Data provider puts data available into the data space through its connector	Data operator	Data needs to be shared	Data must exist and be owned by the provider	Connection to data space
1.1	Create resource self-description	Meta-data model of publishable resource is created using data space models	Data operator	The decision to share has been done	Self-description data model and template	A machine-readable description of data resource
1.2	Define usage policies	Data owner defines the conditions and rules that must be obeyed when data is used by consumer	Data manager	The decision to share has been done	Data resources must be available.	Use agreement proposal for data resource in the connector

1.3	Make data accessible to the connector	Provider makes the actual data element accessible for the connector.	Data operator	Resource and usage policy defined	Data assets must be available in My data management system.	A data asset is available in data space
2	Agree on usage policy	Data consumer agrees on usage policy and data transfer conditions	Data Consumer	The consumer wants to have data with proposed conditions	Provider and consumer identified; the validity of connectors verified.	Legally binding agreement on the use of data
3	Transfer artefacts	Data is transferred from the provider's system to the consumer's system. Transfer is implemented by connectors.	My data management system	Agreement exists.	Physical data transfer link must exist between connectors	Data has been transferred to the consumer. Transfer is registered to data space infrastructure.

Steps – Scenarios

Scenario								
Scenario name:	No. 1 - Publish resource in connector							
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requirement, R-IDs
01	New data is available to be published	Resource creation	Information about the resource is indicated	POST	Data operator	Data Connector	Resource description	

02	Step 01 completed	Catalogue creation	A new catalogue to store resources is created	POST	Data operator	Data Connector	Catalogue description	
03	Step 02 completed	Resource adding	The resource is added to the catalogue	POST	Data operator	Data Connector	Resource ID, Catalogue ID	
04	Step 03 completed	Artefact creation	An artefact is created	POST	Data operator	Data Connector	Artefact description	
05	Step 04 completed	Representation creation	A representation is added	POST	Data operator	Data Connector	Representation description	
06	Step 05 completed	Artefact adding	An artefact is added to the representation	POST	Data operator	Data Connector	Artefact ID	
07	Step 06 completed	Representation adding	A representation is added to the resource	POST	Data operator	Data Connector	Representation ID	

Scenario								
Scenario name:	No. 2 - Agree on usage policy							
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requirement, R-IDs

01	Scenario 1 completed	Rule creation	Defines usage permissions	POST	Data manager	Data Connector	Rule description	
02	Step 01 completed	Contract creation	Creates a contract	POST	Data manager	Data Connector	Contract description, i.e., start and end dates.	
03	Step 02 completed	Rule adding	Adds a rule to a contract	POST	Data manager	Data Connector	Contract ID, Rule ID	
04	Step 03 completed	Contract adding	Adds contract to resource	POST	Data manager	Data Connector	Resource ID, Contract ID	

Scenario								
Scenario name:	No. 3 - Transfer artefacts							
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requirement, R-IDs
01	Scenario 02 completed	Artefact transference	Artefacts are transferred to consumers	POST	My data management system	Data Connector	Artefact	

5.2.2.2 Accessing data

Name of use-case

Use case identification		
ID	Area / Domain (s) / Zone (s)	Name of use case

IDS_UC2	Agricultural data sharing	Accessing data

Scope and objectives of use case

Scope and objectives of use case	
Scope	Accessing data from agriculture data space.
Objective (s)	Acquiring data from different data providers through common data space infrastructure.

Narrative of the use case

Narrative of use case
Short description
Getting data from data space and data providers connectors.
Complete description
Data consumer connects to data space and to its Broker that host self-description (metadata) from the data providers connectors connected to this Broker. Consumer browses the data is entitled to and selects the data assets it is interested in. Consumer uploads the address to Connector hosting the actual data and connects to it. Identities of both parties are verified, and consumers can browse the data resources made available by Provider. The consumer selects the data resource and reads the usage policy agreement. It agrees on the policy that is a legally binding agreement and gets access to the data itself. Consumer requests his Connector to get the data and connectors on both ends transfer the data artefacts from Provider's data system to Consumer's data system.

Use case conditions

Use case conditions
Assumptions
Consumer and Provider are part of the same data space and in the case of point-to-point data sharing, they have previously agreed on it and made the data assets visible only to each other.
Prerequisites
Data infrastructure with Brokers, DAPS, Certification Authority, and Connectors must be operational.

Further information to the use case for classification / mapping

Classification information
Relation to other use cases
Data sharing is a basic feature needed in all business-to-business interactions.

Level of depth
Logical/functional description
Prioritisation
Mandatory
Generic, regional or national relation
Generic
Nature of the use case
Technical

Diagrams of use case

Diagram(s) of use case

Actors

Actors			
Grouping		Group description	
Actor name	Actor type	Actor description	Further information specific to this use case

Data consumer	Human	Person who wants to access data from data space	
My data management system	Software service	Consumers own data management system (file system, database, etc.)	
DAPS	Software service	Data space infrastructure service that verifies identities and certificates and creates dynamic access rights.	
Data Broker	Software service	Database that contains metadata related to data assets (data resources) that are publicly available in data space	Publicly available does not mean open, but only metadata is visible. Data space can have also non-visible data.
Remote Data Connector	Software service	Data connector of data provider that shares the data	

Overview of scenarios

Scenario conditions						
No.	Scenario name	Scenario description	Primary actor	Triggering event	Pre-condition	Post-condition
1.1	Connect to Broker	Consumer connects to Brokers; its identity is verified.	Data Consumer	Consumer wants some data	Data space operational	Consumer has access to data space metadata.
1.2	Browse resources	Consumer queries the metadata from the Broker and selects the interesting	Broker	Connected to Broker	Data space operational	Consumer identifies the location of interesting data.

		data resources.				
1.3	Connect to selected Connector	Consumer Connector connects to Provider Connector	Data Consumer	Interesting connector identified	Data space operational and Connector available	Consumer has access to Providers metadata and sharing conditions.
1.4	Select data resource	Data Consumer browses the data resources in the remote connector and selects some	Remote Data Connector	Interesting data identified	Remote Connector available, data available	Consumer knows the data artefacts he wants and their usage policies.
2	Agree on usage policy	Data consumer agrees on usage policy and data transfer conditions	Data Consumer	Consumer wants to have data with proposed conditions	Provider and consumer identified; the validity of connectors verified.	Legally binding agreement on the use of data
3	Transfer artefacts	Data is transferred from the provider's system to the consumer's system. Transfer is implemented by connectors.	My data management system	Agreement exists.	Physical data transfer link must exist between connectors	Data has been transferred to the consumer. Transfer is registered to data space infrastructure.

Steps – Scenarios

Scenario	
Scenario name:	No. 1 - Select data resource

Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requirement, R-IDs
01	Data Consumers wants to obtain data	Lists resources	Obtains the list of resources published in the broker	GET	Data Consumer	Broker	Resources descriptions	
02	Data Consumer selects resources	Connect connectors	Consumer Connector connects to Provider Connector	EXECUTE	Data connector	Remote Data Connector	Provider URL, Resource ID	

Scenario	
Scenario name:	No. 2 - Agree on usage policy

Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requirement, R-IDs
01	Scenario 01 completed	Policy offering	Adds a policy usage	POST	Data consumer	Data Connector	Artefact ID	

Scenario

Scenario name:	No. 3 - Transfer artefacts							
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requirement, R-IDs
01	Scenario 02 completed	Artefact consuming	Artefacts are retrieved	GET	Data Connector	Data consumer	Artefact	

5.2.3 Geospatial enablers and services

5.2.3.1 Earth Observation data provision

Name of use-case

Use case identification		
ID	Area / Domain (s) / Zone (s)	Name of use case
GEO_UC1	Precision agriculture/ geospatial services	Earth Observation data provision

Scope and objectives of use case

Scope and objectives of use case	
Scope	Registration and indexing of EO data products (i.e., from satellite and UAV origin) in the data cube
Objective (s)	Facilitate the management and access to the different sources of Earth Observation datasets used by the use pilots

Narrative of the use case

Narrative of use case
Short description
The system administrator configures the different EO data products (satellite and UAVs) that will be indexed and served in the data cube so they can be used by the other tools and components.
Complete description

Management and access to the use case pilots on field observations using satellite and UAVs observations require that the corresponding EO data products (i.e., Sentinel 2, Landsat 7/8 and specific data formats provided by the UAVs software) are properly registered in the data cube in order to effectively index and manage the observations time series gathered along the time.

Use case conditions

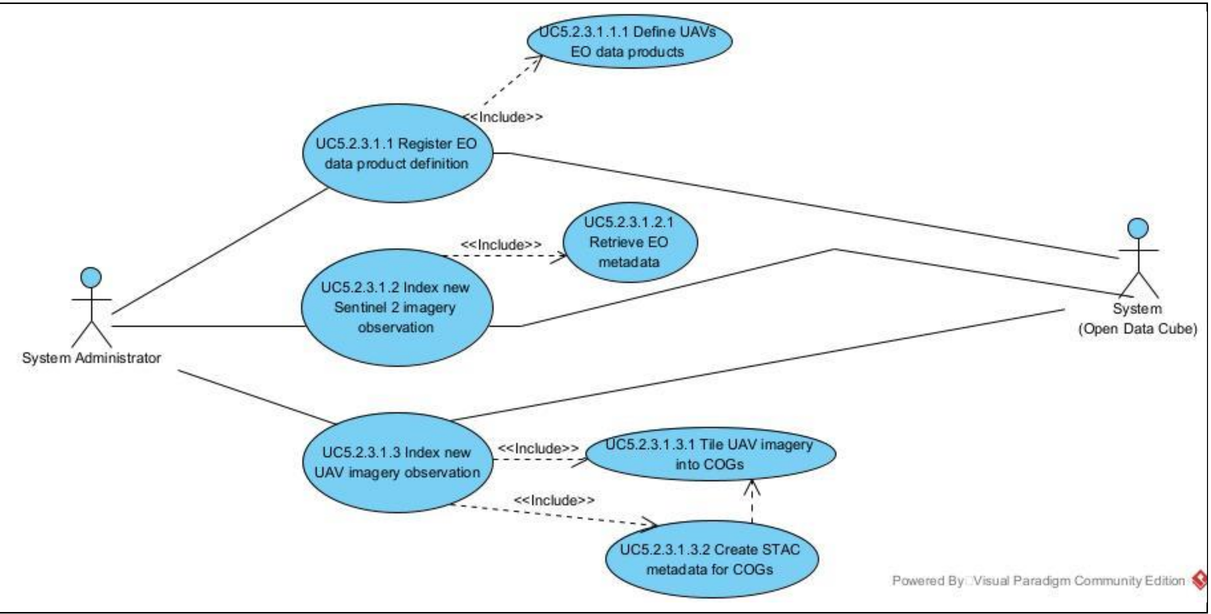
Use case conditions
Assumptions
A geographical bounding box is defined for each of the pilot areas in order to be able to retrieve and index Sentinel 2 images from Copernicus Hub
Prerequisites
The format of the imagery produced by the UAVs is known upfront in order to be able to define the corresponding EO product and register it in the data cube

Further information to the use case for classification / mapping

Classification information
Relation to other use cases
Registration and indexing of the EO products in the data cube is the very first step that enables exploiting them in order use cases (e.g., visualization, running geoprocesses, etc.)
Level of depth
Detailed Use Case
Prioritisation
Mandatory
Generic, regional or national relation
Generic
Nature of the use case
Technical

Diagrams of use case

Diagram(s) of use case



Actors

Actors			
Grouping		Group description	
N/A		N/A	
Actor name	Actor type	Actor description	Further information specific to this use case
System administrator	Human	Registers the EO data products	
External system	System	Provides Sentinel 2/Landsat 7/8 imagery	
UAV	Device	Provides imagery from field areas	

Overview of scenarios

Scenario conditions						
No.	Scenario name	Scenario description	Primary actor	Triggering event	Pre-condition	Post-condition
1	Register EO data product definition	A new EO data product definition is registered in the data cube	System administration	A new EO product must be made available in the system	N/A	Possibility of indexing EO imagery in the data cube according to

						the EO product definition
2	Index new Sentinel 2 imagery observation	A new Sentinel 2 image has to be indexed in the data cube	System component (data cube)	At a given moment, a new Sentinel 2 tile is available for the pilot geographical area. The metadata corresponding to that image is indexed in the data cube so it is aware of it and can offer it	The Sentinel 2 data product definition has been registered in the data cube	The new Sentinel 2 image can be served by the data cube to other services and components using interoperable API
3	Index new UAV imagery observation	A UAV image has to be indexed in the data cube	System component (data cube)	At a given moment, a new image produced by the UAV is available in the system. The metadata corresponding to that image is indexed in the data cube so it is aware of it and can offer it	The UAV image data product definition has been registered in the data cube	The new UAV image can be served by the data cube to other services and components using interoperable API

Steps – Scenarios

Scenario

Scenario name:	No. 1 - Register EO data product definition							
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requirement, R-IDs
01	EO product is available	EO Sentinel 2 product definition registration	Insert in the ODC database metadata about the Sentinel 2 definition	ODC	Sentinel 2 EO definition in YAML format	ODC PostGIS database	N/A	
02	Pilots UAVs imagery is available	Pilots UAVs imagery product definition registration	Insert in the ODC database metadata about the UAVs products definition	ODC	UAVs imagery definition in YAML format	ODC PostGIS database	N/A	

Scenario								
Scenario name:	No. 2 - Index new Sentinel 2 imagery observation							
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requirement, R-IDs
01	New Sentinel 2 images available	Indexing Sentinel 2 imagery	On a daily basis, for each pilot, the system checks whether	ODC	Sentinel 2 imagery and STAC metadata (of each Sentinel 2 image	ODC PostGIS database (new metadata records for the	N/A	

			new Sentinel 2 imagery is available for the specified time ranges and geographic areas		matching the time range and geographic area)	new images indexed are added to it)		

Scenario								
Scenario name:	No. 3 - Index new UAV imagery observation							
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requirement, R-IDs
01	New UAVs images are available	Indexing UAVs imagery	On a daily basis, for each pilot, the system checks whether new UAV imagery is available	Pilot local cloud storage system ODC	UAVs imagery (if possible, in COG format) + STAC metadata describing it	ODC PostGIS database (new metadata records for the new images indexed are added to it)	N/A	

5.2.3.2 EO Data Access and Visualization

Name of use-case

Use case identification		
ID	Area / Domain (s) / Zone (s)	Name of use case

GEO_UC1	Precision agriculture/ geospatial services	EO Data Access and Visualization

Scope and objectives of use case

Scope and objectives of use case	
Scope	Data access and visualization of EO data products (i.e., from satellite and UAV origin) via the data cube services and APIs
Objective (s)	Facilitate the access, processing and visualization of the heterogeneous sources of Earth Observation datasets in the pilots by using the Open Data Cube OGC interfaces (i.e., OGC WMS, OGC WCS)

Narrative of the use case

Narrative of use case
Short description
Different FlexiGroBots' systems and services require access and visualize the pilots' EO datasets using interoperable APIs offered by the data cube so they can be more easily accessed and integrated as inputs into their own workflows.
Complete description
The data cube acts as a facilitator for other systems/services and actors within FlexiGroBots in order to easily access the EO datasets from Copernicus Sentinel 2 satellites and the UAVs observations data products collected by each pilot. Note that Copernicus Sentinel 2 data is retrieved on-demand from the Copernicus Hub (or Amazon Web Services free access copy) based on the area of interest provided when requesting it via the data cube's API. More detailed pre-processing of EO data can be performed via the data cube SDK library and Jupyter notebooks.

