FLEXIGROBOTS

D2.4 Standardisation activities report 1

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List of Acronyms

Abbreviation / acronym	Description
AEF	Agricultural Electronics Industry Foundation
ALTAI	Assessment List for Trustworthy Artificial Intelligence
AI	Artificial Intelligence
CAN	Controller Area Network
COG	Cloud Optimized regular GeoTIFF
DIN	Deutsche Industrial Norms
DIS	Draft International Standard
DSS	Decision Support System
ECU	Electronic Control Unit
EFDI	Extended Farm Management Information
EN	Europaische Norm
FAIR	Findable, Accessible, Interoperable, and Reusable
FMIS	Farm Management Information Systems
GeoTIFF	Geographic Tagged Image File Format
GNSS	Global Navigation Satellite System
HAAM	Highly Automated Agricultural Machines
HTTP	Hypertext Transfer Protocol
IACS	Integrated Administration and Control System.
IEC	International Electrotechnical Commission
IoT	Internet of Things
IP	Internet Protocol
ISO	International Organization for Standardization
JSON	JavaScript Object Notation
MCC	Mission Control Centre
MQTT	Message Queue Telemetry Transport

Abbreviation / acronym	Description
NEN	Nederlands Normalisatie Instituut
NMEA	National Marine Electronics Association
OGC	Open Geospatial Consortium
OS	Operating System
OSRF	Open Source Robotics Foundation
REST	Representational State Transfer
ROS	Robot Operative System
RPIC	Remote Pilot In Command
RTK	Real-Time Kinematic
SC	Subcommittee
SMS	Safety Management System
SOP	Standard Operating Procedures
SPEC	Specification
STAC	Spatio-Temporal Asset Catalog
TC	Task Controller
TCP	Transmission Control Protocol
TS	Technical Specifications
TRL	Technology Readiness Levels
UA	Unmanned Aircraft
UAS	Unmanned Aircraft Systems
WCS	Web Coverage Service
WFS	Web Feature Service
WMS	Web Map Service
WP	Work Package

Executive Summary

This deliverable presents the activities carried out throughout the project related to the standardisation, portability and interoperability of the different parts that make up FlexiGroBots. This document is the result of the work carried out in Task 2.3 (Portability, Interoperability and Standards) of WP2 (Requirements, architecture and standardisation).

This deliverable is mainly composed of a compilation of the most important standards used by the project partners and their uses within the FlexiGroBots activities.

It is of great importance in large projects to ensure portability and interoperability between the different parts of the project. The standards offer a series of recommendations so that the result of the activity being developed is as homogeneous and repeatable as possible. This is why it is considered that the common territory in which these two concepts are most easily developed is through standardisation.

The main objective of this deliverable is to put into context and encourage standardisation-related activities by the project partners. By compiling all this information and presenting it together, the partners are able to better co-ordinate with each other by being aware of the standards they use and where they apply them in their project work. This document is the first version of the Standardisation Activities report 1.

1 Introduction

1.1 Purpose of the document

The aim of this deliverable is to collect and study good practices and regulatory frameworks in robotics for heterogeneous robot fleets working in an agricultural environment. Since robotic prototypes will be designed to perform not just one task, but a series of tasks, a detailed process of analysis and work decomposition will be necessary in order to select the appropriate standard in each case. This document presents a description of a subset of the standards being used in FlexiGroBots that have been selected for their importance within the project at this time. For each of the selected standards, a brief description of the rationale is given, followed by a description of how they are being used in each stage of the project development. It should be noted that this is the first part of the deliverable that will be extended in month 36 of the project, which will provide a complete picture of the final state of the project and the different elements that make it up.

1.2 Relation to other project activities

This document is related to all the deliverables describing the products of this project in which different partners apply different standards in their development. In particular, it is related to the deliverables that have emerged or are about to be published from the following work packages (WPs):

- WP2 (D2.2 Requirements and platform architecture specifications, D2.7 Pilot alignment and joint assessment report and D2.6 ELSE factor analysis and guidelines),
- WP3 (D3.1 FlexiGroBots Platform),
- WP4 (D4.1 Pilot 1 objectives, requirements and design),
- WP5 (D5.1 Pilot 2 objectives, requirements and design) and
- WP6 (D6.1 Pilot 3 objectives, requirements and design).

1.3 Structure of the document

The rest of the document is structured as follows:

- **Section 2** presents the definitions of the concepts: interoperability, portability and standard. It discusses the characteristics that a standard should have and provides guidelines for implementing a standard.
- **Section 3** is dedicated to presenting the methodology that has been followed to compile and organise the FlexiGroBots standards.
- **Section 4** presents the selected standards grouped by areas of application.

- **Section 5** presents the main conclusions derived from the presented standards and how they are applied in the FlexiGroBots consortium.

2 Related concepts

Merriam-Webster dictionary lists the word **portability** as the quality or state of being portable. Considering this definition in the context of a project like FlexiGroBots, we can approach portability from several points of view. When we are talking about portability referring to the software being generated, what we want is that the pieces of the source code are not dependent on the platforms on which they were generated, so that they can be compiled by different operating systems and executed by different processors. The use of standard languages guarantees, to a certain extent, this portability. We can also speak of data portability, in which case the objective is that the data contained in a database or repository are transferred electronically to another database or repository, avoiding having to view and enter data manually.

A good strategy that favours software portability is to build programs that can be executed on different platforms from source code to compilation and execution. The source code must be implemented in a standard language.

The Cambridge Dictionary defines **interoperability** as the degree to which two products, programs, etc. can be used together, or the quality of being able to be used together. Merriam-Webster Dictionary defines interoperability as the ability of a system to work with or use the parts or equipment of another system. The Collins Dictionary defines interoperability as the ability of a system or component to function effectively with other systems or components. To some extent, all these definitions reflect what is meant by interoperability in the context of computing, where interoperability is the ability of computer systems or different products to be connected in order to exchange information without restrictions. Therefore, interoperability requires the construction of services when the individual components of a system are managed by different organizations and/or are technically different. Types of interoperability include syntactic interoperability, where two systems can communicate with each other, and cross-domain interoperability, when organisations or systems from different domains interact by exchanging information and services to achieve their own goals or their common objectives. Interoperability is the strategy that facilitates systems working together.

Finally, for the term **standard** we find multiple meanings in all dictionaries. The definition "a pattern or model that is generally accepted" of the Cambridge dictionary is the closest to the use that will be given to this term within the FlexiGroBots project. Indeed, the use of standards will be the best way to achieve both portability and interoperability in the different elements that are developed and make up the FlexiGroBots project. This is why this deliverable focuses primarily on describing the main standards used in FlexiGroBots.

The International Organization for Standardization (ISO) is a global federation of national standards bodies. ISO technical committees are groups of experts responsible for the preparation of International Standards in liaison with international governmental and non-governmental organizations. The ISO states [1] that "a standard is a document that provides requirements, specifications, guidelines or characteristics that can be used consistently to ensure that materials, products, processes and services are fit for their purpose". In addition, a standard represents industry consensus on the matter.

The world of standards can be difficult to access because of their technical language and continuous references to acronyms and regulations. However, they are very useful in this era of globalisation. It is because of the interconnections of this world that it is of crucial importance to have mechanisms to unify and facilitate the interoperability of the different systems present. For example, everyday things such as the connection between printers and paper are governed by standards that determine the dimensions of paper (DIN A standard), so that printers can be precisely designed to fit these formats. However, standards are not only present in the everyday elements of our lives. They can also be found in industry (ISO 9001, quality control), environment (ISO 14001, environmental regulations) or science (ISO/IEC 17025, quality in laboratories) among others, where IEC is the acronym of International Electrotechnical Commission.

The following statements hold for any standard and Figure 1 shows its main characteristics:

- Standards result from collective work by experts in a field.
- Standards provide a consensus on the matter when they are developed.
- Standards contain technical specifications or other precise criteria designed to be used consistently as a rule, guideline, or definition.
- Standards are voluntary in nature, as they often provide guidelines and recommendations. However, they can be referenced in legislation and thus become mandatory.
- Standards are a common language. This generates benefits such as ensuring compatibility between products and components, reducing technical barriers thus improving international business as well as improving consumer protection and confidence.

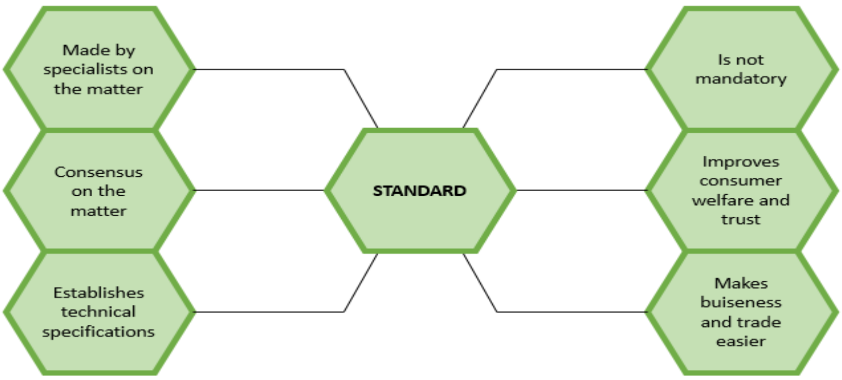


Figure 1. Main characteristics of a standard

The steps followed to create a standard according to the International Organization for Standardization (ISO) are summarised in Figure 2.

