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ACROBA
connect & produce through agile production

D8.10 Standardization Strategy

WP8

Lead Beneficiary Partner Name: BIBA

Delivery date: 2024-11-30

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Version V1.0

BIBA
BIBA - Bremer Institut für Produktion und Logistik GmbH

The ACROBA project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101017284.

Approval Status

	Name and Surname	Role in the Project	Partner(s)
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Reviewed by	José Antonio Dieste Juha-Pekka Alanen	Technological partner WP8 leader	AITIIP ROB
Approved by	Norman Urs Baier	Project Coordinator	BFH

History of Changes

Version	Date	Description of Changes	By
0.1	2024.08.29	ToC - Table of contents	BIBA
0.2	2024.09.05	Working version - First draft for BIBA-intern Review	BIBA
0.3	2024.11.28	Version for review	BIBA
0.4	2024.12.11	Final version to be reviewed	BIBA
1.0	2024.12.13	Final version after review – to be submitted	BIBA

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Executive Summary

This document details the standardization aspects gathered during the T8.4 lifetime (M14-M48). The deliverable starts with the list of all standards and technical specifications used by the project partners for the implementation of ACROBA. The document explains each identified standardization aspect. For the gathering process, several meetings and workshops have been held. A classification approach has been adopted to enable a better understanding for which purposes these aspects are to be considered: HRC, Design, Integration, Interoperability, Communication, etc.,

1 Introduction

In D8.9 (standardization strategies – first report) the policies and procedures that the ACROBA consortium could adopt to govern the standardization activities have been addressed. The document gives a summary of the activities conducted since the beginning of the Task 8.4 (M14) and focuses on the relevant key aspects needed to work out the strategy that will be utilized to achieve the standardization objectives for the project and to coordinate standardization actions amongst the consortium partners. In this document D8.10 (standardization strategies – final report), planned at M48, is focusing on summarizing the potential standardization aspects and related activities. In order to identify standardization aspects, several workshops have been executed.

1.1 Scope of the deliverable

This deliverable outlines the list of standards used for the development of ACROBA and details all the potential standardization aspects, identified by the consortium partners during the project lifetime. Some standardization aspects have the potential to be implemented in a short time. For these, standardization activities have been already started/initiated.

1.2 Relation to other tasks and work packages

The benefits of standards for European industry are extensive. Standards help ACROBA stakeholders (R&D, system integrators, technology providers, industrial partners…) to reduce costs, anticipate technical requirements, and increase productive and innovative efficiency.

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The European Commission recognizes the positive effects of standards in areas such as trade, the creation of Single Market for products and services, innovation and the long-term sustainability. For this reason, close cooperation with T8.1, T8.2 and T8.5, in which the ACROBA exploitation strategy, sustainability plan and IPR management are being to be developed, is sought. It is safe to say that the standardization strategy to be developed will be of great importance for most of the project partners, as knowledge and results developed in the course of ACROBA are best transferred to the market through standardization. Some partners have identified the appropriate standardization organization, which will play the role of the interface between the entire ACROBA project and the world of standardization.

2 Used Standards in ACROBA

For the implementation of the ACROBA platform and related materials, several standards/norms and specifications have been considered and used. The following table gives an overview of these.

Table 1: List of standards used during ACROBA lifetime

Document	Used for/by
Robot Operating System (ROS)	- All ACROBA modules/ Modules developers
Suggested Upper Merged Ontology(SUMO)	- Mainly for Skills/SIGMA and TaskPlanner/BFH, but share with All ACROBA modules
Core Ontology for Robotics and Automation (CORA)	- Mainly for robot skill and primitive and task planning, but share with All ACROBA modules
IEEE 1872-2015: IEEE Standard Ontologies for Robotics and Automation	- Knowledge representation, terms definition in ACROBA
FIWARE	- Communication ACROBA-Backend
Docker	- ACROBA Platform
Gymnasium (Farama)	- DRL Module/DEUSTO - DRL Skills/DEUSTO
Universal Robot Description Format (https://openusd.org/URDF) http://wiki.ros.org/urdf	- VirtualGym/ VICOMTECH - Skills/SIGMA
ROS/ROS Sharp ROS TCP Connector https://github.com/Unity-Technologies/ROS-TCP-Connector	- VrtualGym/VICOMTECH