Use case conditions

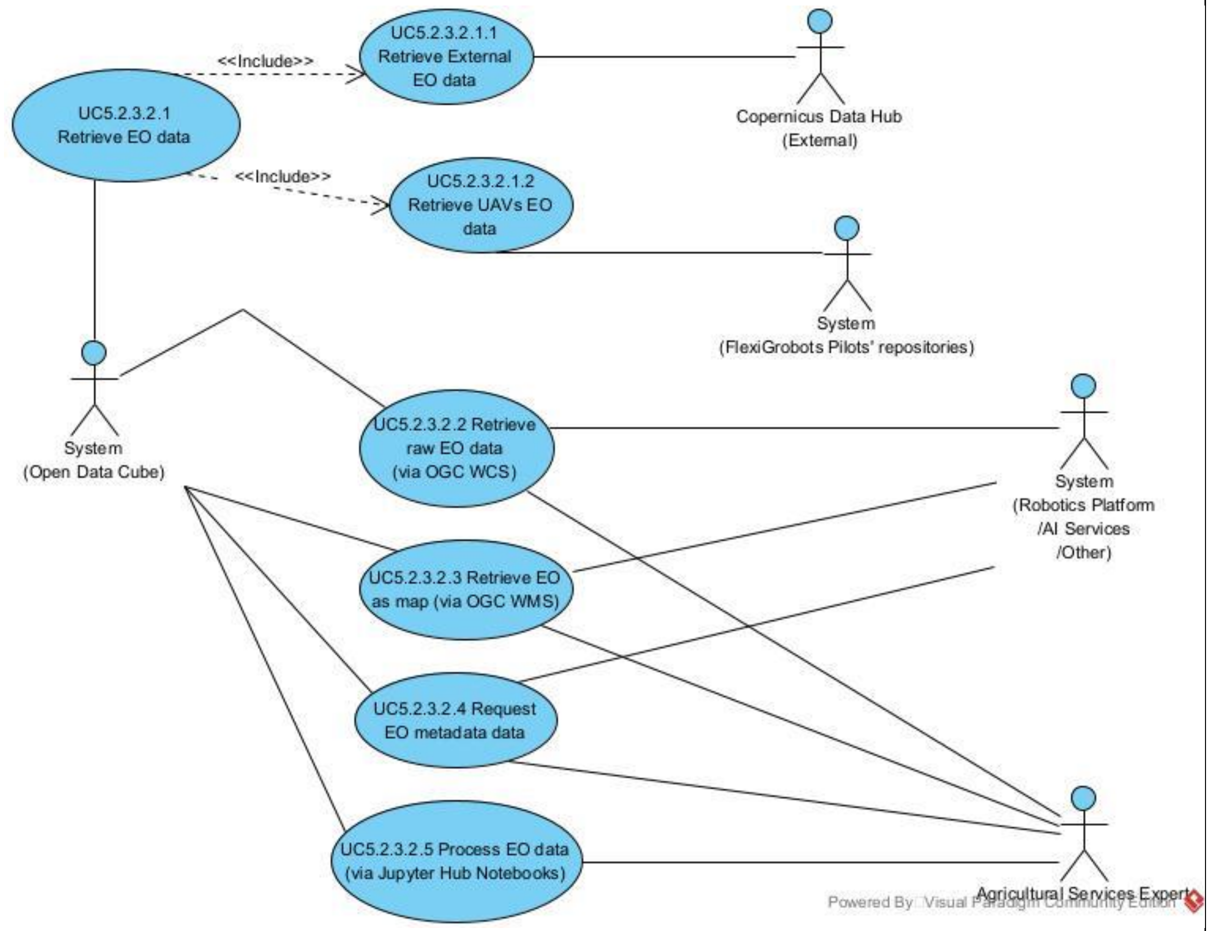
Use case conditions
Assumptions
External parties willing to retrieve information from ODC are capable to understand OGC WMS and/or WCS API standards (or alternatively, can use ODC Python SDK)
Prerequisites
ODC instance is already deployed and contains metadata about indexed satellite imagery and/or UAVs raster-based outputs

Further information to the use case for classification / mapping

Classification information
Relation to other use cases

Registration and indexing of the EO products in the data cube is the very first step that enables exploiting them in order use cases (e.g., visualization, running geoprocesses, etc.) Other use cases requiring the use and integration of EO data into their workflows depend on this Use Case
Level of depth
Detailed Use Case
Prioritisation
Mandatory
Generic, regional or national relation
Generic
Nature of the use case
Technical

Diagrams of use case

Diagram(s) of use case


Actors

Actors			
Grouping		Group description	
N/A		N/A	
Actor name	Actor type	Actor description	Further information specific to this use case
Data Cube	System	Manages and facilitates access to the EO data products	
Copernicus Data Hub /AWS	External System	Provides Sentinel 2/Landsat 7/8 imagery	
Pilots' legacy repositories	System	Provides EO imagery from pilot field areas	
Robotics Platform / AI services /Other	System	FlexiGroBots systems and services that require EO data in order to perform their workflows	
Agricultural Services Expert	Human	Person requiring accessing and processing EO data	

Overview of scenarios

Scenario conditions						
No.	Scenario name	Scenario description	Primary actor	Triggering event	Pre-condition	Post-condition
1	Consult EO metadata in data cube	User or systems willing to know what existing EO data products/layers are offered by data cube makes a GetCapabilities request	System (Robotic Platform/ AI services) or Human (agricultural expert)	Actor wants to know what data is currently available in the data cube	EO data products have been registered and indexed in advance by the data cube	Returned XML response containing information about data format, bounding box and time range covered by specific EO data layer

2	Retrieve raw EO data	User or system wants to retrieve raw EO data (either from Sentinel 2 or UAVs observations) for a specific bounding box area and point in time using the OGC WCS API	System (Robotic Platform/ AI services) or Human (agricultural expert)	System requires raw EO data for a calculation in its workflow	Sentinel 2 data (for the area requested) is retrieved by data cube from Copernicus Hub (and possible further processed e.g., coordinates transformation, data format conversion). Similarly, it is done for the UAV imagery collected by each pilot.	A raster coverage of the size of the bounding box area specified (encoded as Geotiff or netcdf) is returned by the data cube
3	Visualize EO data in the form of a map	User or system wants to visualize EO data (either from Sentinel 2 or UAVs observations) for a specific bounding box area and point in time using the OGC WMS API	System component (data cube)	System /Human needs to visualize EO dataset as another layer in its visualization tool	Sentinel 2 data (for the area requested) is retrieved by data cube from Copernicus Hub (and possible further processed e.g., coordinates transformation, data format	The EO dataset is visualized as a map in the corresponding tool

					conversion). Similarly, it is done for the UAV imagery collected by each pilot.	
4	Process EO data	User or system wants to perform a specific calculation using EO (either from Sentinel 2 and/or UAVs observations) for a specific bounding box area and point in time using the data cube Python SDK library and Jupyter Notebook	System (Robotic Platform/ AI services) or Human (agricultural expert)	System/Human wants to perform a calculation with EO data (e.g., vegetation index) that will be used as input for another process	Sentinel 2 data (for the area requested) is retrieved by data cube from Copernicus Hub (and possible further processed e.g., coordinates transformation, data format conversion). Similarly, it is done for the UAV imagery collected by each pilot.	The result of the process is returned as a raster coverage of the size of the bounding box area specified (encoded as Geotiff or netcdf) is returned by the data cube

Steps – Scenarios

Scenario	
Scenario name:	No. 1 - Consult EO metadata in the data cube

Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requirement, R-IDs
01	A third-party application/ system wants to know what available EO products are offered by the ODC	GetCapabilities query	A third-party application/ system wants to know what available EO products are offered by the ODC (as well as their temporal range and maximum area coverage)	OGC WMS or OGC WCS (via the ODC OWS module)	OGC GetCapabilities request	XML with the GetCapabilities response listing all available layers (e.g., Sentinel 2 layer) with their area extents and time ranges	N/A	

Scenario								
Scenario name:	No. 2 - Retrieve raw EO data							
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requirement, R-IDs
01	A third-party application/system wants to download Sentinel 2 data for a specific area	GetCoverage query	A third-party application/system wants to download Sentinel 2 data for a specific area indicating the temporal	OGC WCS (via the ODC ows module)	GetCoverage query	Raw image data (in the form of GeoTiff or any other support	N/A	

			range and area of interest			s format)		

Scenario								
Scenario name:	No. 3 - Visualize EO data in the form of map							
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requirement, R-IDs
01	A third-party application/system wants to integrate a map of the EO product as a visualization	GetMap query	The GetMap query indicates the layer name, the temporal and spatial extent and the image output format	OGC WMS (via the ODC OWS module)	OGC GetMap request	Image map in the output format specified	N/A	

Scenario								
Scenario name:	No. 4 - Process EO data							
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requirement, R-IDs

01	FlexiGroBots user wants to test an algorithm using EO data offered by the ODC	Execute Jupyter Notebook	The user implements a Python Notebook using the ODC SDK library for accessing and manipulating the EO images	ODC + Jupyter Hub	Jupyter Notebook	Alphanumeric, map images and raw raster output	N/A		

5.2.4 Common application services

The FlexiGroBots platform will count on several software services that the user can access through the AI Platform (Section 5.2.1). These applications are designed not to be specific to a particular Pilot or use-case, rather than common across different agricultural scenarios. Ideally, these can be used and tested in more than one of the Pilots of this project and will be also useful for additional agricultural robotic solutions outside the scope of the FlexiGroBots framework. The following subsections describe the different common modules that are currently planned for development, treated as individual use-cases. They are divided into three separate categories: (i) situation awareness, (ii) utility and (iii) generalization modules. Many of them are focused on computer vision solutions that use monocular cameras that can be placed in UGVs or UAVs depending on the use-case. Some of them involve the use of neural networks and other Machine Learning techniques. These common applications and services will be available in the AI Platform and could be deployed on several devices. Primarily, those would be PC (whether workstations or laptops) and edge devices (for example NVIDIA Jetson). Those computers will run and execute the services that would be fed by cameras and other sensors when needed. The cameras can be placed on UGVs and UAVs as well as the edge devices if needed.

5.2.4.1 SLAM and 3D Scene reconstruction

Name of use-case

Use case identification		
ID	Area / Domain (s) / Zone (s)	Name of use case

CAS_SLAM_UC1	Artificial Intelligence / Machine Learning / Deep Learning - Computer Vision	Simultaneous Localization and Mapping for 3D Scene Reconstruction

Scope and objectives of use case

Scope and objectives of use case	
Scope	Create 3D maps of a field and position the robot within the map using a monocular camera.
Objective (s)	1) Develop a SLAM module for the monocular camera. 2) Incorporate 3D reconstruction. 3) Create a map of a crop field with a live camera mounted in UGV.

Narrative of the use case

Narrative of use case
Short description
Demonstration of mapping and location capabilities of a single monocular camera from UGV. A UGV equipped with a monocular camera should be capable of creating a map of its surroundings by moving through them.
Complete description
The use case describes the implementation of a 3D terrain reconstruction module that reconstructs the terrain surrounding the UGV and geopositioned it on the terrain with sufficient accuracy. For this purpose, a SLAM (Simultaneous Localization and Mapping) algorithm will be implemented by means of which, using an image acquired by a monocular camera, and after its calibration, the position and orientation of the camera with respect to a terrain-based reference system will be estimated. This position and orientation data will be fed to the 3D generation module which will generate a geopositioned 3D model of the environment.

Key Performance Indicators (KPIs)

Key performance indicators			
ID	Name	Description	Reference to mentioned use case objectives
1	SLAM accuracy	The camera position estimated by SLAM compared to that obtained by GPS will be: Difference between signals (x,y,z) < 0.2 m	Objective 1.

2	3D	At least one sector of the field will be reconstructed in pilot 1 and one in pilot 3.	Objective 2. & 3.

Use case conditions

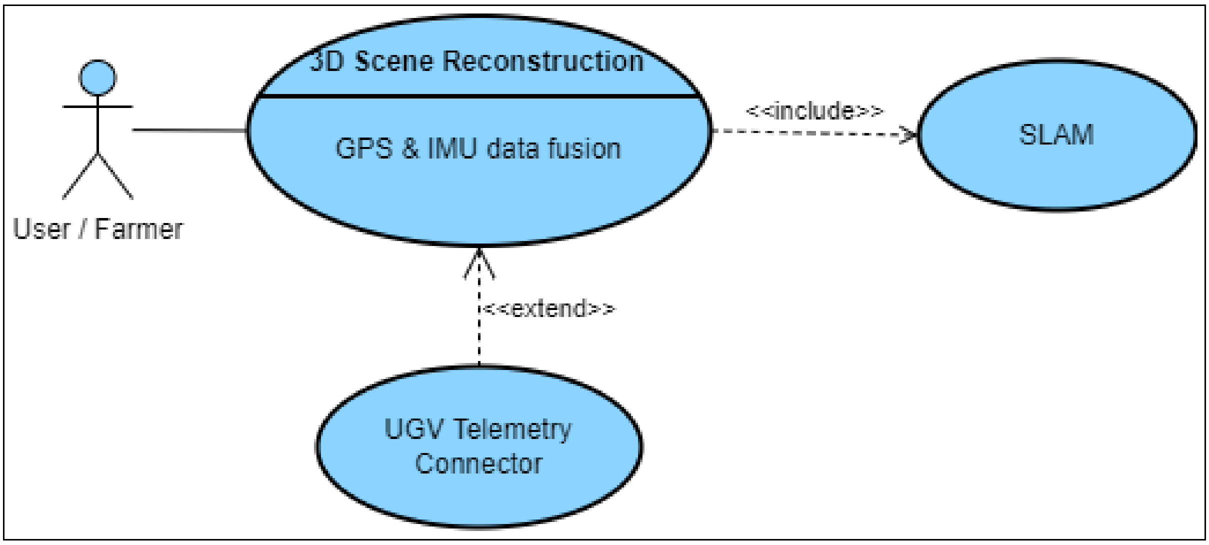
Use case conditions
Assumptions
A UGV with an equipped monocular camera is available.
This equipment is present at least in Pilot 1 and Pilot 3.
It is also desirable to have access to UGV telemetry, inertial platform data and GPS data.
Prerequisites
Camera calibration for measuring distances.
Computing power is needed, by edge devices or the cloud via internet connection.