PROPOSAL STAGE

To confirm that a new International Standard in the subject area is really needed.

PREPARATORY STAGE

A working group is set up by the parent committee to prepare the working draft.

COMMITTEE STAGE

The draft is shared with the members of the parent committee.

ENQUIRY STAGE

Standards at the enquiry stage are open for comments. The draft is circulated to all ISO members who then have 12 weeks to vote and comment on it.

APPROVAL STAGE

The final draft is circulated for vote.

PUBLICATION STAGE

The final document is then published.

Figure 2. Process of making a standard.

3 Methodology

FlexiGroBots is a large-scale project in which fleets of heterogeneous robots are employed to perform various tasks in the field. Additionally, FlexiGroBots will provide various AI (Artificial Intelligent) and data-related services. In such a complex context, in order to get the big picture of the standards used throughout the project, a survey (shown in Annex I of this document) was handed out to gather in a fairly open way the opinion of all the partners. The aim was to know which standards would be used in the project and how partners would use them to foster interoperability and portability of the work they would be doing within FlexiGroBots. After receiving the answers from all the partners, we went on to analyse the responses, trying to group the information received by areas, also finding, as was to be expected, that several partners agreed on the standards used. Subsequently, for each of the defined application areas, a set of standards was selected according to their importance and/or the fact that more than one partner uses them. To prepare this deliverable, a responsible person was assigned for each standard and a list of partners involved in the standard. The idea is that for each of the selected standards, there is a text overview of the standard and then each partner explained how they are using the standard in their tasks in FlexiGroBots.

4 Standards

This section is dedicated to presenting the different standards that are being used in FlexiGroBots or are planned to be used. To organise the presentation, it has been decided to group them by areas. Thus, eight areas have been defined, which are agriculture, machinery, communications, safety, artificial intelligence, software and robotics, geospatial and ethics. Some standards are difficult to classify in a single area and could be part of more than one area. For each of the selected standards, a brief general presentation is given, followed by a description of how it is being applied in the project.

4.1 Agriculture

4.1.1 ISO/DIS 5231

EFDI (Extended Farm Management Information Systems Data Interface, ISO/DIS 5231) [2], where DIS means Draft International Standard, defines the communication between ISOBUS machines and FMIS (Farm Management Information System). While the current ISO 11783 standard covers use cases involving tasks to be executed by tractor-implement combination, EFDI is standard for distributing task files to participants in work processes. Service providers such as machinery providers should be able to receive task files from FMIS. In addition, logged works should be transferred back to the client [3].The EFDI standard is currently under development. For the operational task management, ISOBUS Task Controller (TC) is a standardized device, which is used to document and to control the precision farming operations. The controller definitions are based on the ISO 11783-10 standard [4]. According to the standard, the task data is transferred to the ISOBUS TC (Task Controller) as XML-based ISOBUS Task files. In addition, the ISOBUS Task file can also be used to describe the robot work on the field [5].

Today, more and more FMIS are based on cloud services. For this reason, many manufacturers have made their own solutions for transferring data to the ISOBUS TC from the cloud. In addition, multiple vendors are providing broker services that allow transferring ISOBUS Task files to the ISOBUS TC [6]. In 2017, the AEF (Agricultural Electronics Industry Foundation) organised a working group to develop vendor-independent data transfer between Farm Management software and the TC. The working group has published a Guideline on the definition of EFDI [7] while the process of ISO standardisation is ongoing [8].

In the EFDI's development work, the working group did not develop the protocol from scratch. AEF's EFDI working group exploited appropriate existing protocols and built functionality on top of them by being compatible with the definition of the existing ISOBUS Task file [9].

The conversion from the XML file to protocol buffer format and back is straightforward. EFDI also defines more metadata than the original XML file, describing, for example, what should be done with the transferred Task file. MQTT (Message Queue Telemetry Transport) [10], which is commonly used in various IoT (Internet of Things) systems, was chosen as the data transmission protocol. In addition to these, the http protocol was chosen for logging in to the system.

4.1.1.1 Application in the project

In this project, precision farming 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. The Pilot 2 robot tractor is able to drive along predefined driving lines using a commercial, already integrated, Valtra Guide auto steering system (AGCO autosteering). The driving lines and the information needed for precision farming operations is transferred to the robot using the EFDI communication. EFDI is used also to transfer telemetry information and to give high-level remote commands to the tractor [11].

4.2 Machinery

4.2.1 ISO 18497

ISO 18497 Agricultural machinery and tractors — Safety of highly automated agricultural machines — is a standard that defines principles for design of highly automated agricultural machines or vehicles. Highly automated agricultural machines are referred as HAAM. Although the standard is not literally focusing on robots, it is taken into consideration in this project, for it deals with all significant hazards, hazardous situations and events, relevant to agricultural automated field operations. The main purpose of this standard is to ensure an appropriate level of safety for agricultural (as well as forestry) tractors and self-propelled machines with functions allowing highly automated operations.

The standard lays general principles for protection requiring

- perception system for detecting and locating persons or other obstacles and locating the HAAM as required by the operation,
- ensure safeguarding of the movement of HAAM,
- giving visual or audible warnings for persons in or entering hazardous area and moving HAAM to desired safe state,
- means for local or remote operator to start or stop HAAM operation
- allow adequate supervision of the HAAM.

The standard provides various requirements for enabling machine functions and transitioning between disabled, enabled, and autonomous operation modes.

The standard has specific requirements for various machine functions including

- starting the engine
- motion control
- operational status information to operator
- overriding HAAM functions
- stopping HAAM operations
- operational speeds
- communication and perception systems
- remote control and
- instructions for use.

The standard also provides a test method for verification and validation of protective or risk reduction measures. For the test procedure, a test object is specified to test the perception system in the field conditions.

The standard is not applicable for

- forestry applications
- mobile, semi-mobile or stationary machinery used for farmyard or barn operations;
- operations on public roads including relevant requirements for braking and steering systems.

ISO 14897 was published in 2018. It is the first standard defining functional requirements for autonomous operation of large agricultural machines. ISO 14897 is identified as a B-type Harmonized Standard EN (Europaische Norm) ISO 14897:2018 under the Machinery Directive, since April 2020. This means that machines fitting the scope of the standard must meet or exceed the requirements set by ISO 14897 to meet the essential requirements in the Machinery Directive. In addition, the status as Harmonized Standard allows the manufacturer to assume conformity with the MD if they implement ISO 14897 in their products.

The ISO 14897 sets the functional requirements for HAAM, it does not set the performance and integrity requirements needed to implement those functions. Therefore, it is likely that ISO 25119, the norm that describes the safety requirements for tractors and machinery for agriculture and forestry, is needed to implement the functionalities in ISO 14897.

The ISO 14897 is currently being revised. The standard entered revision phase in March 2021. The standard will be replaced by new ISO 14897 series that will include at least three parts. As the standard is revised, the name and scope of the standard will change. Therefore, as the FlexiGroBots project progresses, it will be necessary to analyse how these changes may affect the project. The new parts are:

- ISO/DIS 18497-1 Agricultural machinery and tractors — Safety of partially automated, semi-autonomous and autonomous machinery — Part 1: Machine design principles and vocabulary
- ISO/CD 18497-2 Agricultural machinery and tractors — Safety of partially automated, semi-autonomous and autonomous machinery — Part 2: Design principles for obstacle protection systems
- ISO/AWI 18497-3 Agricultural machinery and tractors — Safety of partially automated, semi-autonomous and autonomous machinery — Part 3: Design principles for autonomous operating zones

As seen from the titles the new parts are in various phases of development ranging from draft standard to approved work item. This means that the expected publication of standards ranges between two to five years. Also seen from the titles is that the term HAAM has been dropped and the term "partially automated, semi-autonomous and autonomous machinery" has been adopted. This implies widening of the applicability of the standard's requirements.

4.2.1.1 Application in the project

There is no direct use of this standard in the project, as the work is focusing on field-robots, rather than automated tractors. The standard however provides well-structured design principles of handling the safety of automated agricultural machines. The standard approaches the automated agricultural machines also from the point of view of misuse foreseeable by the manufacturer, during the normal operation and service.

The application of ISO 18497 depends on the maturity and technological readiness of the machines in pilots.

It is not necessary to fully implement ISO 18497 and ISO 25119 in developments that are not yet entering the market. However, if the machine falls under the scope of ISO 18497 and risk analysis shows unacceptable risk in any of the risks identified in ISO 18497 annex A the requirements in the standard must be considered before the machine enters the market.. Therefore, the requirements of ISO 18497 need to be considered in the designs used in the project, but the level of implementation depends on the machine's market readiness.

The robotics in the Pilot 2 need to consider the requirements, but we will not implement the requirements fully as there is still distance to market (Technology Readiness Level, TRL6-7) and the requirements need to be considered at the technology transfer phase.

4.3 Communications

4.3.1 ISO 11783

ISO 11783 [7] standard series known as Tractors and machinery for agriculture and forestry—Serial control and communications data network defines a control and communications data network between a tractor and an implement or tool (farm machinery) as well as an information for precision tasks between the machinery and FMIS. The standard series is commonly known by the trade name ISOBUS, which is maintained by AEF.

ISO 11783 standard series is the most accepted machine-to-machine communication standard in the agricultural industry and all the major agricultural machinery manufacturers are committed to the standard series. There are no other competing standards available.