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BPMN (Business Process Model and Notation)	- TaskPlanner/BFH
Machinery Directive 2006/42/EC	- Safe integration of collaborative robots / BIBA - Collaborative use cases/ IKOR and ICPE
Low Voltage Directive 2014/35/EU	- Safe integration of collaborative robots / BIBA - Collaborative use cases/ IKOR and ICPE
Radio Equipment Directive 2014/53/EU	- Safe integration of collaborative robots / BIBA - Collaborative use cases/ IKOR and ICPE
EN ISO 10218-1:2012 "Robots and robotic devices - Safety requirements for industrial robots – Part1: **Robots"**	- Safe integration of collaborative robots / BIBA - Collaborative use cases/ IKOR and ICPE
EN ISO 10218-2:2012 "Robots and robotic devices - Safety requirements for industrial robots - Part 2: **Robot systems and integration"**	- Safe integration of collaborative robots / BIBA - Collaborative use cases/ IKOR and ICPE
ISO/TS 15066:2016 "Robots and robotic devices - Collaborative robots"	- Safe integration of collaborative robots / BIBA - Collaborative use cases/ IKOR and ICPE
EN ISO 13855:2010 "Safety of machinery - **Positioning of safeguards with respect to the approach speeds of parts of the human body"**	- Safe integration of collaborative robots / BIBA - Collaborative use cases/ IKOR and ICPE
EN ISO 13849-1:2016 "Safety of machinery - Safety-related parts of control systems - Part 1: **General principles for design, provides safety requirements and guidance on the principles of design and integration of safety-related parts of control systems (hardware or software).**	- Safe integration of collaborative robots / BIBA - Collaborative use cases/ IKOR and ICPE
EN ISO 13849-2:2013 "Safety of machinery - Safety-related parts of control systems - Part 2: **Validation, specifies the procedures to be followed for validating by analysis or tests, the safety functions of the system, the category achieved, and the performance level achieved**	- Safe integration of collaborative robots / BIBA - Collaborative use cases/ IKOR and ICPE
EN ISO 12100:2011 "Safety of machinery – **General principles for design – Risk assessment and risk reduction"**	- Safe integration of collaborative robots / BIBA - Collaborative use cases/ IKOR and ICPE
EN ISO 13850:2015 "Safety of machinery – **Emergency stop function – Principles for design**"	- Safe integration of collaborative robots/BIBA - Collaborative use cases/ IKOR and ICPE
ISO/TR 20218-1:2018 "Robotics - Safety design for industrial robot systems - Part	- Safe integration of collaborative robots / BIBA - Collaborative use cases/ IKOR and ICPE

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1: **End-effectors"**	
DIN EN 61508 VDE 0803 Beiblatt 1:2005-10 Functional safety of electrical/electronic/programmable electronic safety-related systems Part 0: **Functional safety and IEC 61508**	- Safe integration of collaborative robots/BIBA - Collaborative use cases/ IKOR and ICPE - Rule-based toolkit/BIBA - Finding towards ACROBA HRC concept refinement /BIBA
IEC 61508-1:2010 Functional safety of electrical/electronic/programmable electronic safety-related systems - Part 1: **General requirements**	- Safe integration of collaborative robots/BIBA - Collaborative use cases/ IKOR and ICPE
DIN EN 61508-2 VDE 0803-2:2011-02 Functional safety of electrical/electronic/programmable electronic safety-related systems Part 2: **Requirements for electrical/electronic/programmable electronic safety-related systems**	- Safe integration of collaborative robots/BIBA - Collaborative use cases/ IKOR and ICPE - Rule-based toolkit/BIBA - Finding towards ACROBA HRC concept refinement /BIBA
DIN EN 61508-3 VDE 0803-3:2011-02 Functional safety of electrical/electronic/programmable electronic safety-related systems Part 3: Software requirements	- Safe integration of collaborative robots/BIBA - Collaborative use cases/ IKOR and ICPE - Rule-based toolkit/BIBA - Finding towards ACROBA HRC concept refinement /BIBA
DIN EN 61508-5 VDE 0803-5:2011-02 Functional safety of electrical/electronic/programmable electronic safety-related systems Part 5: **Examples of methods for the determination of safety integrity levels**	- Safe integration of collaborative robots/BIBA - Collaborative use cases/ IKOR and ICPE - Rule-based toolkit/BIBA - Finding towards ACROBA HRC concept refinement /BIBA
DIN EN 61508-6 VDE 0803-6:2011-02 Functional safety of electrical/electronic/programmable electronic safety-related systems Part 6: **Guidelines on the application of IEC 61508-2 and IEC 61508-3**	- Safe integration of collaborative robots/BIBA - Rule-based toolkit/BIBA - Finding towards ACROBA HRC concept refinement /BIBA
OPC Unified Architecture	- Communication between skills and PLC/BIBA and SIGMA
ECMA-404 (JSON Data Interchange Format), IETF RFC 8259, and ECMA-262 (ECMAScript Language Specification, third edition)	- Rule schema and rule definition for the rule-based toolkit/BIBA
REFA	- Description of pilot lines and HRC analysis / BIBA, IKOR and ICPE