Further information to the use case for classification / mapping

Classification information
Relation to other use cases
It is part of the "Situation Awareness" category of common services.
Level of depth
Detailed Use Case
Prioritisation
Mandatory
Generic, regional or national relation
Generic
Nature of the use case
Technical

Diagrams of use case

Diagram(s) of use case



Actors

Actors			
Grouping		Group description	
N/A		N/A	
Actor name	Actor type	Actor description	Further information specific to this use case
User/Farmer	Human	Person who executes the system	N/A

Overview of scenarios

Scenario conditions						
No.	Scenario name	Scenario description	Primary actor	Triggering event	Pre-condition	Post-condition
1	3D Scene Reconstruction	Request for 3D scenario reconstruction and georeferencing.	Farmer	N/A	Monocular camera stream available	3D model and georeferencing is obtained

Steps – Scenarios

Scenario	
Scenario name:	No. 1 – 3D Scene Reconstruction

Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)
01	Start reconstruction process	3D Reconstruction start	Initialization of the 3D reconstruction process, SLAM is initialized on the video stream and GPS and inertial platform data are acquired if available.	Docker	User/Farmer	User/Farmer	3D georeferenced model

5.2.4.2 People detection, location and tracking

Name of use-case

Use case identification		
ID	Area / Domain (s) / Zone (s)	Name of use case
CAS_PDLT_UC2	Artificial Intelligence / Machine Learning / Deep Learning - Computer Vision	People detection, location and tracking

Scope and objectives of use case

Scope and objectives of use case	
Scope	Detect people in RGB images, locate them within the image individually (each person is distinguishable and traceable in a sequence of images) and estimate their distances in relation to the camera.
Objective (s)	1) Detect people in a RGB image. 2) Estimate their location in the image and the distance to the camera. 3) Assign an identification code to each person for tracking through video.

Narrative of the use case

Narrative of use case
Short description
A UGV equipped with a monocular camera could use this service to detect and locate people in its surroundings and estimate its distance towards them. This increases the situation awareness and can be used for safety control of the UGV.
Complete description
The use case describes the use of a video analysis module which is acquired in real-time by the monocular camera of the UGV that will detect the persons present in the image, following them along the sequence of frames and re-identifying them in case of occlusions or momentary losses. The module will infer the distance relative to the camera of the persons present, providing feedback of this distance to the UGV control system for later use for early warning or personalized tracking purposes.

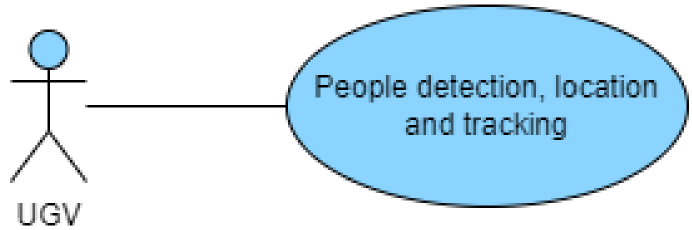
Use case conditions

Use case conditions
Assumptions
A UGV with an equipped monocular camera is available.
This equipment is present at least in Pilot 1 and Pilot 3.
Prerequisites
Computing power is needed, by edge device or via internet connection.
Camera calibration for measuring distances.

Further information to the use case for classification / mapping

Classification information
Relation to other use cases
It is part of the “Situation Awareness” category of common services.
Level of depth
Detailed Use Case
Prioritisation
Mandatory
Generic, regional or national relation
Generic.
Nature of the use case
Technical

Diagrams of use case

Diagram(s) of use case


Actors

Actors			
Grouping		Group description	
N/A		N/A	
Actor name	Actor type	Actor description	Further information specific to this use case
UGV	Robot / System	Unmanned Ground Vehicle – Agrobot	N/A

Overview of scenarios

Scenario conditions						
No.	Scenario name	Scenario description	Primary actor	Triggering event	Pre-condition	Post-condition
1	People detection, location and tracking	In this use case, a module is implemented whereby the UGV will be able to analyse a video stream by detecting the people present, following them and identifying the distance they are from the camera focus.	UGV	N/A	Monocular camera stream available	It is necessary to define a format for the output data interface.

Steps – Scenarios

Scenario

Scenario name:	No. 1 - People detection, location and tracking						
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)
01	Start mission signal	People detection	The process is initiated when the UGV starts the harvester tracking mission. The distance to the UGV is identified at all times by the exclusive use of a monocular camera.	Docker	UGV	UGV	Relative position

5.2.4.3 People behaviour estimation

Name of use-case

Use case identification		
ID	Area / Domain (s) / Zone (s)	Name of use case
CAS_PBE_UC3	Artificial Intelligence / Machine Learning / Deep Learning - Computer Vision	People behaviour estimation

Scope and objectives of use case

Scope and objectives of use case	
Scope	Detect people and recognize their actions (walking, crouching, bending over, reaching...)
Objective (s)	1) Detect people and locate them within the image. 2) Estimate pose and body posture

	3) Recognize actions.

Narrative of the use case

Narrative of use case
Short description
Service to detect people in the video stream, estimate their poses and recognize actions. This can be used to increase the overall safety of robotic operations by estimating intention.
Complete description
The use case will deploy an algorithm capable of detecting the key points of the human body of all persons present in the image. When is executed on a video stream, it will extract the trajectory of all these points giving as outputs discrete signals that will be the position of these points as a function of time. With this information, the actions performed by the people will be classified using an SVM (Support Vector Machine). This estimation is going to be used by the UGV to avoid possible accidents.

Use case conditions

Use case conditions
Assumptions
A UGV with an equipped monocular camera is available.
This equipment is present at least in Pilot 1 and Pilot 3.
Prerequisites
Computing power is needed, by edge device or via internet connection.
Dataset with actions to recognize.

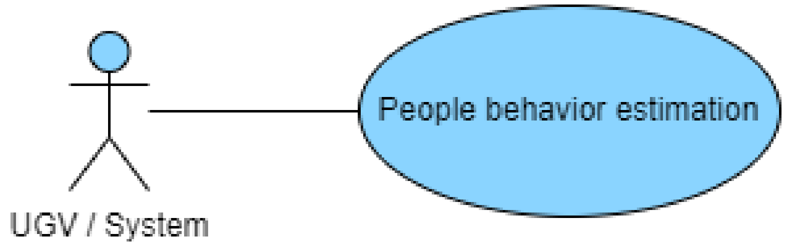
Further information to the use case for classification / mapping

Classification information
Relation to other use cases
It is part of the “Situation Awareness” category of common services.
Level of depth
Detailed Use Case
Prioritisation
Mandatory
Generic, regional or national relation
Generic.

Nature of the use case
Technical

Diagrams of use case

Diagram(s) of use case



Actors

Actors			
Grouping		Group description	
N/A		N/A	
Actor name	Actor type	Actor description	Further information specific to this use case
UGV	UGV	Unmanned Ground Vehicle – Agrobot	

Overview of scenarios

Scenario conditions						
No.	Scenario name	Scenario description	Primary actor	Triggering event	Pre-condition	Post-condition
1	Early warning system	The scenario describes the situation in which video analysis identifies the actions that the people present in the video sequence are taking to alert robots that are	UGV/System	N/A	Monocular camera stream available	It is necessary to define a format for the output data interface.

		deployed, to this event.				

Steps – Scenarios

Scenario							
Scenario name:	No. 1 - People detection, location and tracking						
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)
01	Start mission signal	Action detection	The process is initiated when the UGV starts any defined mission. In these circumstances, the process identifies when a person is presently doing something dangerous that could be in touch with the robot.	Docker	UGV	UGV	Action recognition event

5.2.4.4 Moving objects detection, location and tracking

Name of use-case

Use case identification		
ID	Area / Domain (s) / Zone (s)	Name of use case
CAS_MODLT_UC4	Artificial Intelligence / Machine Learning / Deep Learning - Computer Vision	Moving objects detection, location and tracking

Scope and objectives of use case

Scope and objectives of use case

Scope	This module will be able to detect and track moving objects (vehicles and people) from UAVs flying at 100 to 120 meters high, as well as to measure distances between them.
Objective (s)	1) Detect the object's bounding boxes in the image (including vehicles and people). 2) Assign a unique identification code to each object. 3) Measure distances between objects.

Narrative of the use case

Narrative of use case
Short description
Field surveillance from UAV by detecting and locating vehicles and people in the video stream. This service will detect and track moving objects and estimate the distances between them. This can be used to infer trajectories and predict possible crashes and/or conflicts.
Complete description
The use case presents the object detection and tracking module capable of detecting and tracking vehicles similar to tractors and agricultural machinery, as well as people, from the video stream captured from a UAV.

Use case conditions

Use case conditions
Assumptions
A UAV equipped with a camera with access to RGB channels is available.
This equipment is present in all three Pilots (1, 2 and 3).
Prerequisites
Camera calibration for measuring distances.
Computing power is needed, by edge device or via internet connection.
Dataset collected is good enough.

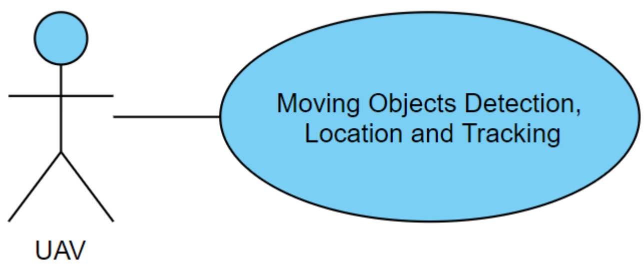
Further information to the use case for classification / mapping

Classification information
Relation to other use cases
It is part of the "Situation Awareness" category of common services.
Level of depth
Detailed Use Case

Prioritisation
Mandatory
Generic, regional or national relation
Generic.
Nature of the use case
Technical

Diagrams of use case

Diagram(s) of use case



Actors

Actors			
Grouping		Group description	
N/A		N/A	
Actor name	Actor type	Actor description	Further information specific to this use case
UAV	UAV	Unmanned Aerial Vehicle – Drone	N/A

Overview of scenarios

Scenario conditions						
No.	Scenario name	Scenario description	Primary actor	Triggering event	Pre-condition	Post-condition
1	Moving objects	In this use case, a module is	UGV	N/A	Monocular camera	It is necessary

	detection, location and tracking	implemented whereby the UAV will be able to analyse a video stream by detecting the present vehicles and people, following them and identifying the distance between them.			stream available	to define a format for the output data interface.

Steps – Scenarios

Scenario							
Scenario name:	No. 1 - Moving objects detection, location and tracking						
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)
01	Start mission signal	Moving objects detection, location and tracking	The process is initiated when the UAV starts the surveillance mission. The algorithm identifies the present vehicles and people and tracks them, inferring possible collisions or proximity alerts	Docker	UAV	UAV	Number and distance between objects position event

			between them.				

5.2.4.5 GIS plug-in

Name of use-case

Use case identification		
ID	Area / Domain (s) / Zone (s)	Name of use case
CAS_GISP_UC5	Artificial Intelligence / Machine Learning / Deep Learning - Computer Vision	GIS (Geographic Information System) plug-in

Scope and objectives of use case

Scope and objectives of use case	
Scope	Create a plug-in to consume Open Geospatial Consortium (OGC) FlexiGroBots endpoints and share own data in a standard data model (FDM extension).
Objective (s)	1. Use SmartDataLoader to extend the GeoServer service. 2. Create a Web App to consume OGC data.

Narrative of the use case

Narrative of use case
Short description
This module consists of a Web App capable of consuming OGC data and showing layers that are published in FlexiGroBots GIS servers. This includes a JavaScript SPA that shows geospatial information by consuming REST services.
Complete description
This module consists of a Web App capable of consuming OGC data and showing layers that are published in FlexiGroBots GIS servers. This includes a JavaScript SPA that shows geospatial information by consuming REST services.

Use case conditions

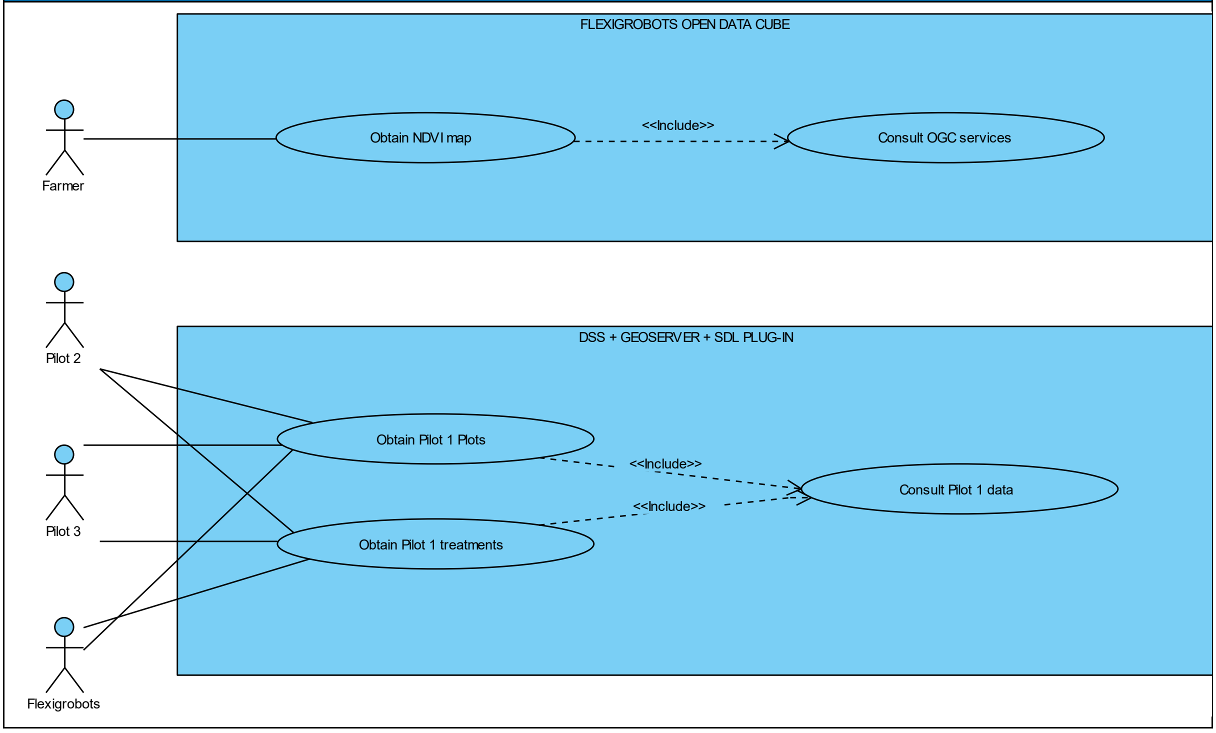
Use case conditions
Assumptions
Prerequisites

Further information to the use case for classification / mapping

Classification information
Relation to other use cases
It is part of the “Utility” category of common services.
Level of depth
Detailed
Prioritisation
Mandatory
Generic, regional or national relation
Generic.
Nature of the use case
Software module.

Diagrams of use case

Diagram(s) of use case



Actors

Actors	
Grouping	Group description

Actor name	Actor type	Actor description	Further information specific to this use case
Farmer	Human	Consults information about the health of the crops through the NDVI index.	
Pilot 2/3	System	Obtain information from the DSS Platform through Geoserver plug-in.	
FlexiGroBots	System	Obtain information from the DSS Platform through Geoserver plug-in.	