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 system. The basic system consists of a tractor Electronic Control Unit (ECU) (T-ECU), an implement (faming machinery) ECU (I-ECU) and a universal user interface usually called as virtual terminal. These devices are used to control the farm machinery combinations (tractor-implement). There can be additional devices attached to the system, such as a positioning device (GNSS, Global Navigation Satellite System), or the TC. The task controller is used to control the work implementation and to store work data. The 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 the "TC-LOG".

In the application task file, it is also possible to include the machine allocation, scheduling and navigation routes in the field in addition to the information needed by precision farming operations. The actual ISO 11783 Task file is also used to document the work that has been done in the field. The ISO 11783-10 Task file can be seen as complete, thus it can be used to give all the instructions that are needed for the autonomous operations by the robots.

4.3.1.1 Application in the project

Pilot 1

Taking into account that the physical layer defined in ISO-11783 is based on the CAN (Controller Area Network) protocol, an ISOBUS has been created in the autonomous vehicles based on Renault's Twizy electric vehicles, to interconnect the different elements that make up the system, see Figure 3.

The on-board computer is responsible for decision-making, speed variation and vehicle orientation. It is connected to the ISOBUS, through which it receives measurements from the sensors. For example, the steering wheel angle sensor on the steering shaft, which is directly connected to the ISOBUS, provides the position and rate of turn of the steering. The Renault

Twizy's own internal CAN bus is also connected to the vehicle's ISOBUS, allowing the speed measured by the car's speedometer to be read, as the latter sends its measurements via the bus. Based on the measurements from these sensors, and the desired speed and orientation, the computer sends commands to the ISOBUS addressed to the microcontrollers connected to it.

The microcontroller in charge of the vehicle's steering actuation receives the commands to vary the torque exerted on the power steering installed in the vehicle and its direction.

As for the accelerator actuation, the microcontroller in charge of this receives the commands through the ISOBUS to vary the electronic signal that reaches the vehicle's internal controller and, in this way, simulates the greater or lesser pressure of the accelerator pedal.

Finally, in the case of brake pedal actuation, as the brake pedal is mechanical, an actuator is needed to depress it. The extension and retraction of the actuator cylinder, as well as its speed, can be controlled through the commands received by the microcontroller in charge of this action via the ISOBUS.

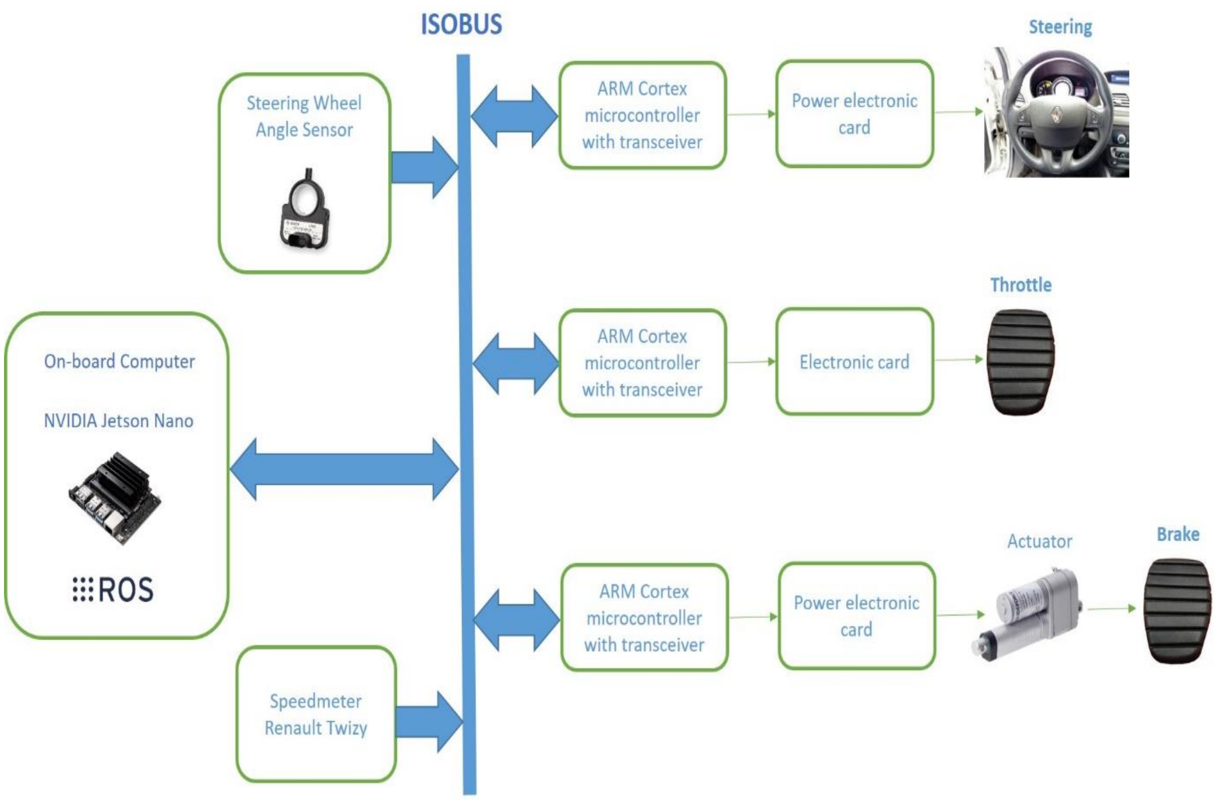


Figure 3. Diagram of the elements connected by ISOBUS

Pilot 2

ISOBUS task file is the format in which Pilot 2 FMIS presents the mission files and receives mission reports. VTT will create mission report files for Pilot 2 drones and weeding robots using this format.

The Pilot 2 work task file is transferred automatically to a commercial ISOBUS Task Controller before the autonomous operation is started. The ISOBUS Task Controller gives set-point commands for implementation based on GPS-location. In turn, the implementation can command the hydraulic AUX-valves, PTO speed and hitch position [11]

MTE utilizes ISO 11783 in MyFarm platform where prescription maps for various field works are made. Selection of this very specific standard is rather easy and straightforward as no competing standards for these tasks do exist. The ultimate benefit of this selection is compatibility to existing farming machinery that support the ISOBUS functionalities. As the standard has capabilities to control the implement it provides very good basis for autonomous actions that require further development of standard. The possibilities to develop standard further to suit autonomous actions is one activities of the FlexiGroBots project.

4.3.2 MAVLink

MAVLink [12] is a communication protocol designed for the exchange of information and commands between Unmanned Aerial Vehicles (UAVs) and ground stations. It follows a very lightweight design and the messages supported by each specific system are defined in XML files (dialects) that can be easily managed with multiple programming languages, facilitating the development of software solutions for drones. The definition of custom messages is possible by adding them in the corresponding XML dialect. MAVLink can be also used for onboard communications between different components.

From the XML dialects, several generators are able to automatically generate libraries in the most common programming languages for drones and other autonomous vehicles, including C, C++, Python, Java, JavaScript and Rust. The generator toolchain is licensed under LGPL (GNU Lesser General Public License) and the resulting libraries under MIT.

MAVLink 2.0, the most recent version of the protocol, was released in 2017, adding improvements with respect to flexibility and security. The structure of a MAVLink 2.0 message can be seen in Figure 4. It consists of a sequence of codified bytes sent through a transceiver and which contains a sequence number (SEQ) to detect lost messages and a checksum.

Figure 4. MAVLink 2 packet format. [13]

Contributions can be done to the protocol specification and the software generators in the corresponding GitHub repositories. For complex changes, a Request for Changes (RFC) template is provided [14].

4.3.2.1 Application in the project

MAVLink is the protocol used by QGroundControl in communication between the control system and drones/robots. VTT will use it in the implementation of MCC (Mission Control Centre) and situation monitoring.

In the situation monitoring the objects and their positions are translated to MAVLink commands so that QGroundControl can visualize the positions of detected objects in the field.

4.3.3 HTTP

Hypertext Transfer Protocol (HTTP) [15] is a protocol used by the internet for transmitting web-based documents, mainly HTML documents, such as web sites. Initially it was designed and developed to communicate web browsers and servers, although it is also used for other purposes.

Within a typical client-server model infrastructure, there is a web client, normally a web browser, that starts a communication with a web server, by making a request. Then the client keeps waiting for a response, while the server processes the request and returns a standardized response to the client.

It is a stateless protocol, which means that every request is atomic and independent, so that the server does not store any information that would allow two requests to be linked.

4.3.3.1 Application in the project

Within the project, the HTTP protocol is used as the basis for the REST (Representational State Transfer) services involved. REST services are practically a communication standard in today's information systems. Communication with IDSA connectors, communications between DSSs (Decision Support Systems) and the MCC, integrations of different systems within the DSSs themselves are just some of the applications of the HTTP protocol within the FlexiGroBots project.

4.3.4 MQTT

MQTT (Message Queue Telemetry Transport) [16] is an open transport protocol, used in network environments to communicate machine or devices. It is based on a publisher/subscriber architecture, and it is designed to be very easy to use and implement. Its principal characteristics are his low weight and his simplicity, which makes it a suitable protocol in contexts where speed and robustness are mandatory.

It runs under TCP/IP (Transmission Control Protocol/ Internet Protocol), although it can run over other protocols as long as they are ordered, bidirectional and lossless connections.