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3 Identified Standardization Aspects

This chapter presents the results of the standardization workshops executed by the consortium partners during the ACROBA project lifetime. The aim of the workshops was the identification of standardization aspects for all the implemented modules in ACROBA and for the whole ACOBA platform. For better understanding and classification, these aspects are described for each ACROBA module.

3.1 HRC – Workplace/Process/Task Description and Taxonomy

Standardization aspect recommended by:	**BIBA**	
Title of the standardization aspect	HRC applications description	
Short description of the standardization Aspect	The design of a guideline for the description of HRC applications to support the analysis and the identification of hazards/risks and reduce time-consuming iterations during the risk assessment procedure	
Are there any standards addressing the identified aspect? (Yes/No)	Yes	
If standards exist	**List the standards (one per line)**	**Is this standard sufficient (Yes/No), If No describe content to be extended**
	REFA	No

<u>Standardization strategy (detailed):</u> For the description and analysis of Human-Robot collaborative applications, several approaches and taxonomies are present. The terminology used to describe this field of work in both academic research and industry is ambiguous and confusing, leading to inconsistent knowledge and analysis of interaction, safety and productivity. The design of HRC applications, mainly performed by experts in the fields of process design and safety, requires a detailed guideline and a unified taxonomy helping the system designer to perform this task following a standardized procedure. The authors of this deliverable are recommending the extension of the established method REFA. The extension consists of the integration of additional workplace parameters to be considered during the description of the process. Required parameters are to be extracted from the technical specification ISO/TS 15066. Examples of potential parameters are:

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- Workplace type: shared, simultaneous. The same approach could be adopted at each process task.
- Physical contact between human operator and robot systems (robot, gripper and parts): yes/no. The same approach could be adopted at each process task.
- Detailed description of the robot system: hand-guiding capabilities (yes/no), allowed speed (max), payload, size,
- Detailed description of the gripper (shape, materials, size). The same approach could be adopted at each process task since gripper can be changed from task to task.
- Detailed description of the parts to be handled by the gripper. The same approach could be adopted at each process task.
- Human operator: expertise (beginner, expert), training (yes/no), age, body size, handedness
- Type of each process task: manual, automated, co-working (coexistence, cooperation, collaboration). The detailed description of potential task types is given in D3.5
- Use of a known taxonomy for the description of HRC applications (e.g. IKOR and ICPE use-cases) in industrial assembly such the taxonomy in [3] and according to DIN 8593, VDI 2860 and DIN 8580

Assemble									
Joining	Filling	Pressing on and pressing in	By primary molding	By forming	By welding	By soldering	Gluing	Textile joining	Saving

Handle				
Saving	Change quantities	Moving	Back Up	Controlloing

Adjustment					
By molding	By remoldelling	By cutting	By joining equalising parts	By setting	By post-treatment

Special operations											
Marking	Heating	Cooling	Cleaning	Deburring	Printing	Covering	Stripping	Unpacking	Oiling	Soaking	Sealing

Figure 1: Assembly tasks according to [3]

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The adoption of this approach will facilitate the identification (through mapping, see annex) of potential hazards/risks per task/process/workplace. A potential standardization activity consists of the development of a DIN specification describing the approach to be adopted to support the design of HRC applications. BIBA has already started in 2023 with this activity and is collaborating with BFH to include the modelling approach developed in 2024 by BFH researchers (see D3.5). The partners will follow the DIN SPEC development process. The selection of appropriate external partners has started. BIBA, as one of the MRK ZIM Network members, intends to invite other members such as ZeMA - Zentrum für Mechatronik und Automatisierungstechnik gGmbH to work on this activity.