Overview of scenarios

Scenario conditions						
No.	Scenario name	Scenario description	Primary actor	Triggering event	Pre-condition	Post-condition
1	Obtain NDVI map	The farmer consults the state of his crops by checking a vigour map.	Farmer	N/A	NDVI map is generated.	-
2	Obtain Pilot 1 plots	An external system consumes geospatial information from Pilot's 1 crops.	Pilot/ FlexiGroBots	N/A	Geospatial information about the crops recorded in the DSS Platform.	Crop's information served in the external system.
3	Obtain Pilot 1 treatments	An external system consumes information from Pilot's 1 exploitation.	Pilot/FlexiGroBots	N/A	Phytosanitary treatments recorded in DSS Platform.	Exploitation's information served in the external system.

Steps – Scenarios

Scenario								
Scenario name:	No. 1 - Obtain NDVI map							
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requirement, R-IDs
1	NDVI map request		Farmer request NDVI map	DSS Visor	-	Farmer		

Scenario								
Scenario name:	No. 2 - Obtain Pilot 1 plots							
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requirement, R-IDs
1	Request plots information	Obtain plot's geometries.	Obtain geospatial information about pilots' 1 crops.	SDL Plug-in	-	Pilot 2/3, FlexiGroBots		

Scenario	
Scenario name:	No. 3 - Obtain Pilot 1 treatments

Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requirement, R-IDs
1	Request treatment information.	Obtain plot's treatments.	Obtain information about the phytosanitary treatments applied in pilot's 1 crops.	SDL Plug-in	-	Pilot 2/3, FlexiGroBots		

5.2.4.6 Disease detection in fruit

Name of use-case

Use case identification		
ID	Area / Domain (s) / Zone (s)	Name of use case
CAS_GDIS_UC6	Artificial Intelligence / Machine Learning / Deep Learning - Computer Vision	Disease detection in fruit

Scope and objectives of use case

Scope and objectives of use case	
Scope	Module capable of training neural networks for disease detection given small datasets, as well as making predictions with them.
Objective (s)	1) Training service by fine-tuning specific *Botrytis* detection model and specific grapevine detection model. 2) Inference service for making predictions using the trained models.

Narrative of the use case

Narrative of use case
Short description
Pretrained deep learning model to detect disease in fruit.
Complete description

Module for automating transfer learning between a specific neural network model for *botrytis* detection in grapevines into a custom disease detection in a given fruit.

Use case conditions

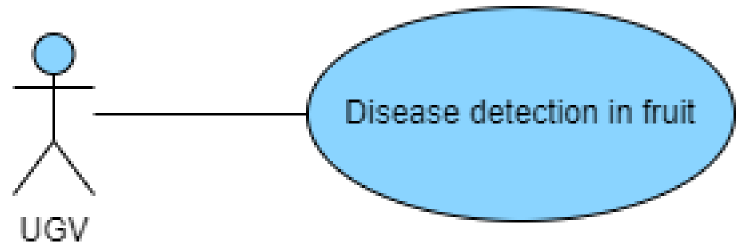
Use case conditions
Assumptions
A UGV with an equipped monocular camera is available.
This equipment is present at least in Pilot 1 and Pilot 3.
The user has a small dataset for re-training.
Prerequisites
Computing power is needed, by edge device or via internet connection.

Further information to the use case for classification / mapping

Classification information
Relation to other use cases
It is part of the "Generalization" category of common services.
Level of depth
Detailed Use Case
Prioritisation
Mandatory
Generic, regional or national relation
Generic.
Nature of the use case
Technical

Diagrams of use case

Diagram(s) of use case



Actors

Actors

Grouping		Group description	
N/A		N/A	
Actor name	Actor type	Actor description	Further information specific to this use case
UGV	UGV	Unmanned Ground Vehicle – Agrobot	N/A

Overview of scenarios

Scenario conditions						
No.	Scenario name	Scenario description	Primary actor	Triggering event	Pre-condition	Post-condition
1	Disease detection	This use case implements a module to detect a disease in fruits. More concrete botrytis in grapes	UGV	N/A	Monocular camera stream available	It is necessary to define a format for the output data interface.

Steps – Scenarios

Scenario							
Scenario name:	No. 1 - Disease detection						
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)
01	Start mission signal	Disease detection	The process is initiated when the farmer starts the recognition module, in this case, the streaming	Docker	UGV	UGV	Botrytis recognition event

			is analysed by this component identifying if grapes present in images have botrytis or not.				

5.2.4.7 Insect infestation detection

Name of use-case

Use case identification		
ID	Area / Domain (s) / Zone (s)	Name of use case
CAS_GINS_UC7	Artificial Intelligence / Machine Learning / Deep Learning - Computer Vision	Insect infestation detection in crop fields

Scope and objectives of use case

Scope and objectives of use case	
Scope	Service for, given a small dataset, training neural networks for insect detection in crops, as well as making predictions with them.
Objective (s)	1) Training service by transfer learning from specific *meligethes aeneuss* detection model. 2) Inference service for making predictions using the trained models.

Narrative of the use case

Narrative of use case
Short description
In the context of this use case, a convolutional neural network will be developed to detect a specific species of insect present in crops.
Complete description

An annotated dataset will be generated with enough images of the insect to be identified. Subsequently, a convolutional neural network will be trained for the detection of this type of insect using the previous dataset. In principle, it is intended to deploy this module onboard a UAV or to analyse the video streaming acquired by the UAV's onboard camera. In order to achieve this requirement, it could be necessary to develop a stabilization filter to improve the behaviour of the camera gimbal and reduce vibration noise.

Use case conditions

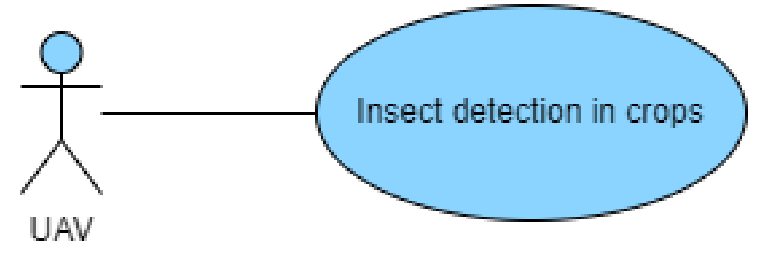
Use case conditions
Assumptions
A UAV with an equipped monocular camera is available.
This equipment is present at least in Pilot 2 and Pilot 3.
The user has a small dataset for re-training.
Prerequisites
Computing power is needed, by edge device or via internet connection.

Further information to the use case for classification / mapping

Classification information
Relation to other use cases
It is part of the “Generalization” category of common services.
Level of depth
Detailed Use Case
Prioritisation
Mandatory
Generic, regional or national relation
Generic.
Nature of the use case
Technical

Diagrams of use case

Diagram(s) of use case



Actors

Actors			
Grouping		Group description	
N/A		N/A	
Actor name	Actor type	Actor description	Further information specific to this use case
UAV	UAV	Unmanned Aerial Vehicle – Drone	N/A

Overview of scenarios

Scenario conditions						
No.	Scenario name	Scenario description	Primary actor	Triggering event	Pre-condition	Post-condition
1	Insect detection	This use case implements a module to detect insects in crops.	UGV	N/A	Monocular camera stream available	It is necessary to define a format for the output data interface.

Steps – Scenarios

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

01	Start mission signal	Insect detection	The process is initiated when the farmer starts the recognition module, in this case, the streaming is analysed by this component identifying if crops present in images have insects or not.	Docker	UAV	UAV	Insect recognition event

5.2.4.8 Weed detection in row planting fields

Name of use-case

Use case identification		
ID	Area / Domain (s) / Zone (s)	Name of use case
CAS_GWEED_UC8	Artificial Intelligence / Machine Learning / Deep Learning - Computer Vision	Weed detection in row planting fields.

Scope and objectives of use case

Scope and objectives of use case	
Scope	Service capable of reusing trained features and methods from a weed detection method in row planting fields to produce, given a small dataset, a re-trained model (transfer learning).
Objective (s)	1) Training module by transfer learning from Pilot 3's weed detection model. 2) Inference application for detecting weeds using the newly trained models.

Narrative of the use case

Narrative of use case

Short description
In this use case a weed detection deep neural network will be developed.
Complete description
Module for automating transfer learning between a specific neural network model for weed detection in row planting fields into a model for custom weed species detection.

Use case conditions

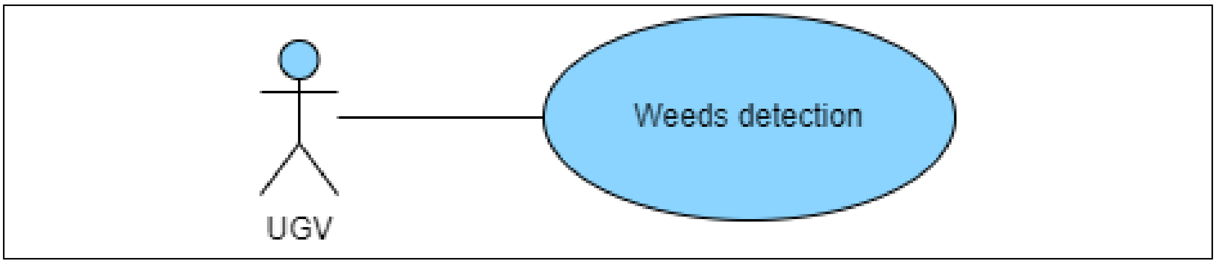
Use case conditions
Assumptions
A UGV with an equipped monocular camera is available.
This equipment is present at least in Pilot 1 and Pilot 3.
The user has a small dataset for re-training.
Prerequisites
Computing power is needed, by edge device or via internet connection.

Further information to the use case for classification / mapping

Classification information
Relation to other use cases
It is part of the “Generalization” category of common services.
Level of depth
Detailed Use Case
Prioritisation
Mandatory
Generic, regional or national relation
Generic.
Nature of the use case
Technical

Diagrams of use case

Diagram(s) of use case



Actors

Actors			
Grouping		Group description	
N/A		N/A	
Actor name	Actor type	Actor description	Further information specific to this use case
UGV	UGV	Unmanned Ground Vehicle – Agrobot	N/A

Overview of scenarios

Scenario conditions						
No.	Scenario name	Scenario description	Primary actor	Triggering event	Pre-condition	Post-condition
1	Weed detection	This use case implements a module to detect weeds in fields.	UGV	N/A	Monocular camera stream available	It is necessary to define a format for the output data interface.

Steps – Scenarios

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

01	Start mission signal	Weed detection	The process is initiated when the farmer starts the recognition module, in this case, the streaming is analysed by this component identifying if there are weeds in the field.	Docker	UGV	UGV	weeds recognition event

5.2.5 Mission Control Centre

5.2.5.1 Vehicles' provision

Name of use-case

Use case identification		
ID	Area / Domain (s) / Zone (s)	Name of use case
MCC_UC1	Precision agriculture/ robotics system	Vehicles' provision

Scope and objectives of use case

Scope and objectives of use case	
Scope	Registration and configuration of the ground and aerial robots that will be used in the execution of heterogeneous multi robots' missions.
Objective (s)	Maximise the flexibility and customisation features of the MCC.

Narrative of the use case

Narrative of use case
Short description
The mission operator configures the MCC with the robots that are going to be used during the execution of the mission.
Complete description

The appropriate communication protocol is selected from the list of supported options, checking that the connection with the specific unit is supported. The MCC supports uploading new firmware to the robot (through the Robot Fleets Management Systems) in case updates are available and the configuration of different parameters, e.g., navigation models, safety thresholds, camera and sensors options.

Key Performance Indicators (KPIs)

Key performance indicators			
ID	Name	Description	Reference to mentioned use case objectives
	Supported robots	Through the adoption of standard protocols, the MCC should be compatible with a wide number of ground and aerial robots.	

Use case conditions

Use case conditions
Assumptions
Prerequisites
Communication infrastructure to exchange data between the MCC and the robots.
Robot Fleets Management Systems should implement one of the communication protocols supported by the MCC.

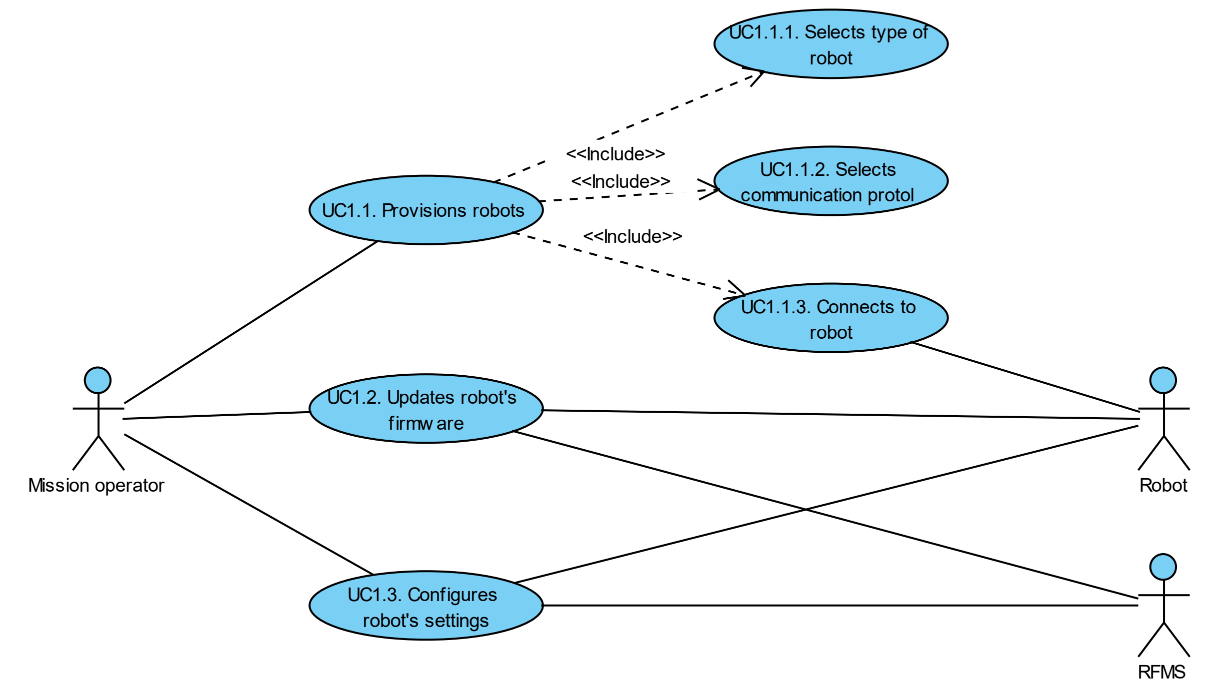
Further information to the use case for classification / mapping

Classification information
Relation to other use cases
Provisioning vehicles or robots is the first step before planning or executing the mission.
Level of depth
Detailed Use Case
Prioritisation
Mandatory
Generic, regional or national relation
Generic
Nature of the use case