MQTT provides different levels or qualities of service:

- "At most once", where messages are delivered based on OS (Operating System) efforts. This method allows for data loss, so it is used in environments where this is not a must.
- "At least once", where the arrival of messages is ensured at least once, although duplicate arrivals may occur.
- "Exactly once", where messages are guaranteed to reach their destination exactly once, no more and no less.

This protocol knows nothing about the payload itself, i.e., the message it carries. In addition, it provides the parties involved with a mechanism that notifies them when connectivity between them is lost.

4.3.4.1 Application in the project

At the current stage of project development, the main idea is that MQTT is used to broker messaging between the MCC and the DSSs (Decision Support Systems), in order to represent the telemetry of the robots. Pilot 1 will use MQTT messages to communicate with other modules in the FlexiGroBots platform such as the MCC, whereas in Pilot 2, the robots, MCC, and situation awareness service will communicate using MQTT messages.

4.3.5 DIN/SPEC 27070

DIN SPEC 27070:2020-03 was published in December 2019 by DIN (Deutsche Industrial Norms). DIN SPEC specifies requirements and reference architecture of a security gateway for the exchange of industry data and services.

This standard DIN SPEC relates to is — DIN EN IEC 62443-4-2: Security for industrial automation and control systems (IACS) — Part 4-2: Technical security requirements for IACS components.

DIN SPEC 27070 defines the requirements for the development of a secure gateway for secure data exchange and implementing cyber security measures. It establishes four security profiles that will be selected according to security requirements of the use case scenarios.

4.3.5.1 Application in the project

IDSA contributes to data spaces standardization in W3C, ISO, DIN and CEN CENELEC. For this purpose, they have developed an IDS roadmap for DIN SPEC standard internationalization. They have contacted with DIN and NEN (Nederlands Normalisatie Instituut), and with others.

They have addressed to ISO committees such as ISO JTC 1: Information Technology and ISO/IEC JTC1/SC 27 meeting, where SC means Subcommittee.

VTT will implement Pilot 2 data space where all the connectors will communicate using IDSA protocol that is defined in this standard. Six data space connectors will be installed.

4.4 Safety

4.4.1 ISO/TC 20/SC 16

ISO/TC 20/SC 16 (First edition, 2019-11) focuses on the standardization in the area of unmanned aircraft systems (UAS). There are seven ISO standards published under the ISO/TC 20/SC 16, including the categorisation, design, manufacturing, operation (including maintenance) and safety management of UAS operations. Among them, ISO 21384-3:2019 [12] operational procedures are essential, regarding safe commercial UAS operations. The document gives prescriptions for operations, applying to all commercial UAS regardless of size, categorization, application or location. Moreover, the document includes helpful definitions of UAS operations issues.

This standard states that operators shall implement a safety management system (SMS) as a standard practice. Moreover, it defines the documents, controls, and maintenance plans to be carried out to prevent accidents involving unmanned aircraft (a person is injured as a result of a direct contact with a UA (Unmanned Aircraft) or the UA sustains damage) or other incidents involving UA (an event related to the aircraft operation that is not an accident,).

4.4.1.1 Application in the project

In addition to the legislation in force and the local regulations in each country, the following should be considered within the project, according to the ISO Standard. The legislation shall be followed in case of conflict between the local aviation authority legislation and the ISO standard. Therefore, firstly, UA operators shall establish procedures to ensure that they and RPIC (Remote Pilot In Command) follow legislation in force, rules of the air and regulations defined in airspace areas.

The operators shall ensure that a UA will not be operated in a manner that may invade a person's privacy. According to the ISO, a SMS should be implemented by the operators, including a safety policy, in order to control human error. In autonomous operations (the UAS can conduct pre-programmed flight path operations in which no human input is required for the system to complete its operation) the operator shall ensure that: a) human intervention is possible during all operations; b) all operations are monitored to ensure that human intervention is taken in the case of a safety failure.

Operators must hold the following documents:

i) operator details,
ii) flight manual of each model of UA,
iii) registration or the serial number of each UA (each UA must have an ID number or operator's contact information),
iv) operations manual, including the documents:
    a. a risk assessment conducted for every type of operation;
    b. every worker is in a healthy condition and psychologically stable, and is professionally competent;
    c. the maintenance program of each UAS follows the recommendations of the manufacture;
    d. registration and serial number of each UAS;
    e. assigned pilot-in-command (PIC) and other crew members' roles for each mission;
    f. emergency actions/checklists;
    g. minimum equipment list by mission type;
    h. standard operating procedures (SOPs) defined by the operator.
    i. pre-flight inspection checklist, that shall be developed or supervised by the PIC before each flight, following the operations manual, including:
        i. visual condition inspection of the UA components
        ii. flight surfaces and linkages
        iii. registration markings
        iv. motors and propulsion system
        v. rotor or fan shrouds are not damaged
        vi. power systems
        vii. avionics and electronics
        viii. correct functioning of the display panel
        ix. landing and take-off systems and other ground support equipment.
        x. secure attachment of any payloads
        xi. verification of all controller operations and proper function of heading and altitude sensors
        xii. constraints and obstacles that could affect the UA
        xiii. availability of fire extinguishing and first aid equipment
v) maintenance control manual: For each UA, the operator shall implement a maintenance program according to the manufacturer's manuals. The operations shall be registered in the maintenance control manual. The UAS should be updated periodically and maintained in a safe condition for flight, and the link between their components shall work properly.
vi) insurance certificate: Operators must have appropriate insurance for their operations.

vii) duplicates of licenses of RPIC staff, responsible for the operation. The RPIC shall ensure that everything is working correctly, such as all control links or enough fuel or energy to perform the mission, and carry all necessary documentation at the point of operations (in agreement with the operator):
   a. flight manual
   b. journey logbook maintained for every UA (including UA registration; date of flight; remote crew members and duties; departure and arrival places (location and time); flight route; purpose and type of flight; observations (if any), and signature of the remote RPIC)
   c. operational plan (Operators shall ensure that flight planning is conducted and documented for every flight operation. It shall include: a) weather and meteorological information; b) fuel and energy requirements; c) flight plan (including point of departure, landing point, cruising speeds, and cruising levels); d) airspace classification and restrictions; e) risk assessment; f) communications; g) the actions of the pilot in the event of unforeseen situations; h) notifications. In a UAS accident, the operational plan will be stored for at least one year.
   d. notice to airmen (If necessary)
   e. operations manual
   f. risk assessment
   g. the operator's contact information
   h. remote pilot certificate

4.4.2 ISO 12100:2010

ISO 12100 “Safety of machinery — General principles for design — Risk assessment and risk reduction” provides designers with an overall framework and guidance for decisions during the development of machinery to enable them to design machines that are safe for their intended use.

4.4.2.1 Application in the project

In Pilot 2, the general framework of ISO 12100 is being applying in designing operations of the weeding robot to be in general safe.

4.5 Artificial Intelligence

4.5.1 Artificial Intelligence Act

The Artificial Intelligence Act is a recent legislative proposal by the European Commission in order to define common and harmonised rules on the usage of AI. Its mission is to foster the adoption of this technology in high-impact sectors and to reinforce the sovereignty and leadership position of European companies in the global competition that is taking place worldwide and which will be essential for the future development of business opportunities leveraging digital technologies. Nevertheless, it also aims to prevent the negative consequences and risks that can derive from the usage of AI with respect to compliance with the European values and human rights. The proposal of the AI Act can be seen as one of the milestones as part of the European Commission strategy for AI-based systems and which was initiated by actions like the creation of the High-Level Expert Group on Artificial Intelligence (HLEG AI) or the publication of the White Paper on AI.

Although the AI Act is not strictly a standard and it is not yet in force at the time of writing, it includes a set of requirements that must be fulfilled by all AI-based systems, and which could become a global or de-facto standard in the short-term. For this reason and due to the legal obligations, that will surge once it becomes a reality, the analysis of the AI Act is relevant for the FlexiGroBots project and for the present document.

The current draft establishes four levels of risk according to the pyramid in Figure 5, defining different requirements for each class:

- Unacceptable risk: AI practices that are banned in the EU, e.g., subliminal techniques, exploitation of vulnerable groups, social scoring and real-time biometric identification in public spaces.
- High risk: systems that may have severe consequences for safety or fundamental rights are included in this group. They must comply with an exhaustive list of requirements before being commercialized or deployed in production environments:
  - Registration in database provided by the European Commission.
  - Perform a self-assessment to demonstrate conformity to high-risk AI requirements and to obtain the CE marking.
  - Application of a continuous and iterative process for risk management, including testing for the intended purpose.
  - Adoption of good practices for data governance and management, including technical mechanisms to mitigate biases.
  - Detailed and updated technical documentation must be produced and maintained.
  - Events must be automatically logged during the operation of high-risk AI systems guaranteeing the traceability during the complete lifecycle.
  - Transparency must be offered to the final users so that they can interpret and understand properly its design and operation.
  - Human oversight must allow preventing or minimizing risks through appropriate interfaces.

  - High-risk AI systems must provide enough accuracy and be resilient to errors and faults. In order to achieve robustness, back-up plans are needed. Feedback loops should be addressed during the design phase.
  - Cybersecurity practices must be adopted to avoid attacks and manipulation, e-g., data poisoning, adversarial examples.
  - Put in place a quality management system to ensure compliance with the clauses of the regulation.
- Limited risk: They must satisfy transparency obligations.
- Minimal risk: Systems under this category do not have any kind of restriction.