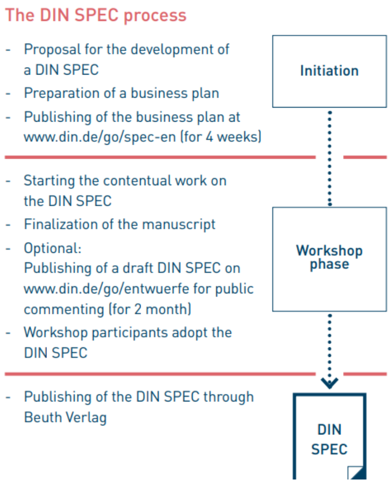
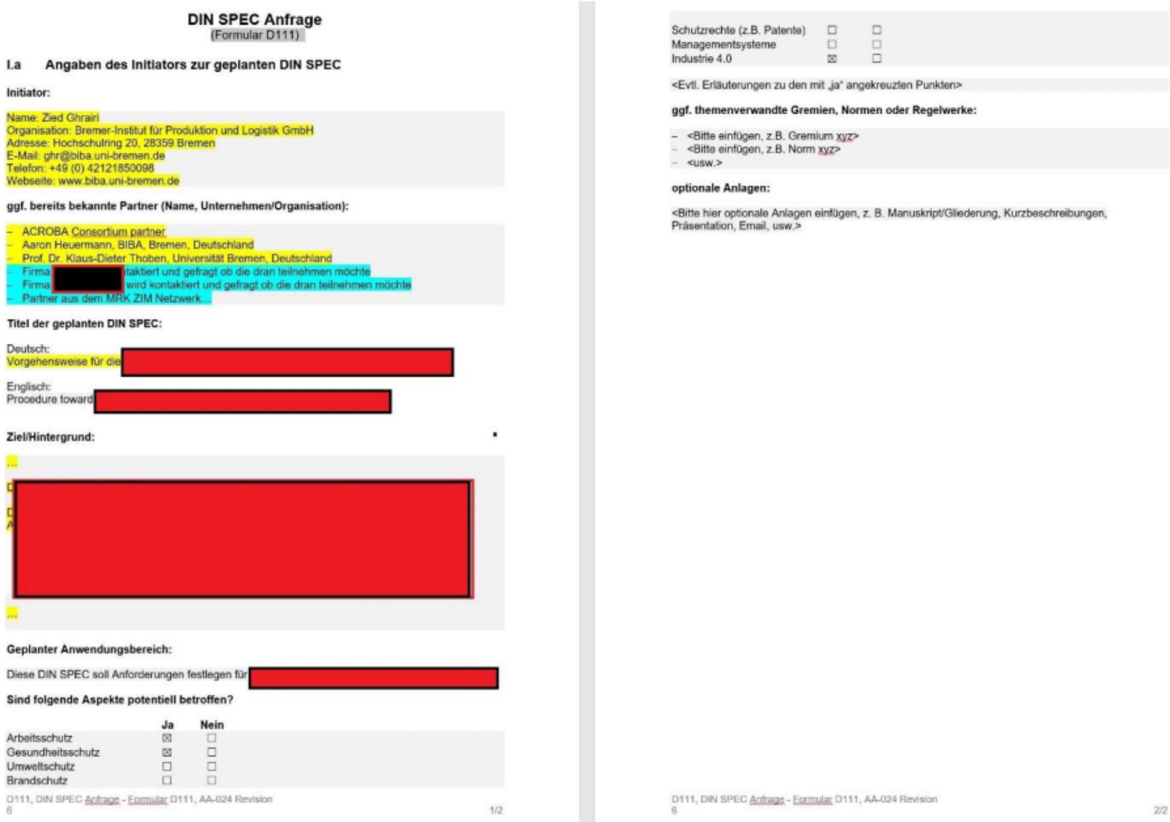


Figure 2: DIN SPEC process steps



DIN SPEC Anfrage
(Formular D111)