Technical

Diagrams of use case

Diagram(s) of use case



Actors

Actors			
Grouping		Group description	
N/A		N/A	
Actor name	Actor type	Actor description	Further information specific to this use case
Mission operator	Human	Performs the provision of the vehicles in the MCC	
Robot	Device	It is registered and configured using the MCC	

Overview of scenarios

Scenario conditions						
No.	Scenario name	Scenario description	Primary actor	Triggering event	Pre-condition	Post-condition

1	Provisions robots	A new robot is registered in the MCC	Mission operator	A new robot must be used	N/A	Connectivity between robot and MCC, through Robot Fleets Management Systems
2	Updates robot's firmware	New firmware is uploaded to the robot	Mission operator	Firmware update is available	Connectivity between MCC and robot, through Robot Fleets Management Systems	Robot's firmware is updated
3	Configures robot's settings	Values are changed for configurable parameters	Mission operator	The robot's configuration must be adjusted	Connectivity between MCC and robot, through Robot Fleets Management Systems	Robot configuration adjusted

Steps – Scenarios

Scenario								
Scenario name:	No. 1 – Provisions robots							
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requirement, R-IDs
01	A new robot must be used	Type selection	Robot type and model are selected	POST	Mission operator	MCC	Robot type, robot model	
02	Step 01 completed	Communication protocol	Communication protocol	POST	Mission operator	MCC	Communication	

			with the robot is selected and configured				protocol, parameters	
03	Step 02 completed	Robot connection	A connection is established with the robot or with the RFMS	N/A	MCC	Robot	N/A	
04	Step 03 completed	Robot information	Information about the robot is retrieved	GET	Robot	Mission operator	Robot information	

Scenario								
Scenario name:	No. 2 – Update's robot firmware							
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requirement, R-IDs
01	Firmware update is available	Firmware selection	A new firmware file is uploaded to the MCC	POST	Mission operator	MCC	Firmware	
02	Step 01 completed	Firmware upload	The new firmware is uploaded to the robot through the RFMS	POST	MCC	Robot	Firmware	

03	Step 02 completed	Firmware checking	The firmware update operation is confirmed	N/A	Mission operator	Robot	Firmware version	

Scenario								
Scenario name:	No. 3 – Configure robot's settings							
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requirement, R-IDs
01	The robot's configuration must be adjusted	Retrieve configuration options	Possible configuration parameters and current values are listed.	GET	Robot / RFMS	MCC	Configuration parameter and values.	
02	The robot's configuration must be adjusted	Sets configuration	A new value is defined for one or several parameters.	POST	MCC	Robot	Configuration parameter and new value.	

5.2.5.2 Mission plan creation

Name of use-case

Use case identification		
ID	Area / Domain (s) / Zone (s)	Name of use case
MCC_UC2	Precision agriculture/ robotics system	Mission plan creation

Scope and objectives of use case

Scope and objectives of use case	
Scope	Planification of precision agriculture missions to be executed by fleets of heterogeneous ground and aerial robots.
Objective (s)	Provide mechanisms to facilitate the definition and planification of complex robotics missions for precision agriculture tasks, considering the specific characteristics of target fields and crops and making it possible to orchestrate actions between the different members of the fleets of robots.
Related business case (s)	N/AS

Narrative of the use case

Narrative of use case
Short description
The mission operator uses the functionalities of the MCC to generate a mission plan, assigning specific actions to each one of the robots of the fleet according to the initial goals and constraints.
Complete description
The main goal of the use case is the generation of a mission plan to achieve the objectives of a specific precision agriculture task (e.g., pests' detection and treatment, soil sampling). It implies the specification of the role that each UAV or UGV must perform taken into account the characteristics of the field and crops in terms of boundaries, physical configuration, etc. The drone operator will have graphical tools and interfaces in order to complete this task in an easy and intuitive manner.

Use case conditions

Use case conditions
Assumptions
The characteristics of the fleets of robots are appropriate to execute the mission.
Prerequisites
Robots have been previously loaded in the MCC

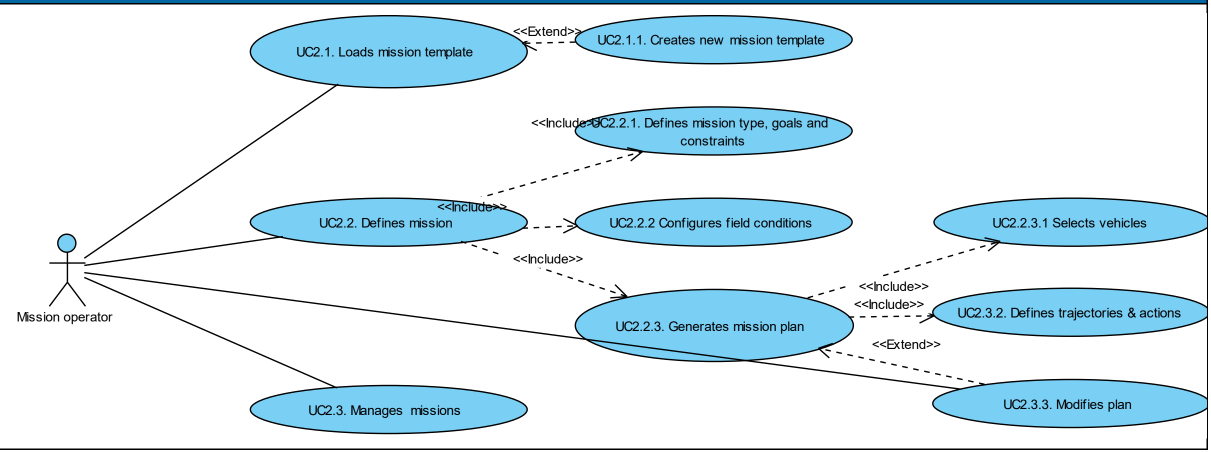
Further information to the use case for classification / mapping

Classification information
Relation to other use cases
Mission plan creation is required for execution and supervision (MCC_UC3, MCC_UC4)
Level of depth

Detailed Use Case
Prioritisation
Mandatory
Generic, regional or national relation
Generic
Nature of the use case
Technical

Diagrams of use case

Diagram(s) of use case



Actors

Actors			
Grouping		Group description	
Actor name	Actor type	Actor description	Further information specific to this use case
Mission operator	Human	Performs the planification of the mission.	

Overview of scenarios

Scenario conditions						
No.	Scenario name	Scenario description	Primary actor	Triggering event	Pre-condition	Post-condition

1	Loads mission template	From available pre-defined mission templates provided by the MCC, the mission operator selects the most appropriate.	Mission operator	N/A	Mission templates are available	Mission template is loaded
2	Defines mission	Configuration of the mission and assignment of tasks to each one of the robots.	Mission operator	N/A	Mission template selected; robots are provided	Mission plan generated
3	Manages missions	Missions can be read, updated and deleted.	Mission operator	N/A	Mission plans are created	Missions are updated

Steps – Scenarios

Scenario								
Scenario name:	No. 1 – Loads mission template							
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requirement, R-IDs
1	Mission operator plans a new mission. An appropriate template does not exist	Mission template creation	A new mission template is created with pre-defined options and types of robots	POST	Mission operator	MCC	Mission description	

2	Mission operator plans a new mission. An appropriate template exists	Mission template load	An available mission template is loaded from the library.	GET	Mission operator	MCC	Mission template	

Scenario								
Scenario name:	No. 2 – Defines mission							
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requirement, R-IDs
1	Scenario 01 completed	Set goals and constraints	Definition of objective and constraints for the execution of the mission	POST	Mission operator	MCC	Mission information and metadata	
2	Step 01 completed	Configures field condition	Selection of geographical area, identification of relevant infrastructure, description of field conditions.	POST	Mission operator	MCC	Field conditions	

3	Step 02 completed	Vehicle selection	Mission is decomposed into tasks. For each one, a robot is assigned.	POST	Mission operator	MCC	Robot ID	
4	Step 03 completed	Set trajectories and actions	Defines waypoints, regions of interest, patterns, etc. Selects actions to be executed.	POST	Mission operator	MCC	Robot ID, trajectories, actions	
5	Step 03 completed	Plan modification	The mission plan can be adjusted	POST	Mission operator	MCC	Mission plan updated	

Scenario								
Scenario name:	No. 3 – Manages mission							
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requirement, R-IDs
1	Mission operator needs to manage missions	Reads missions	Retrieves the list of missions	GET	MCC	Mission operator	Mission's list	
2	Step 01 completed	Reads mission	Retrieves a mission plan	GET	MCC	Mission operator	Mission ID, Mission information	

3	Step 02 completed	Updates mission	Updates a mission plan	POST	Mission operator	MCC	Updated mission	
4	Step 03 completed	Deletes mission	A mission is removed	DELETE	Mission operator	MCC	Mission ID	

5.2.5.3 Missions' execution

Name of use-case

Use case identification		
ID	Area / Domain (s) / Zone (s)	Name of use case
MCC_UC3	Precision agriculture/ robotics system	Mission's execution

Scope and objectives of use case

Scope and objectives of use case	
Scope	Execution of precision agriculture missions by fleets of heterogeneous robots.
Objective (s)	Automation of time-consuming and heavy tasks, support for farmworkers in farm operations, improve the yield and the environmental sustainability of agriculture procedures. Guarantee the safe execution of the robotics missions.

Narrative of the use case

Narrative of use case
Short description
Missions' plans will be uploaded to the robotics fleets potentially through RFMS. The mission operator will start the mission, monitoring through the MCC its correct and safe execution.
Complete description

The actions to be performed by each one of the members of the fleet will be uploaded through the corresponding interfaces or through the Robot Fleet Management System. Depending on the specific goals of the mission and the capacities of each robot, different levels of automation will be enforced. Once the mission is started by the mission operator, the ground and aerial robots will start to execute the missions. Through the MCC user interface, the mission operator will receive detailed real-time information to check that the mission is being done according to the plan and that no major issues are detected. In order to allow controlling more than one robot at the same time, the MCC will incorporate mechanisms to automatically detect potential failures or risks both in the behaviour of each unit and at the mission level. Alerts will be raised to the mission operator so that appropriate actions can be made. Finally, the MCC will interact in real-time with the rest of the systems available in the scenario (e.g., FMS, AI services) to improve the real-time adaption capabilities of the overall system.

Use case conditions

Use case conditions
Assumptions
Mission operator has all required permissions and licenses to execute the mission.
Mission operator has enough knowledge about the involved robots to safely execute the mission.
Appropriate safety measures have been adopted taking into account potential risks.
The mission plan is correct and takes into account the goals of the task and the characteristics of the field / farm.
Prerequisites
A mission plan has been created in the MCC.
The MCC is compatible and interoperable with involved robots and RFMS.

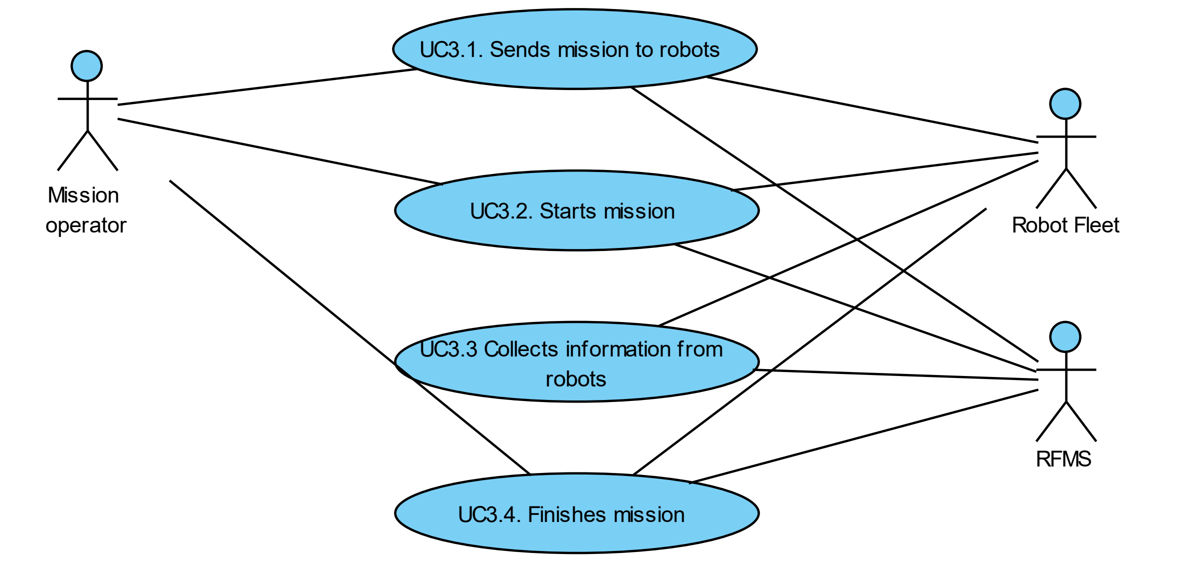
Further information to the use case for classification / mapping

Classification information
Relation to other use cases
The creation of a mission plan following MCC_UC2 is required for the execution of the mission. Once it is started, it will be monitored through MCC_UC4.
Level of depth
Detailed Use Case
Prioritisation
Mandatory
Generic, regional or national relation

Generic
Nature of the use case
Technical

Diagrams of use case

Diagram(s) of use case



Actors

Actors			
Grouping		Group description	
Actor name	Actor type	Actor description	Further information specific to this use case
Mission operator	Human	Send the mission to the robots' fleet and trigger the execution through the MCC.	
Robot Fleet	Device	Fleet of multiple robots including UGVs and UAVs.	
Robot Fleet Management System	System	System in charge of the low-level management of a set of robots.	

Overview of scenarios

Scenario conditions						
No.	Scenario name	Scenario description	Primary actor	Triggering event	Pre-condition	Post-condition
1	Sends mission to robots	The mission plan is sent to the fleet through the corresponding interfaces or RFMS.	Mission operator	N/A	A mission plan has been defined.	Robot fleet ready to start the mission.
2	Starts mission	Mission is launched.	Mission operator	N/A	The mission is uploaded to the robots.	Robots start the execution.
3	Collects information from robots	Detailed information is collected from the robot fleet during the execution of the mission.	Robot fleet	Mission is started		Real-time data from robots
4	Finishes mission	The mission is stopped.	Mission operator	N/A	Mission is started	Mission is stopped

Steps – Scenarios

Scenario								
Scenario name:	No. 1 – Sends mission to robots							
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requirement, R-IDs
1	Mission operator triggers the	Generate individual	The MCC splits the complete mission	N/A	MCC	MCC	Mission ID	

	service to send a mission to the robot fleet	mission plans	plan between the several robots.					
2	Step 01 completed	Sends mission	Robots or RFMS received the corresponding mission plan	POST	MCC	Robot Fleet, RFMS	Mission	

Scenario								
Scenario name:	No. 2 – Starts mission							
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requirement, R-IDs
1	Mission operator triggers the option to start the mission	Starts mission	MCC launches the order to start the mission to the robot fleet, potentially through the RFMS.	POST	MCC	Robot fleet, RFMS		

Scenario

Scenario name:	No. 3 – Collects information from robots							
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requirement, R-IDs
1	Mission is started	Gets telemetry data	MCC retrieves telemetry data from the robot fleet / RFMS.	GET	Robot fleet, RFMS	MCC	Telemetry data	
2	Mission is started	Get logs	MCC retrieves additional logs from the robot fleet / RFMS.	GET	Robot fleet, RFMS	MCC	Logs	
3	Steps 01 or 02 completed	Stores information	MCC stores received information	EXECUTE	MCC	MCC		

Scenario								
Scenario name:	No. 4 – Finishes mission							
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requirement, R-IDs

1	Mission operator stops the mission	Stops mission	MCC launches the order to stop the mission to the robot fleet, potentially through the RFMS.	POST	MCC	Robot fleet, RFMS		

5.2.5.4 Missions supervision

Name of use-case

Use case identification		
ID	Area / Domain (s) / Zone (s)	Name of use case
MCC_UC4	Precision agriculture/ robotics system	Missions supervision

Scope and objectives of use case

Scope and objectives of use case	
Scope	Monitoring and supervision of the mission execution.
Objective (s)	Ensures the safe and successful implementation of the mission plan according to the high-level goals and constraints, providing mechanisms so that the mission operator can manage and control multiple robots in parallel.