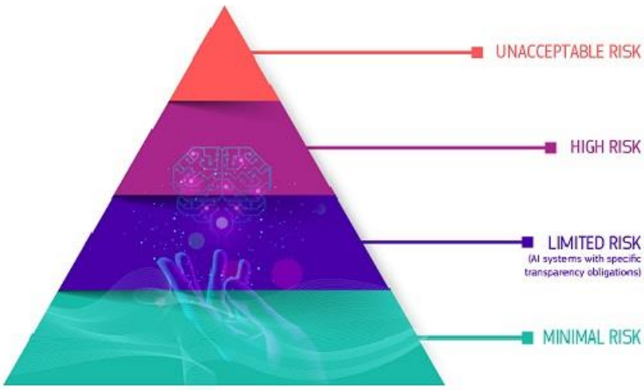


Figure 5. Pyramid of risks proposed by the AI Act.[17]

4.5.1.1 Application in the project

As it is stated in Article 6 of the AI Act,

"(1) … an AI system shall be considered high-risk where both of the following conditions are fulfilled:

a) the AI system is intended to be used as a safety component of a product, or is itself a product, covered by the Union harmonisation legislation listed in Annex II.

(b) the product whose safety component is the AI system, or the AI system itself as a product, is required to undergo a third-party conformity assessment with a view to the placing on the market or putting into service of that product pursuant to the Union harmonisation legislation listed in Annex II.

(2) In addition to the high-risk AI systems referred to in paragraph 1, AI systems referred to in Annex III shall also be considered high-risk."

Although some of the use-cases target by FlexiGroBots do not match any of these conditions since used AI systems are intended for pest detection, improving context awareness or making intelligent decisions, there are other developments where autonomous ground and aerial vehicles are used and which may include also embedded software relying on machine learning models or other types of AI-based systems. These cases may fit under the scope of several of the Union harmonization legislations included in Annex II:

- Regulation (EC) No 300/2008 of the European Parliament and of the Council of 11 March 2008 on common rules in the field of civil aviation security and repealing Regulation (EC) No 2320/2002 (OJ L 97, 9.4.2008, p. 72).
- Regulation (EU) No 168/2013 of the European Parliament and of the Council of 15 January 2013 on the approval and market surveillance of two- or three-wheel vehicles and quadricycles (OJ L 60, 2.3.2013, p. 52).
- Regulation (EU) No 167/2013 of the European Parliament and of the Council of 5 February 2013 on the approval and market surveillance of agricultural and forestry vehicles (OJ L 60, 2.3.2013, p. 1).

For that reason, and although FlexiGroBots will be limited to piloting activities, the project will aim to adopt some of the requirements proposed by the AI Act for high-risk systems with two different objectives:

i) to assess the impact that it will cause in the development of innovative AI-driven systems including robotics technologies for precision agriculture;
ii) to increase the level of maturity of the results and to minimize the regulatory barriers that may limit its short-term exploitation.

The lessons learnt as part of the process that could be useful from a standardization perspective will be presented to EU policy makers as part of D7.9, which is led by the CEPS team, which includes a member of the HLEG AI group Andrea Renda.

4.6 Software & Robotics

4.6.1 ROS

ROS (Robot Operative System) is an open source meta-operating system for robots. It provides the functionalities of an operating system, including hardware abstraction, device drivers, libraries, inter-process message communication, package management, enabling distributed architectures, etc. ROS has packages, libraries and tools that help the development and reuse of software in robotics applications.

Development of ROS began in 2007 as part of the Stanford AI Robot Project at Stanford University's Artificial Intelligence Lab. In 2008, its development moved to the Willow Garage robotics research lab. Since 2013, ROS has been maintained by the Open Source Robotics Foundation (OSRF), which in 2017 changed its name to Open Robotics (www.openrobotics.org). The ROS community has grown very fast and now has a large number of users and developers worldwide. Most companies and robotics research labs are developing using ROS, making it a standard in robotics.

Nodes are the basic processing unit of ROS, encapsulating the different processes running on the system. Each node is an executable file that performs a specific function. The main advantage of using nodes is their modular design, with each node being independent. Nodes are compiled individually from each other, and are executed and managed by the main node of the system, named ROS Master.

Thus, the main functionality of the ROS Master is to allow the nodes in ROS to locate each other in order to communicate. This master node registers all nodes, services and topics (defined below) that are running.

Nodes need to communicate with each other to perform their tasks. ROS solves the problem of communication between the nodes by means of a system of publications and topic subscriptions. Each topic is an information channel, where nodes can either publish data or subscribe to get the information that other nodes publish. When a topic is created, the structure of the data to be published is defined.

Advantages of using ROS:

- **Reduced development time**. There are many specialized ROS packages that offer diverse capabilities, such as interfaces for sensors and actuators, protocols, functionalities commonly used in robotics, etc., which are easily integrated into any robot, allowing code reusability.
- **Modularity**. In ROS, it works in a parallel and distributed way: each node executes a different process. This characteristic also makes it suitable for scalable systems, which grow as the system develops.
- **Resource usage**. Normally, the use of the same hardware resource by more than one process is problematic and sometimes impossible. However, due to the way ROS works, through nodes and topics, this complexity disappears, allowing this functionality easily.
- **Multilanguage**. ROS can work with different modern programming languages, such as Python, C++ and Lisp, so ROS nodes can run and communicate with each other regardless of the language in which they are written.
- **Free and Open Source**. ROS is developed under the open source license, BSD license, which allows commercial and non-commercial use.
- **Active community**. Being an open source platform, it has a continuous development and support from the international robotics community, both in the academic and industrial environment.

4.6.1.1 Application in the project

In Pilot 1 this standard is used in all ground robots, as well in the ground robots in Pilot 3.

Detecting and treatment ground robots

To carry out the Pilot 1 ground inspection tasks, the Renault Twizy vehicle was equipped with an on-board computer, NVIDIA Jetson Nano. ROS has been installed in this computer to facilitate the tasks to be carried out, to allow rapid integration of the elements to be used in the system, and to simplify communication between them. In this way, it has been possible to automate the vehicle, with the aim of achieving autonomous navigation. A similar setup was made in Pilot 3, where the ground robot uses ROS as a backbone for running the modules for image recognition, robotic sprayer movement and conducting the process of laboratory soil analysis.

Different packages available in ROS have been used to allow the communication of the different elements through the CAN bus. In this way, it has been possible to quickly integrate the steering sensor installed in the vehicle's steering system, which directly supplies CAN frames with the position and rotational speed of the steering. Similarly, thanks to these packages, it has been possible to connect the system to the vehicle's own CAN bus and read data such as the speed measured by the Renault Twizy's speedometer. Furthermore, since the system has a distributed architecture, where each actuating element (acceleration, braking and steering) has its own microcontroller with CAN transceiver, these packages have enabled the on-board computer to receive readings from these elements and send commands to them.

Other ROS packages used in the project were those necessary to read the GNSS coordinates of the vehicle supplied by the vehicle's on-board receiver. Similarly, another ROS package has been used to allow the connection of a joystick to the system and, in this way, to be able to test the automation of the vehicle by teleoperating it.

For the different sensors connected to the bus, different nodes have been developed that read the measurements taken by these sensors and publish them in different topics, so that they are available to any node that wants to have access to each measurement, simply by subscribing to the corresponding topic.

As for the control of the speed and orientation of the vehicle, independent nodes have been created, subscribed to the topics of the measurements supplied by the speedometer and steering sensor, and which publish the necessary orders on the CAN bus to modify the speed and orientation of the robot.

A node has also been created for the teleoperation of the vehicle, subscribed to the joystick topic, which indicates the buttons pressed, and which publishes on the bus the necessary commands to change the speed, direction and braking of the robot.

Harvesting assistance

Robotnik's RB-VOGUI robot, which is responsible for the harvesting aid in Pilot 1, is equipped with a computer with ROS installed, and with the necessary ROS packages for controlling the robot's movement pre-installed. In this way the linear and angular speed of the robot can be easily varied. The robot is delivered together with a joystick with which the vehicle can be teleoperated using some of the ROS packages pre-installed in the system.

Thanks to the available ROS packages for Intel RealSense cameras and for UWB systems, colour and depth aligned images can be easily obtained from the robot's on-board camera, RealSense D415, as well as position and orientation measurements given by the UWB equipment. This information is available in topics, which a node developed for this project consumes, processing all this data, and obtaining the real position and orientation of the operator with respect to the robot.

Once these are known, a node has been created in ROS that decides the linear and angular velocity that the robot should have. To do this, both are published in a topic that a node belonging to a ROS package pre-installed in the robot consumes, causing the vehicle to move according to its characteristics.

ROS packages are also used to read the GNSS coordinates from the receiver installed on board the robot, as well as to read the measurements provided by the scale with which the robot is equipped. A node has been developed that subscribes to the topics that publish the GNSS coordinates, and the weight measured by the scale, and combines both measurements to generate a grape weighing map.

4.6.2 ISO 10218-1/2

ISO 10218-1 "Robots and robotic devices — Safety requirements for industrial robots — Part 1: Robots" specifies requirements and guidelines for the inherent safe design, protective measures and information for use of industrial robots. It describes basic hazards associated with robots and provides requirements to eliminate, or adequately reduce, the risks associated with these hazards.