I.a Angaben des Initiators zur geplanten DIN SPEC

Initiator:

Name: Zied Ghrairi
Organisation: Bremer-Institut für Produktion und Logistik GmbH
Adresse: Hochschulring 20, 28359 Bremen
E-Mail: ghr@biba.uni-bremen.de
Telefon: +49 (0) 42121850098
Webseite: www.biba.uni-bremen.de

ggf. bereits bekannte Partner (Name, Unternehmen/Organisation):

- ACROBA Consortium partner
- Aaron Heuermann, BIBA, Bremen, Deutschland
- Prof. Dr. Klaus-Dieter Thoben, Universität Bremen, Deutschland
- Firma [redacted]taktiert und gefragt ob die dran teilnehmen möchte
- Firma [redacted] wird kontaktiert und gefragt ob die dran teilnehmen möchte
- Partner aus dem MRK ZIM Netzwerk…

Titel der geplanten DIN SPEC:

Deutsch:
Vorgehensweise für die [redacted]

Englisch:
Procedure toward [redacted]

Ziel/Hintergrund:

…

[redacted]

…

Geplanter Anwendungsbereich:

Diese DIN SPEC soll Anforderungen festlegen für [redacted]

Sind folgende Aspekte potentiell betroffen?

	Ja	Nein
Arbeitsschutz	☒	☐
Gesundheitsschutz	☒	☐
Umweltschutz	☐	☐
Brandschutz	☐	☐
Schutzrechte (z.B. Patente)	☐	☐
Managementsysteme	☐	☐
Industrie 4.0	☒	☐

<Evtl. Erläuterungen zu den mit „ja" angekreuzten Punkten>

ggf. themenverwandte Gremien, Normen oder Regelwerke:

- <Bitte einfügen, z.B. Gremium xyz>
- <Bitte einfügen, z.B. Norm xyz>
- <usw.>

optionale Anlagen:

<Bitte hier optionale Anlagen einfügen, z. B. Manuskript/Gliederung, Kurzbeschreibungen, Präsentation, Email, usw.>

D111, DIN SPEC Anfrage - Formular D111, AA-024 Revision 6 1/2

D111, DIN SPEC Anfrage - Formular D111, AA-024 Revision 6 2/2

Figure 3: DIN Specification for HRC process description - First step

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3.2 Unified Cell Calibration

Standardization aspect recommended by:	**VICOMTECH, DEUSTO, SIGMA**	
Title of the standardization aspect	Unified Cell calibration approach	
Short description of the standardization Aspect	A standardized way to calibrate a cell	
Are there any standards addressing the identified aspect? (Yes/No)	No	
If standards exist	**List the standards (one per line)**	**Is this standard sufficient (Yes/No), If No describe content to be extended**
	Universal Robots (UR) Calibration	No (can be only applied to UR robot)
	Intel RealSense Calibration	No, can be only applied to Intel RealSense Camera for intrinsic calibration
	MoveIt Hand-Eye Calibration	Yes, for camera calibration only (not the whole cell at once)

Standardization strategy (detailed): Currently, there is no standardized calibration process for robotic cells used within the ACROBA project. Each use case performs calibration manually on their own setup, using a variety of existing calibration strategies from individual hardware manufacturers. These include for example:

- Universal Robots (UR) Calibration: Calibration methods provided by UR for their robotic arms.
- Intel RealSense Calibration: Intel RealSense's calibration tools for their depth cameras.
- MoveIt Hand-Eye Calibration: RViz plugins for conducting hand-eye camera calibration. Calibrations can be performed for cameras rigidly mounted in the robot base frame (eye-to-hand) and for cameras mounted to the end effector (eye-in-hand).

While these individual calibration processes work for specific components, the current manual calibration efforts are time-consuming, error-prone, and vary across different use cases. There is no standardized process to calibrate the entire robotic cell, leading to inconsistencies between setups and making it difficult to scale across multiple systems or integrate new hardware components seamlessly.

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In the future, we could standardize the calibration process to:

- Develop a Unified Calibration Framework: Define a standardized set of calibration procedures that can be applied across different robotic cells, ensuring consistent and accurate results regardless of the hardware components used.
- Cross-Platform Calibration Tools: Create calibration tools that are flexible enough to support hardware from different manufacturers (e.g., UR robots, RealSense cameras) while maintaining a unified calibration process.
- Proposing a Calibration Standard: Once a unified calibration framework is developed, it could be proposed as a standard within the ROS ecosystem to promote wider adoption and ensure consistency across robotic applications.