Narrative of the use case

Narrative of use case
Short description
Once the mission execution starts, the MCC collected detailed information from the robots. The data is analysed in order to detect potential failures are safety risks, launching appropriate alarms and unchaining needed corrective actions.
Complete description

One of the main goals of the FlexiGroBots project is to enable the execution of complex agricultural missions by fleets of multiple and heterogeneous robots with the capacity to interact between them, modifying dynamically their initial tasks according to new circumstances and events. In this sense, the role of the MCC is to obtain from the different members of the fleets (potentially through the RFMS) detailed data about telemetry and sensors' observations to assess the evolution of the mission according to the initial plan. The collected information will be analysed in real-time in order to detect anomalies, incidents or potential risks. Depending on the level of criticality and the level of automation configured by the mission operator, the MCC will try to overcome the situation by enforcing appropriate actions. In all cases, notifications and alarms will be sent to the operator so that human intervention is guaranteed.

Use case conditions

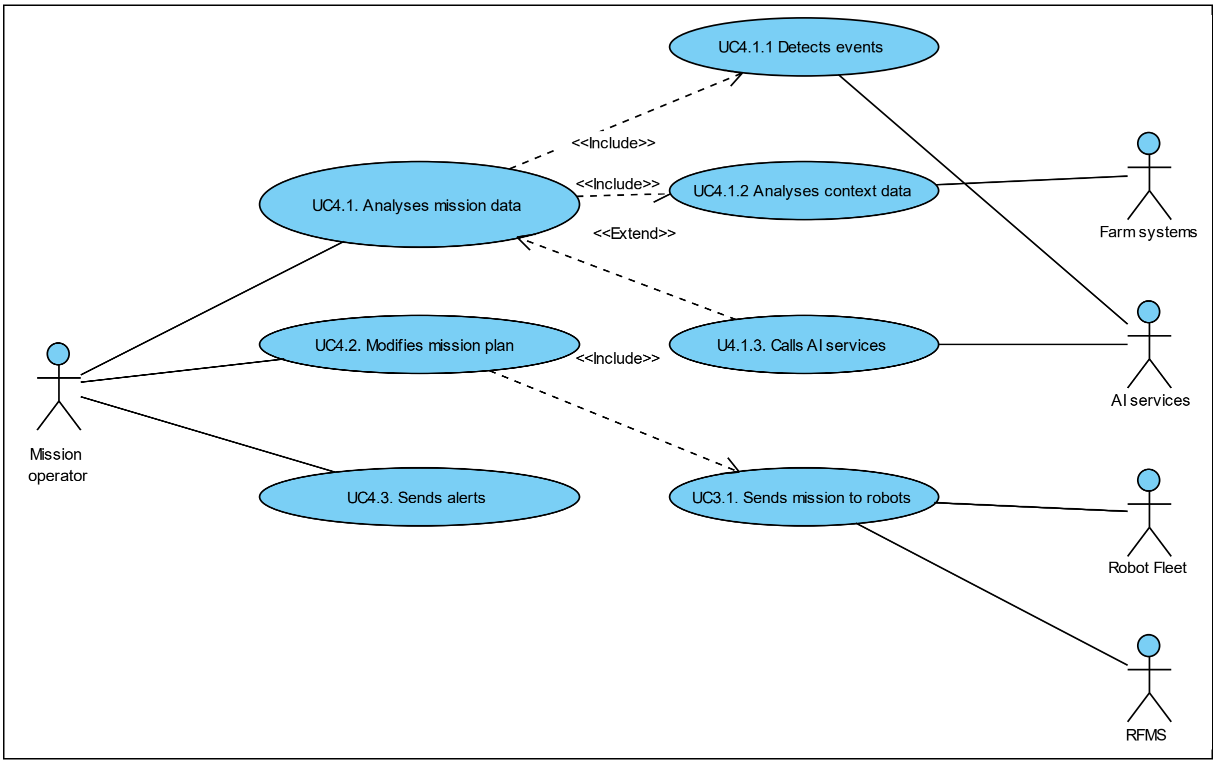
Use case conditions
Assumptions
Mission operator has enough knowledge about the involved robots to safely execute the mission and to monitor them.
Prerequisites
The mission plan is correct and takes into account the goals of the task and the characteristics of the field / farm.
Appropriate safety measures have been adopted taking into account potential risks.

Further information to the use case for classification / mapping

Classification information
Relation to other use cases
Previous use-cases (MCC_UC1, MCC_UC2, MCC_UC3) are required for MCC_UC4.
Level of depth
Detailed Use Case
Prioritisation
Mandatory
Generic, regional or national relation
Generic
Nature of the use case
Technical

Diagrams of use case

Diagram(s) of use case



Actors

Actors			
Grouping		Group description	
Actor name	Actor type	Actor description	Further information specific to this use case
Mission operator	Human	Responsible for the supervision and control of the mission execution.	
Robot Fleet	Device	Fleet of UAVs and UGVs in charge of implementing the mission.	
Farm systems	System	Digital systems are used as part of the farm operations.	
AI services	System	ML models and AI serviced were developed using the	

		FlexiGroBots AI platform.	
RFMS	System	System in charge of the low-level management of a set of robots.	

Overview of scenarios

Scenario conditions						
No.	Scenario name	Scenario description	Primary actor	Triggering event	Pre-condition	Post-condition
1	Analyses mission data	Collected information from the execution of the mission is analysed and processed together with context data from other systems.	MCC	Mission is launched	Data from the mission is available	Events or failures are detected
2	Modifies mission plan	Considering unexpected situations and the evolution of the mission, the mission plan is adjusted automatically or with the intervention of the operator.	MCC	Detection of events during the mission	Data from the mission is available	Mission plan is updated
3	Send alerts	Alerts are sent to inform the mission operator about events or problems during the execution. Level of	MCC	Detection of events during the mission	Data from the mission is available	Notifications are sent.

		criticality is considered.				

Steps – Scenarios

Scenario								
Scenario name:	No. 1 – Analyses mission data							
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requirement, R-IDs
1	Mission is launched	Events detection	AI services are used by the MCC in order to detect issues in the data obtained from the robots.	POST	MCC	AI services	Mission data, events	
2	Mission is launched	Context data analysis	Context data from FMS, geospatial services or AI models are analysed.	GET	MCC	Farm systems	Context data	

Scenario	
Scenario name:	No. 2 – Modifies mission plan

Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requirement, R-IDs
1	Detection of events during the mission	Mission plan update	The MCC introduces automatically changes in the mission plan according to the situation.	EXECUTE	MCC	MCC	Updated mission plan	
2	MCC introduces changes in the mission	Plan update confirmation	The MCC requests confirmation of changes in the plan to the operator, who may add additional updates.	POST	MCC	Mission operator	Updated mission plan	
3	Mission operator confirm or introducing additional changes in the mission plan	Send mission plan	The MCC sends the updated mission plan to the robot fleet / RFMS	POST	MCC	Robot fleet / RFMS	Updated mission plan	

Scenario

Scenario name:	No. 3 – Sends alerts							
Step No.	Event	Name of process / activity	Description of process / activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requirement, R-IDs
1	Detection of events during the mission	Filter alerts	Considering mission configuration, MCC decides which alerts must be shown to the operator.	EXECUTE	MCC	MCC	N/A	
2	Critical situations are detected	Show alerts	Critical alerts are shown in the MCC GUI.	POST	MCC	Mission operator	Alerts	

5.3 Development view

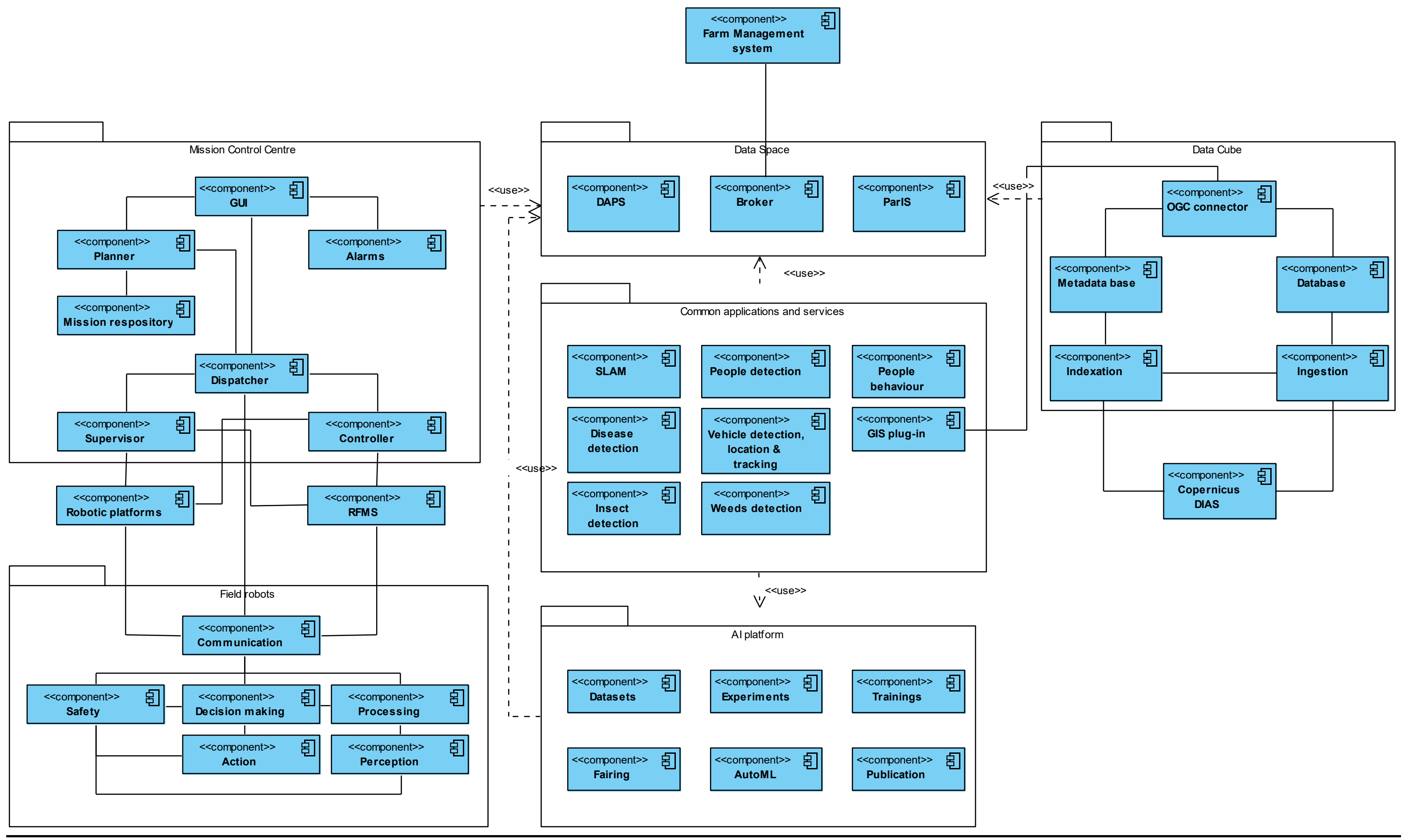


Figure 26 FlexiGroBots platform development view presented using a UML component model

Figure 26 presents the process view of FlexiGroBots platform technical architecture in the form of a UML component diagram. As can be seen, it is composed of several layers or main building blocks in order to realize the implementation of the required functionalities to support multi robots missions. In the following paragraphs, each one of the layers or building blocks present in FlexiGroBots is described:

- **Copernicus DIAS:** the five existing Copernicus DIAS [61] (or Data and Information Access Services) provide centralised and standardised access to Copernicus data and information. They include also analytical and processing tools.
- **Data Cube**: the Open Data Cube (ODC) [25] is an open-source solution for accessing, managing, and analysing large quantities of Geographic Information System (GIS) data - namely Earth observation (EO) data.
- **Robotics platforms and robots' fleets management systems (RFMS):** systems developed by manufacturers for the low-level control and operation of aerial and ground robots. They are used to manage and deploy robots and fleets, providing in some cases real-time information for monitoring purposes.
- **Mission Control Centre (MCC):** a group of components that belong to the FlexiGroBots platform devoted to allowing planning, executing and supervising complex precision agriculture missions executed by fleets of heterogeneous ground robots. It includes a set of graphical users' interfaces so that operators have the possibility to easily design missions considering available historic and real-time information from the crop. The MCC may interact directly with the robots or more often with robotics platforms or RFMs to retrieve telemetry information and to send missions or actuation commands. An important functionality of the MCC will be devoted to guaranteeing the successful and secure execution of the mission, by analysing real-time information and raising potential alerts to the operator if needed.
- **Data Space:** based on IDSA reference architecture and guidelines and available open-source implementation of required components, the goal of this layer is to break silos between different vendors or systems' providers, not just addressing technical issues like interoperability, semantics or data models but for paying attention to governance policies that must allow controlling data access and usage. FlexiGroBots Data Space will be built around the minimum and required components proposed by IDSA reference architecture to create a viable implementation.
- **AI platform:** end-to-end management of the operations required to build and deploy Machine Learning models following an MLOps paradigm. The AI platform should be offered as a service, facilitating access to powerful specialised hardware and software resources in a seamless manner to data scientists and ML engineers working in the precision agriculture domain. The interconnection with FlexiGroBots data space will bring the possibility to ingest high added-value information from multiple farmers while

preserving their privacy and rights, also opening the door to train or to improve a wide variety of Machine Learning models, which will be published also in the AI4EU catalogue. Besides downloading the models so that they can be deployed and served on-premises, FlexiGroBots considering offering these models also following an "as a service approach" so that anyone can benefit from them without having AI knowledge.