ISO 10218-2 "Robots and robotic devices - Safety requirements for industrial robots - Part 2: Robot systems and integration" specifies safety requirements for the integration of industrial robots and industrial robot systems as defined in ISO 10218-1, and industrial robot cell(s). ISO 10218 describes the basic hazards and hazardous situations identified with these systems, and provides requirements to eliminate or adequately reduce the risks associated with these hazards.

4.6.2.1 Application in the project

ISO-10218-1 specifies a collaboration space with human operators and robot arms, and gives four types of collaborative operations, where the human operator and the robot can co-exist in this space: "Safety-rated monitored stop", "Hand guiding", "Speed and separation monitoring" and "Power and force limiting by inherent design or control". We are following the guidelines for "Safety-rated monitored stop", and "Speed and separation monitoring" to design the weeding motions of the robot arm to consider situations where human workers or livestock and animals in general, are in the neighbourhood of the robot.

4.6.3 ISO/TS 15066

ISO/TS 15066:2016 "Robots and robotic devices — Collaborative robots" specifies safety requirements for collaborative industrial robot systems and the work environment, and supplements the requirements and guidance on collaborative industrial robot operation given in ISO 10218-1 and ISO 10218-2.

ISO/TS 15066:2016 applies to industrial robot systems as described in ISO 10218-1 and ISO 10218-2. It does not apply to non-industrial robots, although the safety principles presented can be useful to other areas of robotics.

4.6.3.1 Application in the project

We are applying ISO/TS 15066, Technical Specifications, in designing the safe motions of the weeding arm, especially with the guidelines for minimum separation distances and biomechanical limits.

4.6.4 ISO 18646-2:2019

ISO 18646-2:2019 “Robotics – Performance criteria and related test methods for service robots” relates to navigation performance of mobile robots measured by pose accuracy and repeatability, and also the ability to detect and avoid obstacles.

4.6.4.1 Application in the project

This document only deals with indoor environments. However, the information could also be applicable to outdoor environments. This could be relevant since navigating accurately to the weed location is an important part of the weeding demonstration, as well as avoiding obstacles in the field. Therefore, we may apply this standard when developing the mobile robot navigation on grass fields.

4.6.5 ISO 18646-3:2021

ISO 18646-3:2021 “Robotics – Performance criteria and related test methods for service robots” relates to specifying and evaluating the manipulation performance of service robots, including grasp size, strength and slip resistance, for applications such as opening a hinged door and sliding door.

4.6.5.1 Application in the project

This document deals with indoor environments, however it may provide insights relevant for the weed removal/manipulation component of the weeding demonstration. We may therefore apply parts of this standard.

4.7 Geospatial

4.7.1 OGC

The Open Geospatial Consortium [18] 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).

These standards, which have been defined to address specific interoperability challenges, such exchanging geoinformation in a variety of contexts (e.g., publishing map content on the Web, sensor information and satellite imagery, etc.) and enabling the fusion of information from diverse sources, are used by software implementors to build open interfaces and encodings into their products and services. The list of standards defined [19]is currently greater than 70, covering from Services and APIs to Data Models and Encodings, as well as Sensors, among others [20].

4.7.1.1 Application in the project

The FlexiGroBots geospatial components leverage on a subset of commonly and widely used OGC (Open Geospatial Consortium) standards used for encoding, describing, and making accessible geospatial-related information in an interoperable manner.

These are:

- **Data Models and Encodings**
  - **GeoTIFF**: The Geographic Tagged Image File Format (GeoTIFF) is a standard for using the Tagged Image File Format (TIFF) for the exchange of georeferenced or geocoded imagery.
    FlexiGroBots makes extensive use of satellite imagery (e.g., Landsat and Copernicus Sentinel) and UAV collected data which is provided in GeoTIFF formats, each pixel of the raster containing a measured value (e.g., the blue (B2), green (B3), red (B4), and near-infrared (B8) channels at 10-meter resolution of a Sentinel 2 image). These images can be used for visualization and processing to combine with other sources and extract further knowledge.
    A particular case of GeoTIFF images are a **Cloud Optimized regular GeoTIFF** (COG)[21], aimed at being hosted on a HTTP file server, with an internal organization that enables more efficient workflows on the cloud. It does this by leveraging the ability of clients issuing HTTP GET range requests to ask for just the parts of a file they need.
    The Data Cube geospatial component provided by FlexiGroBots makes use of COGs in order to provide a more efficient access to the satellite imagery and the collected raster imagery from the pilot drones. This avoids having to download large files (e.g., a Sentinel 2 tile can weight up to 6GB compressed) for processing just a small are for the project pilots.
  - **GeoJSON**, which is a JSON (JavaScript Object Notation)-based format for encoding a variety of geographic data structures (i.e., lines, points, polygons). In FlexiGroBots, areas with Botrytis infections detected are provided in GeoJSON files.
  - The **Spatio-Temporal Asset Catalog** (STAC) [22], which provides a common language to describe in the form of metadata (JSON files) a range of geospatial

information, so it can more easily be indexed and discovered. In FlexiGroBots, STAC is used together with the Cloud Optimized GeoTIFFs, thus making easier to index, find and use geospatial assets like satellite and UAV imagery using the Data Cube.

- **Services and APIs**

  FlexiGroBots geospatial services (many of them using open-source implementations) provide access to the geospatial datasets, either raster (e.g., via the Open Data Cube, https://www.opendatacube.org/) or vector-based (e.g., via Geoserver, https://geoserver.org/) by means of their open and interoperable APIs:
  - **Web Map Service** (WMS)[23] provides a simple HTTP interface for requesting geo-registered map images from one or more distributed geospatial databases (either raster or vector-based). A typical scenario of use would be requesting a map of satellite/UAV image (in JPEG or PNG format) for visualizing the pilot area of study.
  - **Web Feature Service** (WFS)[24] provides a simple HTTP interface for requesting geographical features. A typical scenario of use would be requesting the polygons that define the pilot farm and its plot areas so they can be visualized and/or used for filtering other datasets (e.g., a query to the farming system database to collect crop information for a specific plot area defined by the polygon).
  - **Web Coverage Service** (WCS)[25] provides a simple HTTP interface for requesting multi-dimensional coverage data. A typical scenario of use would be requesting various bands of satellite/UAV image (in GeoTIFF/COG format) for later on calculating the vegetation index for the pilot area of study.

4.7.2 NMEA

NMEA 0183 is a standard developed by the National Marine Electronics Association for regulation of GPS (global positioning systems). There are various aspects of GPS tackled by the standard, in terms of data communication, signals used, communication timing/synchronicity and the formats of the sentences, that are transmitted through the serial data bus using a 4800 baud rate. The standard regulates the buses, which are designed for broadcast communication (1 sender and many receivers). The format of the data is the printable ASCII and contains information on the position of the sender, its speed, elevation, time of transmission etc. The version implemented in this project is 4.11, i.e. the latest one.

In terms of hardware, we will be using the EIA-422 standard for electronics, although there is a possibility of using EIA-232 for most hardware with NMEA-0183-compatible output. A typical connection diagram is shown in Figure 6.

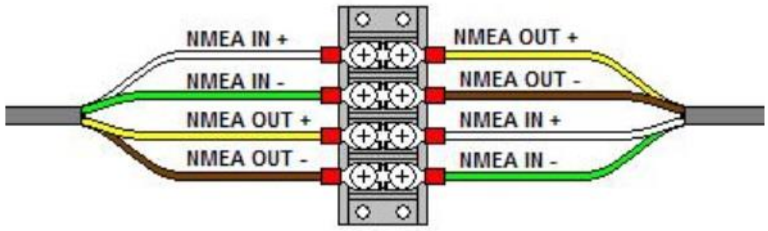


Figure 6. Usually NMEA connection

Regarding communication layer (data link layer) it uses messages in ASCI format with printable characters. Reserved characters are used by NMEA 0183 for the uses display in Table 1.

ASCII	Hex	Dec	Use
<CR>	0x0d	13	Carriage return
<LF>	0x0a	10	Line feed, end delimiter
!	0x21	33	Start of encapsulation sentence delimiter
$	0x24	36	Start delimiter
*	0x2a	42	Checksum delimiter
,	0x2c	44	Field delimiter
\	0x5c	92	TAG block delimiter
^	0x5e	94	Code delimiter for HEX representation of ISO/IEC 8859-1 (ASCII) characters
~	0x7e	126	Reserved

Table 1. NMEA characters

The $GPGGA messages are a typical representative of the NMEA messages with a fixed structure. They are used for sending the GPS location information.

$GPGGA,181901.00,3404.7040778,N,09044.3964270,W,3,14,2.00,485.134,M,28.200,M,0.10,0000*40

4.7.2.1 Application in the project

The GNSS receivers used in ground robots of the pilot 1 are the Septentrio mosaic-H receivers. These receivers have a dual-antenna input, being able to supply accurate and trustworthy positioning and heading with centimetre-level RTK (Real-Time Kinematic). GNSS heading properly works in both static and dynamic conditions, eliminating dependence on vehicle motion. Septentrio's GNSS are equipped with the most advanced technologies in order to work in the hardest conditions, mitigating interferences, tracking robustly when high vibrations and shocks are present, applying multipath reduction to disentangle direct signal and those reflected in the surroundings, and giving protection against ionosphere disturbances.

- RTK performance: Horizontal accuracy 0.6 cm + 0.5 ppm
- Heading: 0.15° (Antenna separation 1 m)
- Maximum update rate (RTK + heading): 20 Hz
- Operating temp: -40 to 85° C

The receivers get the position corrections via Internet, through the free public service of the Spanish National Geographic Institute (www.ign.es). In this way, the receivers are able to establish RTK positioning.