While no formal standardization has been implemented yet, there is significant potential to create a standardized calibration framework for robotic cells in the future. This effort would build existing tools and strategies from hardware manufacturers and the ROS community, reducing manual effort and ensuring consistency across use cases.

3.3 HRC – Interaction analysis

Standardization aspect recommended by:	**BIBA**	
Title of the standardization aspect	Sensor data-based Interaction Analysis	
Short description of the standardization Aspect	Analyze Interaction between human and robot systems in co-working environments using sensor technologies	
Are there any standards addressing the identified aspect? (Yes/No)	No	
If standards exist	**List the standards (one per line)**	**Is this standard sufficient (Yes/No), If No describe content to be extended**
	N/A	N/A

Standardization strategy (detailed): This standardization aspect focuses on a novel approach for interaction analysis between humans and robot systems in collaborative working environments using sensor technologies. The aim is to support HRC designers and safety experts by offering a DIN SPEC explaining approaches interaction between human operators and robots can be analyzed with the goal of gaining/extracting knowledge related to safety issues.

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The interaction assessment and optimization approaches are based on gathering sensor data. mless cooperation by leveraging sensor data to assess and optimize interactions. The need for this standardization stems from innovations protected under patents EP 3 772 396 A1 and DE 102019211770. These patents outline methods and technologies for sensor-based interaction analysis to improve the safety and effectiveness of human-robot collaboration in workplaces. Here are the potential steps for Standardization:

- DIN SPEC (DIN Specification): The initial step involves creating a DIN SPEC to outline the core principles and guidelines for sensor data-based interaction analysis. DIN SPECs are typically developed quickly through an industry-driven process, allowing for faster adoption and refinement based on industry needs.
- DIN Standard: Based on the insights gained from the DIN SPEC, a formal DIN standard will be developed. This standard will provide detailed, enforceable guidelines for implementing sensor-based interaction analysis in human-robot collaborative environments.
- Optional Future Steps – EN and ISO: After establishing the DIN standard, efforts may be directed towards developing a European (EN) standard or an International (ISO) standard to achieve broader acceptance and uniformity across industries globally.

3.4 Ontology for Skill-based Robotic Process Planning

Standardization aspect recommended by:	**BFH/SIGMA**	
Title of the standardization aspect	Standard ontology for skill based robotic process planning	
Short description of the standardization Aspect	There are existing domain ontologies available in the area of robotics. However, many are very specific, and the terms used in the different ontologies are very different. There is no standardized domain ontology for the area of skill based robotic process planning. Our motivation is to create a standardization for the terms used in this area and share it among the community.	
Are there any standards addressing the identified aspect? (Yes/No)	Yes	
If standards exist	**List the standards (one per line)**	**Is this standard sufficient (Yes/No), If No describe content to be extended**

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	Suggested Upper Merged Ontology (SUMO) is an upper-level ontology that provides definitions of basic ontological concepts for all domains to use as a foundation.	No, it is an upper-level ontology that a new ontology should be built on top.
	Core Ontology for Robotics and Automation (CORA). IEEE has developed this standard ontology for robotics and automation.	No, it lacks lower-level details about skills, primitives etc.

Standardization strategy (detailed): As there is no domain ontology for the need of ACROBA, we decided to develop a new ontology based on existing ontology standards. The intension is to connect the ontology for skill-based robotics process planning (ORPP) to the standard ontologies for robotics and automation: CORA (IEEE standard ontology for robotics and automation) and its theoretical foundation SUMO (Suggested Upper Merged Ontology). It can reach a higher level of maturity and compatibility as well as increase acceptance and ensure reusability and alignment with existing standards. CORA aims to create a common vocabulary/language for robotics and automation domain. It formally defines robots, robot parts, robot groups, robot positions and configurations, robot autonomy levels, and robotic systems. SUMO is the Suggested Upper Merged Ontology, which is an upper-level ontology that provides definitions of basic ontological concepts for all domains to use as a foundation. The following figure illustrates an overview of ontology architecture.