- **FlexiGroBots services:** featuring as common applications and services there will be a series of software modules designed with the purpose of being shared and reused; both within the different use-cases of the project and in other agricultural robotic solutions in the future. The list of these components is still open and there could be some changes in the future. The current list of common services is the following:
  - Simultaneous Location And Mapping (SLAM) with 3D scene reconstruction from a monocular camera.
  - Computer vision module for people detection, location and tracking. Each person would have a unique identification code, and the module would estimate the distances to the camera.
  - Computer vision module for agricultural vehicle detection, location and tracking. This module will be specifically trained for agricultural robots, tractors and vehicles to be detected from high heights (UAVs).
  - Photogrammetry: all three pilots will use high-resolution images built by assembling sequences of pictures (typically from UAVs). The focus and scope of this task are currently being defined. The first proposal for this service would be to develop a module for the automatic generation of said photogrammetry images.
  - GIS consumption. This software module will interact with the Open Data Cube in order to allow consuming data from it.
  - Generalization of the specific computer vision components of each Pilot: disease detection in fruit, insect infestation detection in crops, weed detection in berry fields. In this module the partners will apply domain adaptation and transfer learning, among other techniques, to create common services from the specific components of their pilots. This includes common modules for classification, object detection and image segmentation tasks.
- **Farm Management Systems:** they are the main interface used by farmers in order to visualise all the relevant data and to make decisions. Typically, web dashboards and mobile applications are the predominant technologies.

5.4 Logical view

Figure 27 presents the logical view model for two FlexiGroBots subsystems: the AI platform and the common application services. A UML class diagram has been used. The AI platform will be able to handle *Datasets* following the description of the use-cases included in 5.2.1.1.

An important functionality will be the possibility to manage multiple versions so that AI developers can track changes in the information and to have visibility and traceability about the information used to generate each training and model. Trainings will be linked to *Datasets* and *Experiments* and they will produce *Models* that may be used to create *CommonApplicationServices*. At the same time, the models will be served from the AI platform or on-premises using Kubernetes manifests.

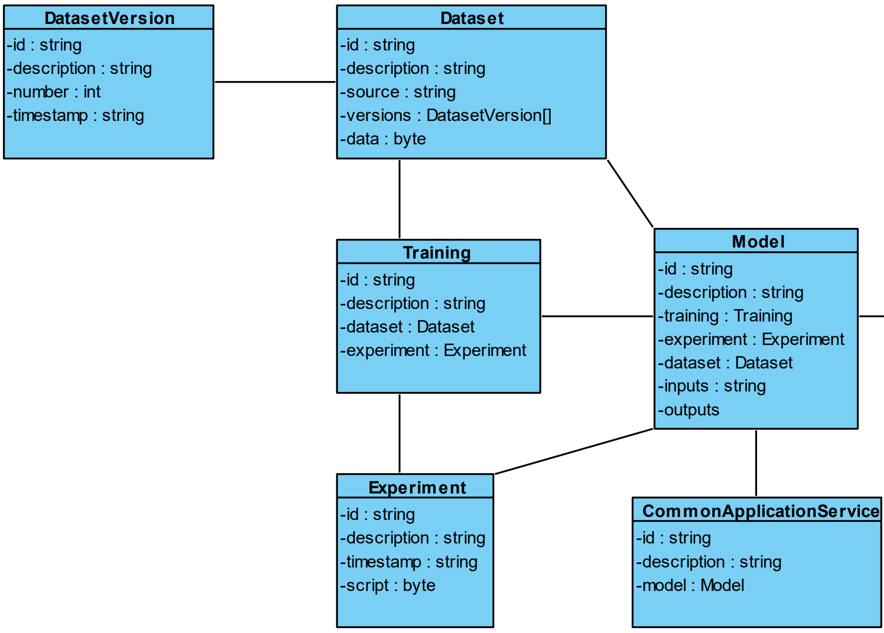


Figure 27 Logical view of FlexiGroBots AI platform and common application services

In the case of the common data services, the information model is described in detail in [62]. An example is included in Figure 28.

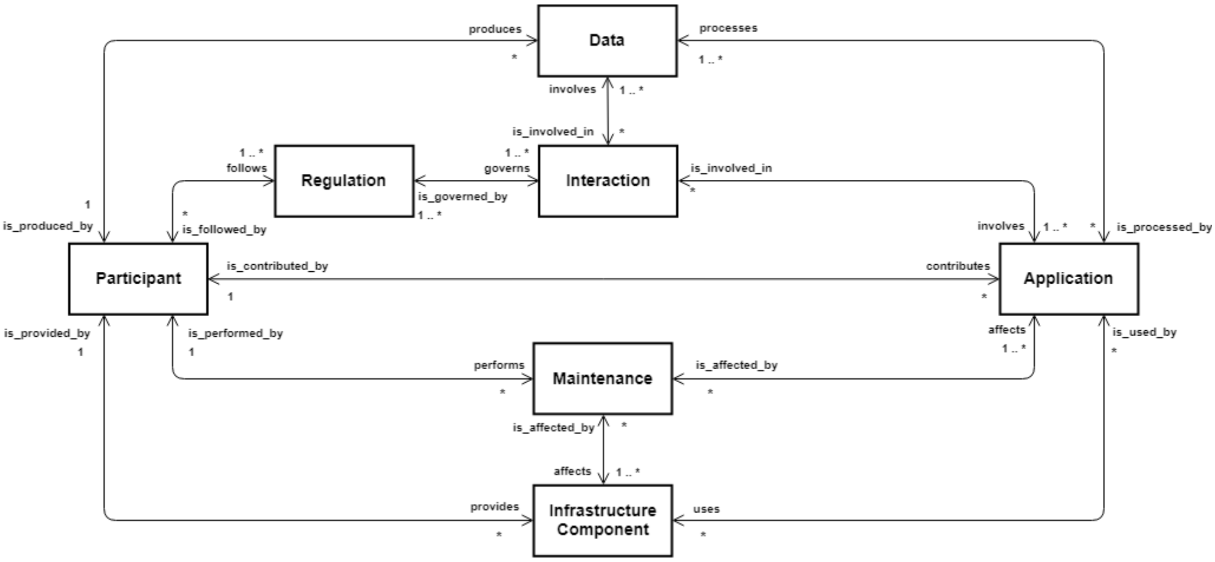


Figure 28 Facets of the IDS Information Model. Source: [62]

The geospatial enablers and services are based on the Foodie data model described in section 3.2.7.

For the Mission Control Centre, the corresponding class diagram is included in Figure 29 using again a UML class diagram.

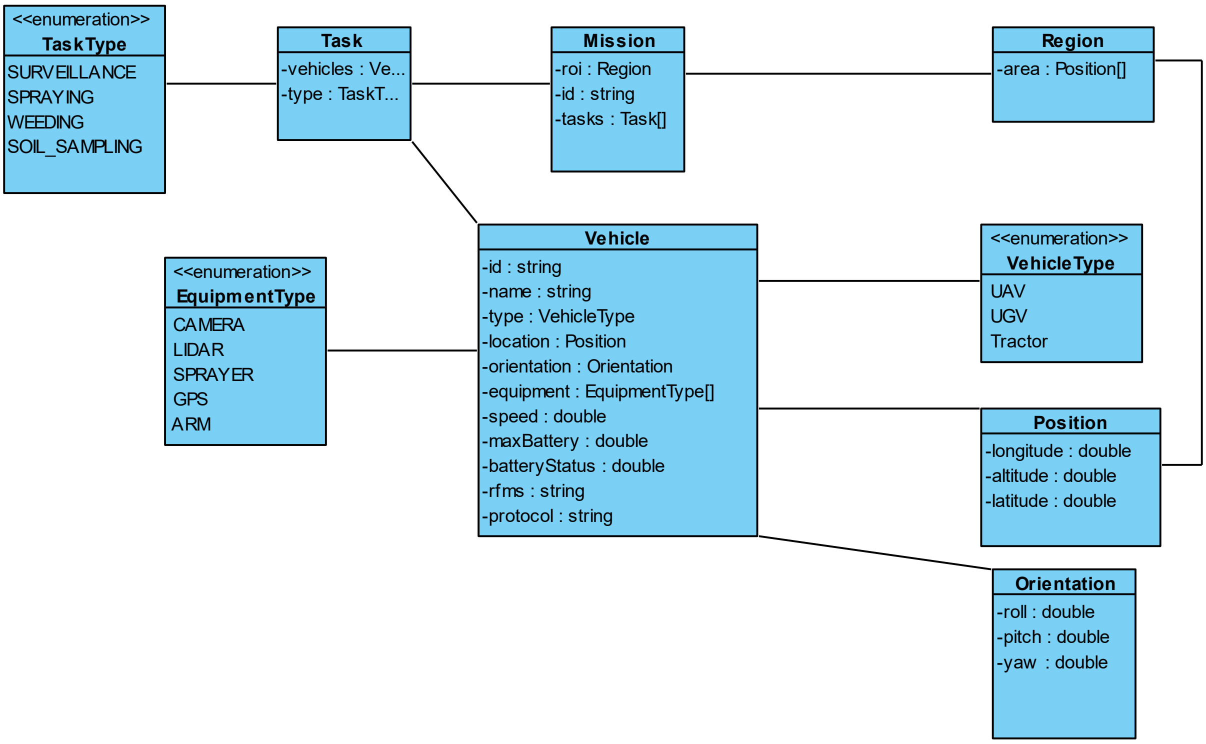


Figure 29 Logical view of FlexiGroBots MCC

UAVs and UGVs are represented as *Vehicles* that will incorporate different types of cameras, sensors or specialised equipment, which is modelled using an enumeration *EquipmentType*. The type of vehicle (*VehicleType*) considers at this moment UAVs, UGVs and Tractors. In order to reflect their current status, *Orientation* and *Position* are defined. Finally, the *Mission* is composed of a group of *Tasks* that must be performed in a certain *Region* by a fleet of *Vehicles*. An enumeration *TaskType* is used to model possible tasks.

5.5 Process view

Under the umbrella of the process view, UML sequence diagrams are used to model the exchanges and interactions that happen between the different components in order to realise the functionalities described in the use-cases of section 5.2.

Figure 30 shows the process to make data resources available in the FlexiGroBots Agriculture Data Space so that they can be discovered and consumed by third parties in order to create new applications and services. It must be noted that this sequence diagram follows the specification of the use-case described in 5.2.2.1.

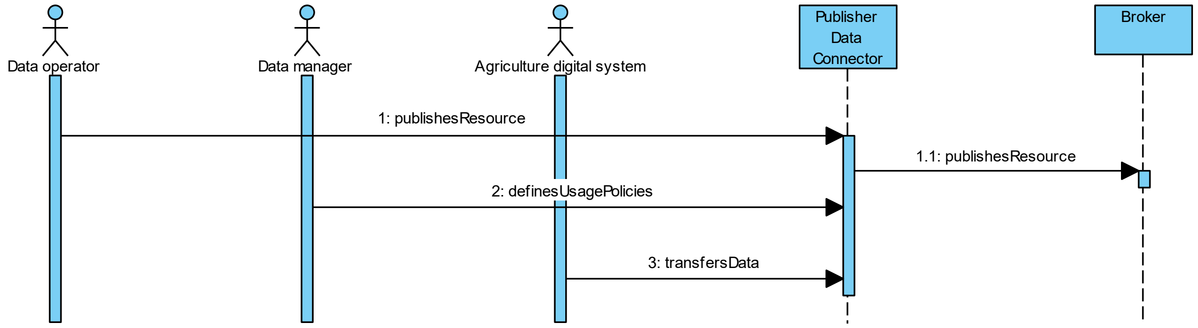


Figure 30 Publication of data in the FlexiGroBots ADS

Figure 31 contains the sequence diagram for the consumption of the data by the AI platform through FlexiGroBots ADS. This will allow that AI developers can seamlessly collect high-quality datasets from any IDSA-compliant digital system used in the agriculture domain to create powerful AI applications powered by ML models. The rest of the interactions show the process needed to generate a new model. This sequence diagram must be seen as a combination of the use-cases described in 5.2.1 and 5.2.2.2. Some details have been omitted for the sake of the understandability of the diagram.

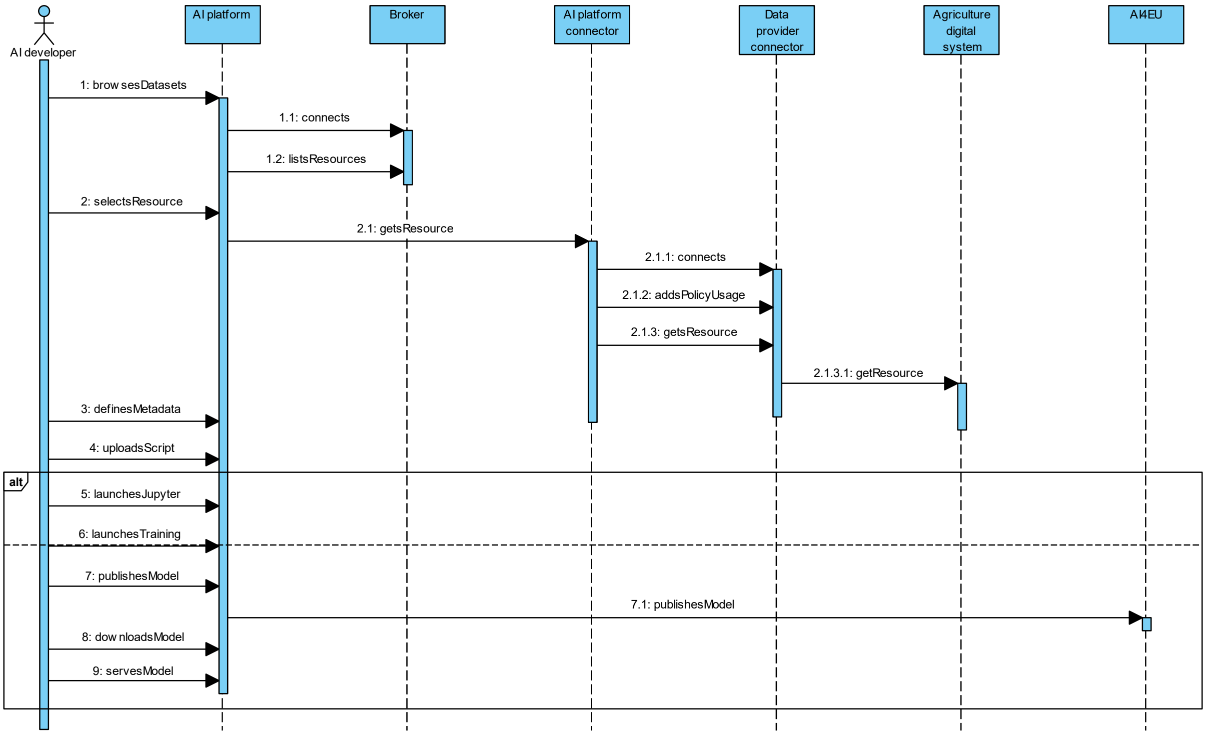


Figure 31 Consumption of data from FlexiGroBots ADS by the AI platform. Generation of new models

Figure 32 is the sequence diagram that allows implementing the functionalities described by the MCC use-cases of 5.2.5, covering the provisioning of the robots, the creation of the mission plan, its execution, supervision and the continuous analysis of collected data in order to detect unexpected situations or failures that must be notified to the mission operator so that the original mission plan can be modified properly.