The receivers send two types of NMEA messages to the computers in charge of controlling the robots: 1) the $GPGGA message, which provides the position (latitude, longitude) of the vehicle with which the receiver is equipped; and 2) the $GPHDT message, which provides the heading of the vehicle, thanks to the two antennas connected to the receiver.

The latitude and longitude provided in the NMEA message is transformed to the Universal Transverse Mercator (UTM) Coordinate system. This uses a 2-dimensional Cartesian coordinate system to give locations on the surface of the Earth. The use of this coordinate system facilitates the division of the crop fields to be sampled into grids, and the use of local reference systems, which allows the error derived from working with very large numbers of global coordinates to be eliminated. In this way, the robots can navigate accurately.

4.8 Ethical aspects

4.8.1 ALTAI

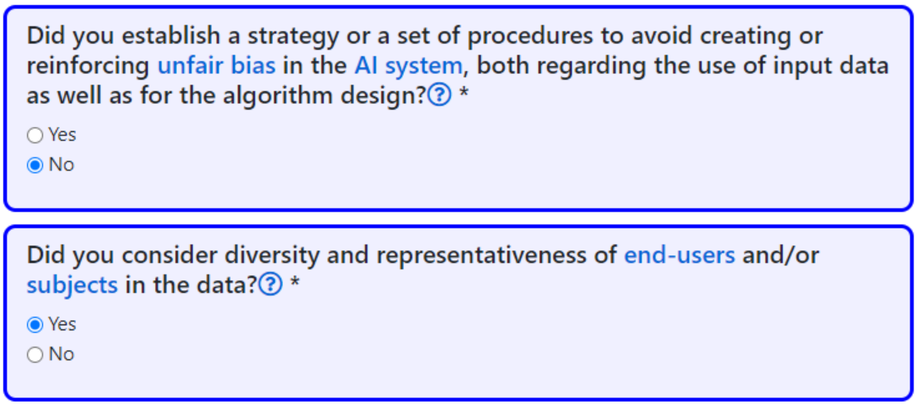
The Assessment List for Trustworthy Artificial Intelligence (ALTAI) is a set of guidelines and a questionnaire designed for ethical (self-)assessments of AI systems. The ALTAI was developed between June 2018 and June 2020 and is based on the “Ethics Guidelines for Trustworthy AI” [26] by the High-Level Expert Group on Artificial Intelligence (AI HLEG) of the European Commission. The ALTAI questionnaire is used in the FlexiGroBots project for the ethical assessment of the pilots and the platform.

Beyond the ALTAI, there are several initiatives trying to introduce standards for ethical AI, either through soft standards or hard law, from the private or public sector. Prominent examples for **soft private standards** are: First, the “Model Cards for Model Reporting” [27] proposed by Google. Model cards provide a standardized way for developers to report on technically and ethically relevant properties of their algorithms to enable others to better understand the capabilities and limitations of the respective algorithm. Second, the

"Datasheets for Datasets" [28] proposed by Microsoft and others. Datasheets provide a standardized way for dataset authors to report on technically and ethically relevant properties of their datasets. (3) Several other, smaller initiatives exist, for example, CodeCarbon [29], which provides standardized software to calculate the carbon emissions produced during AI training.

Moreover several **governments have proposed hard laws or soft standards** related to AI ethics: Australia is developing a voluntary AI ethics framework based on eight principles similar to the ALTAI requirements; Canada has developed a directive on automated decision-making; the German data ethics commission proposed a risk classification scheme with five levels of criticality; Japan proposed contract guidelines on the utilization of AI and data; Singapore developed a model governance framework on AI; the UK government provided a guide on using AI in the public sector; and the United States has drafted guidance for regulation of AI applications. For a comprehensive overview of these initiatives see [30].

Last but not least, the High-Level Expert Group on Artificial Intelligence (AI HLEG) of the European Commission proposed the **ALTAI** in July 2020. The guidelines and questions were developed by the AI HLEG and refined in a piloting process with 350 stakeholders [31] to make them concrete and practical. This resulted in the final Assessment List for Trustworthy Artificial Intelligence [32] in both PDF format and an online questionnaire. Especially the interactive online questionnaire tool is designed to enable stakeholders to (self-)assess the ethical readiness of their AI technologies according to seven ethical requirements. The ALTAI questionnaire contains batteries of questions (see e.g. Figure 7) for each of seven overarching requirements: (1) human agency and oversight; (2) technical robustness and safety; (3) privacy and data governance; (4) transparency; (5) diversity, non-discrimination and fairness; (6) environmental and societal well-being and; (7) accountability.


Did you establish a strategy or a set of procedures to avoid creating or reinforcing unfair bias in the AI system, both regarding the use of input data as well as for the algorithm design? *

- ○ Yes
- ◉ No

Did you consider diversity and representativeness of end-users and/or subjects in the data? *

- ◉ Yes
- ○ No

Figure 7. Examples of two questions from the ALTAI online questionnaire

The ALTAI provides a concrete set of guidelines and questions for self-assessment applicable to micro-level use-cases, which is why FlexiGroBots has chosen the ALTAI as an important standard to follow for the projects ethical assessments.

4.8.1.1 Application in the project

The ALTAI is used as a standardized assessment tool for each pilot in the respective FlexiGroBots pilot assessment tasks (T4.4/T5.4/T6.4). Moreover, it informs the ethical guidelines developed in T2.4. An initial ALTAI self-assessment was conducted in August/September 2021 and the ALTAI questionnaire was filled in for each pilot and the FlexiGroBots platform during a series of interviews led by CEPS. As a result of these interviews, several recommendations were developed (see D2.6).

Note that the FlexiGroBots pilots and platform are not finished products (yet), but prototypes are being developed throughout the three years of the project. The partners have therefore agreed to repeat and update the assessments throughout the project to accompany the development process from an ethical perspective and to account for the increasing readiness levels of the technologies and pilots.

The online questionnaire produces automatic written recommendations as well as scores visualized in a spider chart (see Figure 8). One initial finding for the first series of interviews is that some of the ALTAI questions can be too general, as they have been developed to cover a very wide variety of AI technologies and not all questions (and scores) apply to the FlexiGroBots use-cases. We are therefore not only using the questionnaire as-is, but adapt it to the specific needs of the project. CEPS is therefore following up with the pilots and platform developers in a more tailored way, to adapt the questions to the specific case of autonomous robot systems for agricultural.

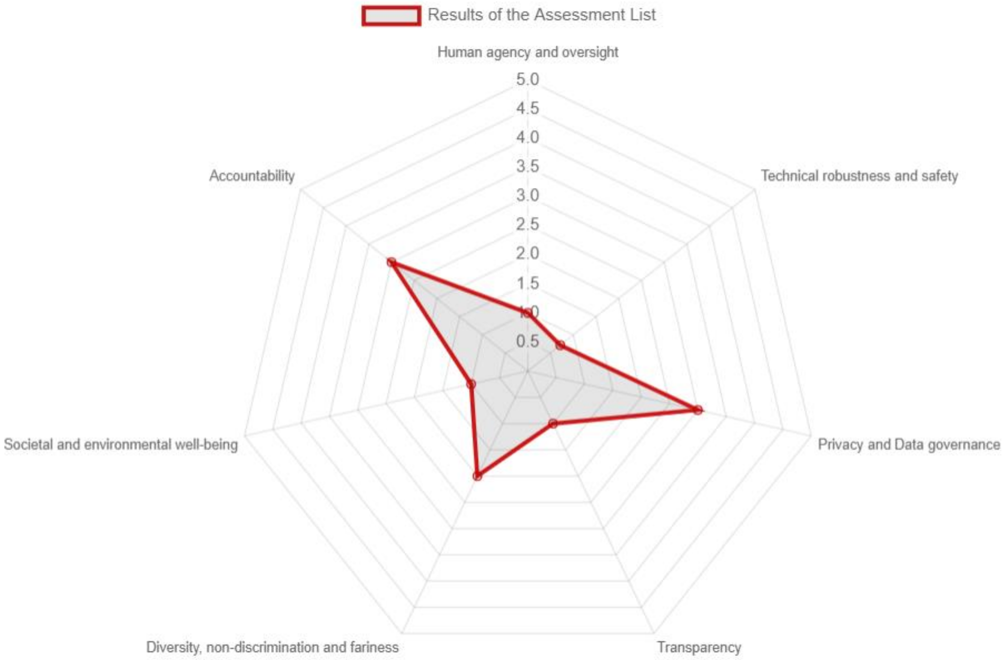


Figure 8. Illustrative example of output from the ALTAI online tool

5 Conclusions

Following a survey sent to all project partners, an initial set of standards that partners are already using or plan to use were analysed and selected. In order to present the information in a systematic and understandable way it was decided to define a number of areas of interest and to divide the selected standards according to these areas. The result is that in the area of agriculture, only one standard appears related to communications between the ISOBUS of the machinery and FMIS. This standard could have been grouped in the area of communications, but as it is so specific to agricultural machinery and farm management systems, it was decided to keep the area. It is also noted that the partners do not identify any standards for the conduct of field experimentation, we will try to address this issue in more detail in the next version of this deliverable. On the other hand, the areas with the highest number of standards is communications, where the partners describe five types of standards, some of which are widely used, and software and robotics, where the partners also identify five standards.