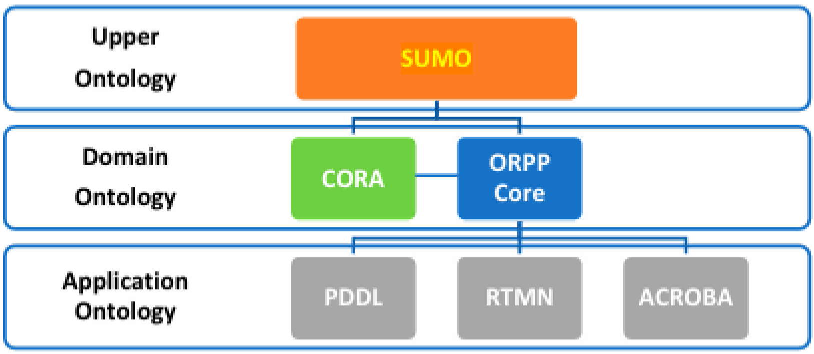

Figure 4: Ontology Architecture [1]

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The ORPP architecture consists of two levels of ontologies: the domain ontology and the application ontology. The domain ontology “ORPP Core” covers the main robotic process concepts. The application ontologies, marked in grey, cover the task planning (PDDL), use case ontology (ACROBA), and the Robot Task Modeling Notation (RTMN) concepts.

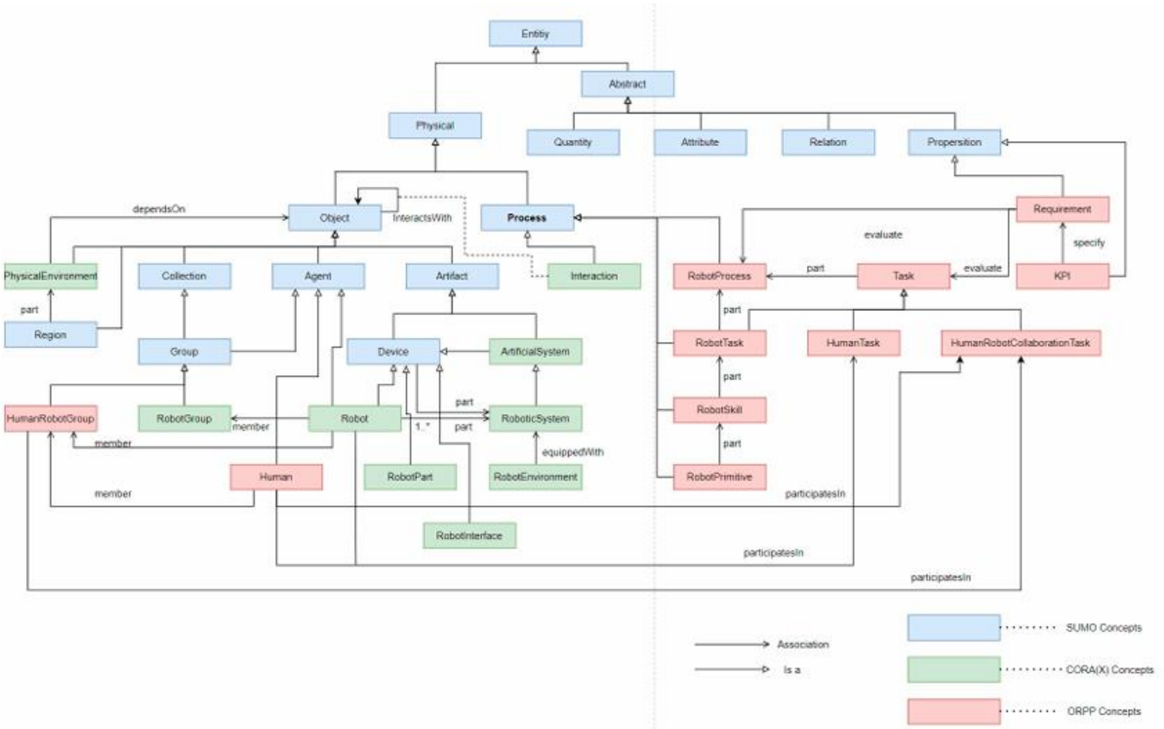

Figure 5.Taxonomy of the main concepts of ORPP and their relation to the other ontologies

Figure 5 presents the overall concepts based on the ORPP architecture. It is modeled as a UML diagram. This new ontology is published in [1]. More details can be found in this paper.