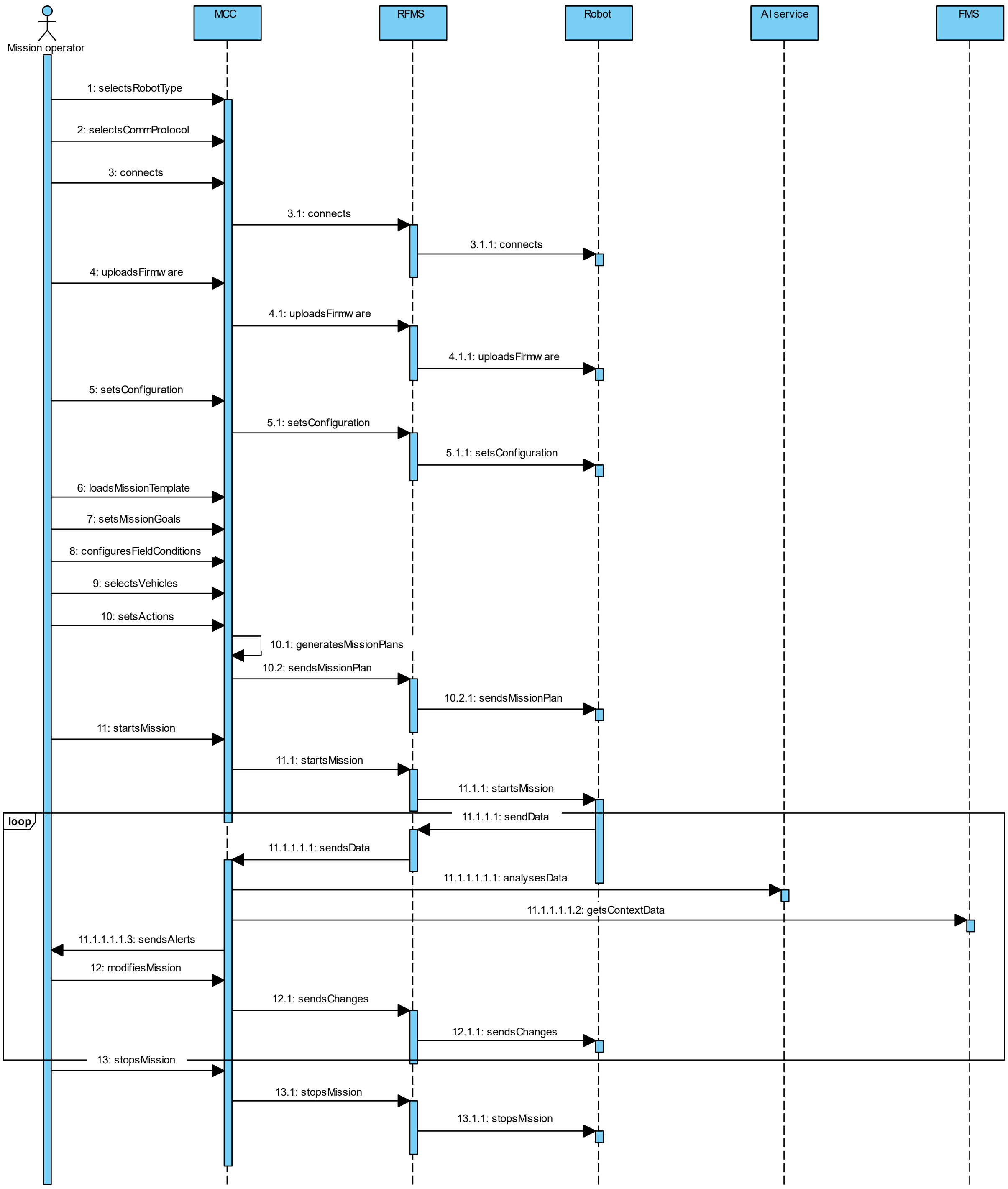


Figure 32 Robots' provisioning, mission plan creation, mission execution and supervision

Finally, Figure 33 is used to present dynamic aspects of the use-cases for the geospatial enablers and services as described in 5.2.3. It covers the registration and indexing of new Earth Observation data coming from Sentinel 2 and UAVs, but also the functionalities needed to get access and process this information.

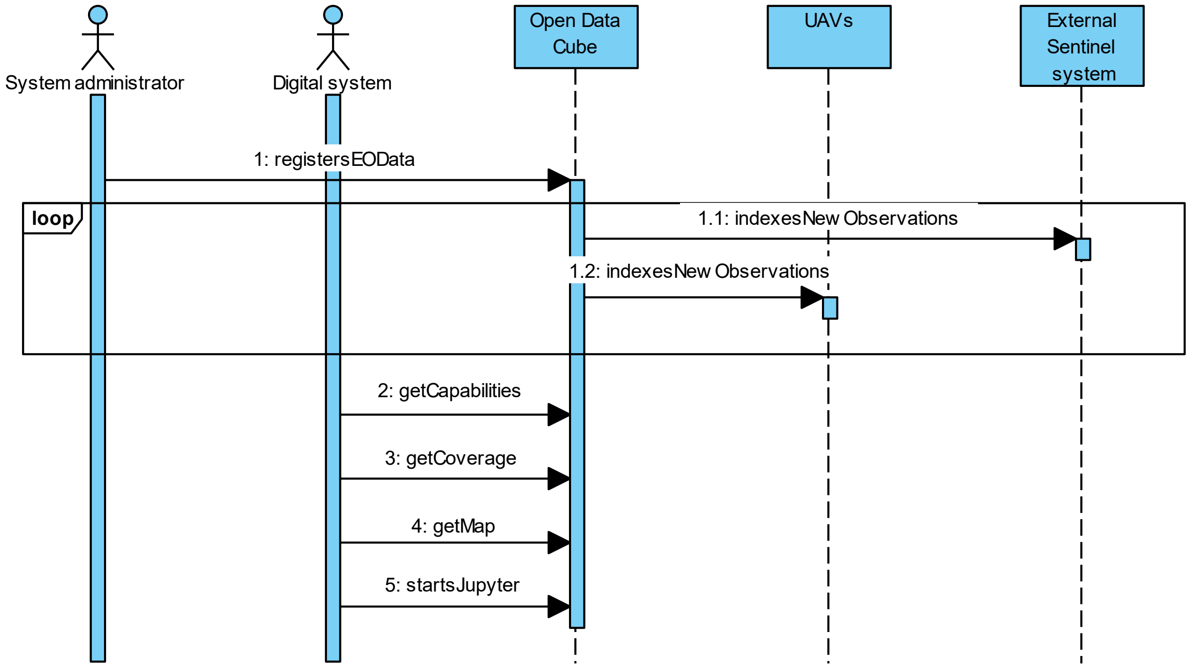


Figure 33 Provisioning and access to EO data

5.6 Physical view

Figure 34 presents the UML deployment diagram for the FlexiGroBots platform, which corresponds to the UML component model or development view of Figure 26. The purpose of this kind of diagram is to illustrate the aspects related to the physical configuration of the platform, showing in which nodes and devices each one of the artefacts will be deployed. The figure shows that certain common application services will be embedded directly within the UGVs. This is the case of the SLAM that will be used to improve the autonomous navigation capabilities of the agriculture ground robots, components to detect and identify people and their behaviours so that safe interaction with human workers can be enforced and finally for the detection of diseases, insects and weeds in the crops. UAVs and UGVs will be connected to a part of the MCC that will be installed in a ground control station, near the vehicles. Initially, the rest of the FlexiGroBots platform will be deployed in the cloud tier using Kubernetes as orchestrator. This will open the door also to have on-premises deployments if needed.

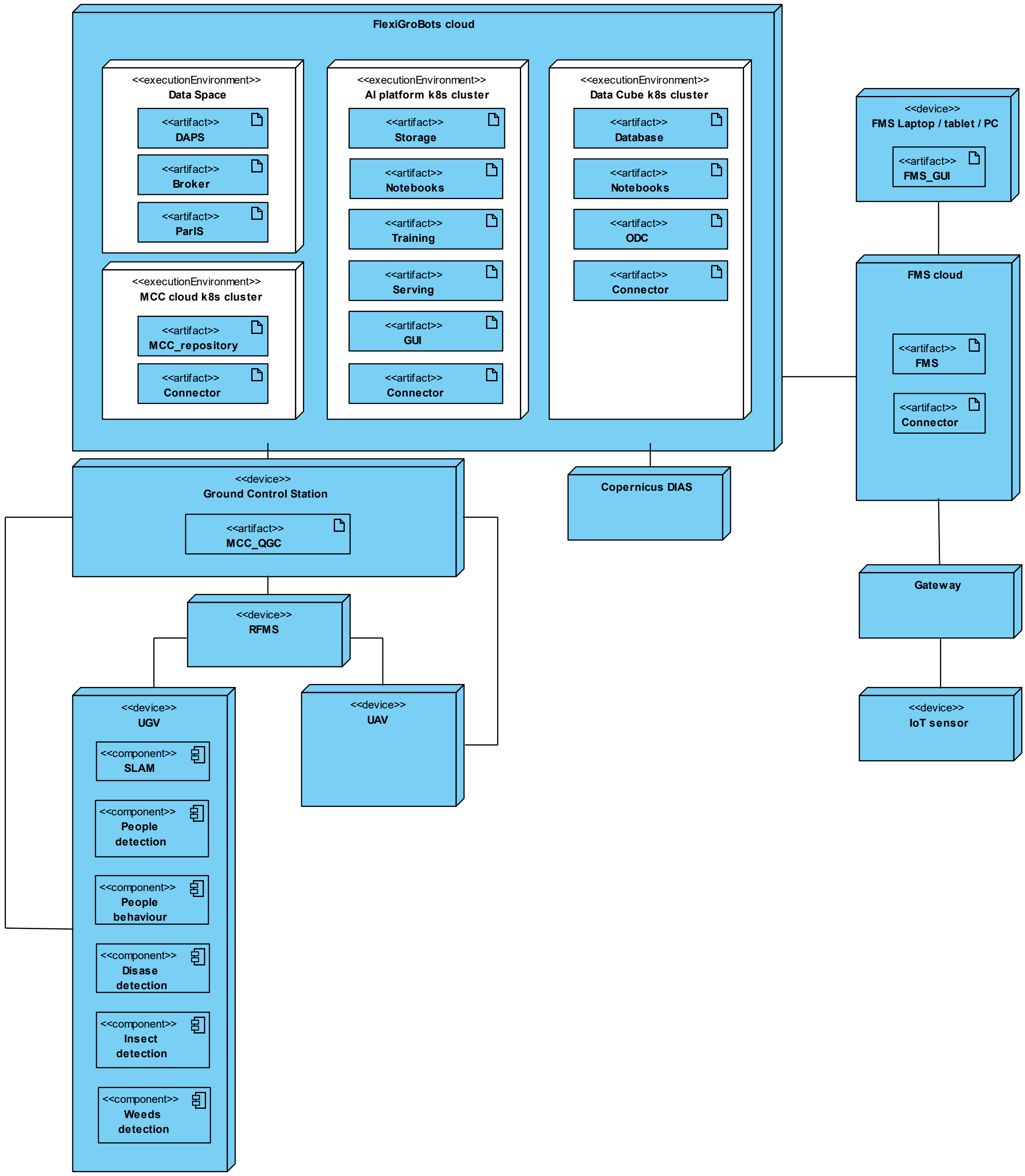


Figure 34 FlexiGroBots architecture physical view model

6 Conclusions

This document has presented the FlexiGroBots platform architecture and technical specifications, providing a detailed description of the expected functionalities to be implemented and the main technical building blocks that will be developed in order to support the execution of missions by fleets of heterogeneous vehicles. FlexiGroBots platform architecture and technical specification has been derived from an exhaustive evaluation of the requirements imposed by the main stakeholders of the project and also leveraging the results and lessons learnt of multiple initiatives and projects.

First, in order to maximise synergies with previous and ongoing activities, the partners have studied the outcomes of some of the most prominent European initiatives in the area of emerging digital technologies and data spaces, i.e., International Data Spaces, GAIA-X, FIWARE and the Copernicus programme. In all the cases, FlexiGroBots will have a strong alignment with them through the adoption of IDSA concepts as a core element of the platform architecture and the implementation of specific connectors and the integration of the Open Data Cube. This part of the deliverable was complemented with the evaluation of a good number of research and innovation projects thanks to the wide expertise and participation of the consortium partners. In this sense, it must be highlighted that the FlexiGroBots AI platform will be interoperable with AI4EU, that the Mission Control Centre resulting from RHEA will be re-used and extended and that the FOODIE data model will be also leveraged. With respect to standards, initially, the project plans to benefit from ISOBUS and OGC. Obviously, robotics technologies like ROS and NMA will be present in FlexiGroBots implementations.

In the next step, the document provides the evaluation of functional and non-functional requirements that have been extracted thanks to the inputs provided by the three pilots and by the experience and knowledge from all the partners. A value-proposition methodology has been put in practice to abstract this analysis from the project technologies and follows a customer-centric approach. From the list of pains and gains obtained for each type of stakeholder, user stories have been built which correspond to the functional specifications to be delivered by the project. It is important also to emphasise that thanks to the collaboration with CEPS, trustworthy or ELSEC requirements have been included in the analysis.

Finally, the core content of D2.2 is devoted to the introduction of FlexiGroBots platform architecture. Its vision is completely aligned with the European Data Space concept, having the ambition to constitute one of the first agricultural embryonic data spaces. By embracing IDSA reference architecture and principles, FlexiGroBots will aim to achieve secure and safe data flows between several platforms and stakeholders, promoting interoperability and the creation of new business opportunities. The architecture introduces novel concepts, such as the presence of a specific Artificial Intelligence platform that should facilitate the seamless creation of powerful Machine Learning models, including access to powerful hardware and software technologies. It will include a set of off-the-shelf AI common services that will be directly applicable to multiple precision agriculture scenarios, some of them specific for robotics solutions. The exploitation of satellite images and remote sensing data will be also possible since an Open Data Cube system will be also part of the solution. Finally, the outputs of all these elements will be powerful inputs to guide the execution of complex missions by fleets of heterogeneous robots, under the planification, supervision and control of the Mission Control Centre.

The functionalities of each of the components of the FlexiGroBots platform is described in detail following the IEC 62559 standard, including use-cases diagrams, presentation of involved actors and expected exchanges of information. Following the 4+1 architectural view model, logical, development, process and physical views have been also proposed for the introduced architecture.

As the next steps, in D2.3 a fine-tuned version of the presented architecture will be included thanks to the valuable feedback that will be collected during the implementation process that is being addressed as part of WP3 and the results of the three pilots in WP4, WP5 and WP6. Thus, D2.3 can be considered as a direct extension of the present document, containing the final version of FlexiGroBots platform architecture.

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