It is also worth noting that many of the standards could have been classified in more than one area. In these cases we chose to include them in the area we believe they are most closely related to. In any case, for the second part of this deliverable we will consider other possible ways of organizing the presentation of the standards, based on the fact that the project will be concluding. At the end of the project, it will be clear which standards have finally been handled and the degree of implication and importance in each of the products that have emerged from FlexiGroBots.

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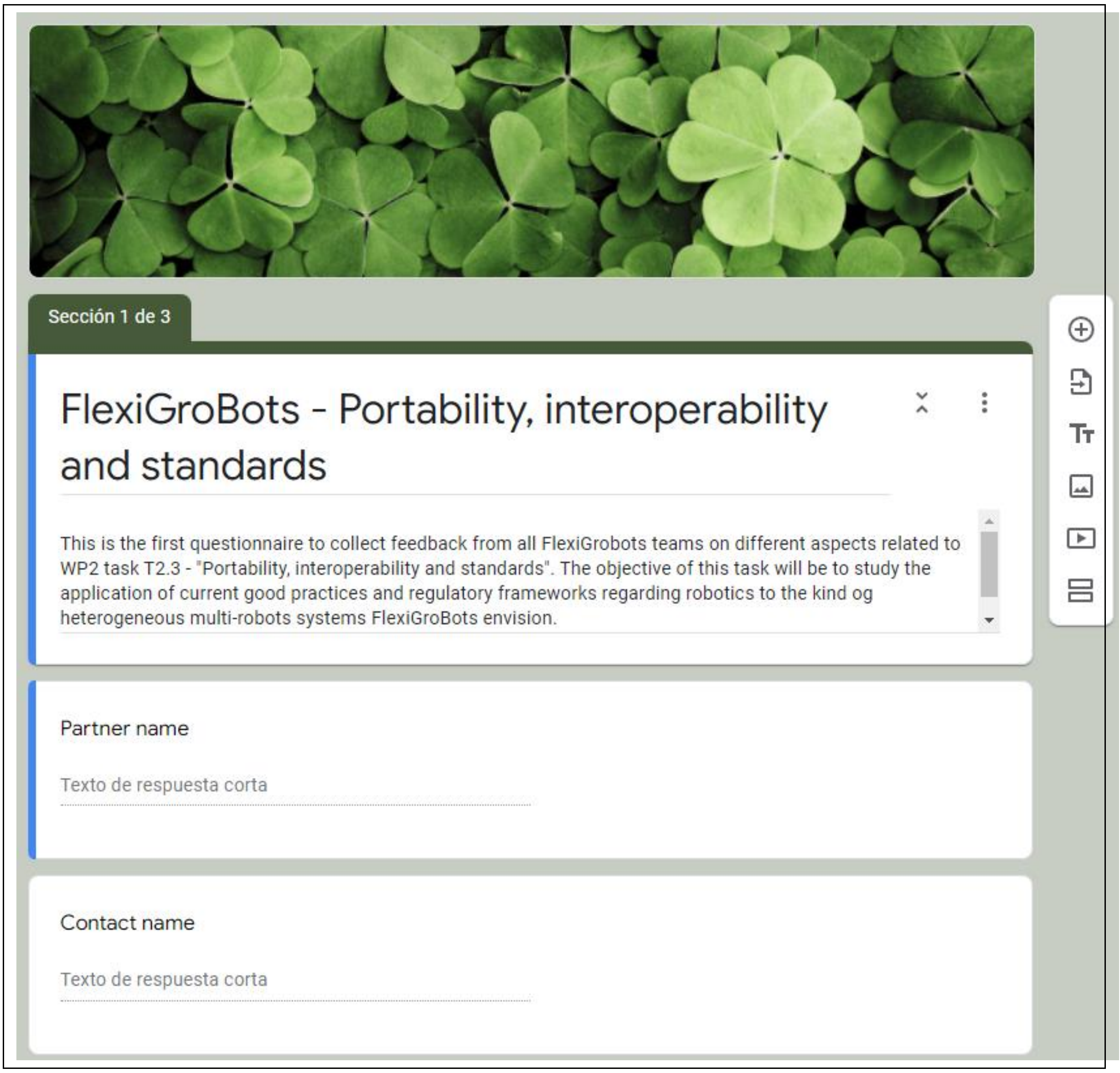
Annexes

Annex I

This annex shows the pages of the survey that was prepared to collect information on the standards that were being used and are planned to be used within the FlexiGroBots project. The survey was sent to all partners.



Sección 1 de 3

FlexiGroBots - Portability, interoperability and standards

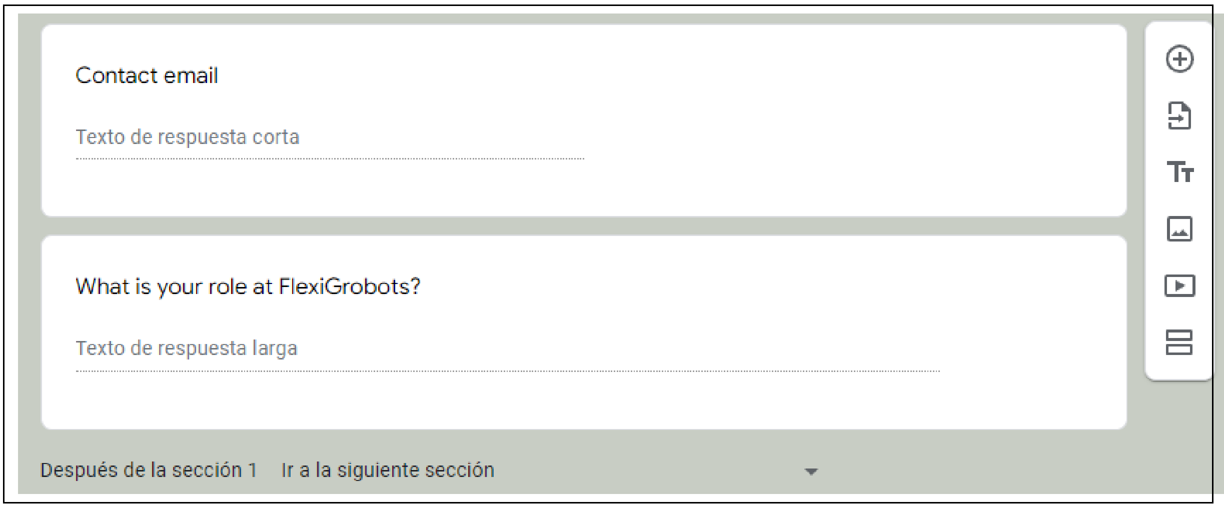
This is the first questionnaire to collect feedback from all FlexiGrobots teams on different aspects related to WP2 task T2.3 - "Portability, interoperability and standards". The objective of this task will be to study the application of current good practices and regulatory frameworks regarding robotics to the kind og heterogeneous multi-robots systems FlexiGroBots envision.

Partner name

Texto de respuesta corta

Contact name

Texto de respuesta corta


Contact email

Texto de respuesta corta

What is your role at FlexiGrobots?

Texto de respuesta larga

Después de la sección 1 Ir a la siguiente sección

Sección 2 de 3

Definitions

A number of definitions are set out below. Please read them carefully.

"A standard is a document that provides requirements, specifications, guidelines or characteristics that can be used consistently to ensure that materials, products, processes and services are fit for their purpose." ISO (International Organization for Standardization)

"Portability refers to be able to move software from one machine platform to another. It refers to system software or application software that can be recompiled for a different platform or to software that is available for two or more different platforms

"Interoperability refers to the basic ability of different computerized products or systems to readily connect and exchange information with one another, in either implementation or access, without restriction. Hence, interoperability involves the task of building coherent services for users when the individual components are technically different and managed by different organizations. Types of interoperability include syntactic interoperability, where two systems can communicate with each other, and cross-domain interoperability, where multiple organizations work together and exchange information. "

In your opinión is the definiton of the standard concept fine? Is this definition complete?

Texto de respuesta larga

Please, let us know which standards you are already using and which ones you plan to use in this project.

Texto de respuesta larga

In your opinión is the definiton of the portability concept fine? Is this definition complete?

Texto de respuesta larga

Please, let us know what is your team doing to increase de portability of the software under development. What are your plans for Flexigrobots?

Texto de respuesta larga

In your opinión is the definiton of the Interoperability concept fine? Is this definition complete?

Texto de respuesta larga

Please, let us know what strategy you are using to increase Interoperability among the systemas under development. What are your plans for Flexigrobots?

Texto de respuesta larga

Sección 3 de 3

Project Open DEI

Aligning Reference Architectures, Open Platforms and Large-Scale Pilots in Digitising European Industry

OPEN DEI will be an essential pillar of the implementation of EU digitisation policies by addressing in particular the "support" to the Large-Scale Pilots (LSPs) and platform projects financed by the European Commission under the Digitising European Industries (DEI) Focus Area and currently ongoing, which work in different strategic sectors: one of them is represented by agri-food.

https://www.opendei.eu/agri-food-sector/

Do you kown the Open DEI Project? Do you think it can help us in the context of FlexiGroBots project? How it is useful for you?

Texto de respuesta larga

Do you know of other projects we should consider? Please provide the list of projects and the associated scope.

Texto de respuesta larga

In this space you can include relevant information that has not been reflected in the previous sections.

Texto de respuesta larga

Thank you very much for your cooperation!

Descripción (opcional)