3.5 Control - Skills and Primitives for ROS-based Grippers

Standardization aspect recommended by:	**SIGMA**
Title of the standardization aspect	ROS Based Gripper Control
Short description of the standardization Aspect	A set of standard interfaces to command robotics end-effectors in an agnostic fashion.
Are there any standards addressing the identified aspect? (Yes/No)	Yes

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If standards exist	List the standards (one per line)	Is this standard sufficient (Yes/No), If No describe content to be extended
	Existing ROSEndEffector project https://advrhumanoids.github.io/ROSEndEffectorDocs/	No as it is now discontinued

Standardization strategy (detailed): In the current state of the ACROBA architecture, no formal standardization has been implemented for controlling robotic grippers. Instead, specific control primitives have been created for individual gripper types, such as Robotic grippers, which have been used as reference implementations. Partners have adapted these primitives for their own systems, leading to a range of custom solutions for different grippers. This approach has worked in the short term but lacks consistency and scalability across different robotic platforms and hardware.

Recognizing the limitations of this approach, we are considering the potential for future standardization of gripper control interfaces. As part of this effort, we have identified ROSEndEffector [6] project as an example of a past initiative that sought to define a standardized interface for controlling end-effectors in ROS. While the ROSEndEffector project is no longer actively maintained, its design principles could serve as a valuable foundation for developing a unified interface for gripper control in the future.

The goal of future standardization would be to create a set of ROS interfaces that abstract away the specifics of individual gripper hardware, enabling consistent control commands across various robotic platforms. This would involve:

- Developing Standard Gripper Control Interfaces: Defining common ROS messages and services for basic gripper operations (e.g., open/close, set position, force control) to simplify integration across different hardware.
- Creating Hardware-Specific Adapters: Designing modular adapters for each gripper type to translate standardized commands into the hardware-specific protocols.
- Alignment with ROS-Industrial: Aligning with the ROS-Industrial initiative to integrate widely used industrial grippers into ROS.

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- Using Actionlib for Feedback and Control: Incorporating Actionlib to manage gripper actions with real-time feedback and preemption capabilities.
- Proposing a ROS Enhancement Proposal (REP): Formalizing the interface as a ROS Enhancement Proposal to promote community adoption and extend interoperability.

While no formal standardization has been implemented yet, there is strong potential to create a unified, scalable solution for gripper control, drawing on efforts like ROSEndEffector.

3.6 Control - Skills and Primitives for ROS-based Robots

<table>
<tr><td>Standardization aspect recommended by:</td><td colspan="2">SIGMA</td></tr>
<tr><td>Title of the standardization aspect</td><td colspan="2">ROS Based Robot Control</td></tr>
<tr><td>Short description of the standardization Aspect</td><td colspan="2">Adaptation of the MoveIt motion planning framework standard to be compatible with ACROBA architecture</td></tr>
<tr><td>Are there any standards addressing the identified aspect? (Yes/No)</td><td colspan="2">Yes</td></tr>
<tr><td>If standards exist</td><td>List the standards (one per line)</td><td>Is this standard sufficient (Yes/No), If No describe content to be extended</td></tr>
<tr><td></td><td>No, but established frameworks at research level.
ROS Control / MoveIt standard
http://wiki.ros.org/ros_control
https://moveit.ros.org/</td><td>Yes</td></tr>
</table>

Standardization strategy (detailed): The MoveIt motion planning framework offers a set of APIs, tools, and interfaces designed for use with various ROS toolkits, such as the MoveIt motion planning plugin in RViz. We have adapted the C++ MoveIt API to ensure compatibility with our requirements leveraging core MoveIt functionalities, such as trajectory generation and execution with collision checking.

As part of this integration, we developed and standardized a skill MoveTo that combines two key primitives GenerateTrajectory and ExecuteTrajectory. This skill enables the robot to generate and execute a trajectory from its current state to one or more given target poses. The skill is designed with a flexible set of parameters, allowing for customization based on specific motion requirements (end effector selection, speed and acceleration limitations, usage of

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either cartesian or joint-space motion etc). This skill is fully integrated with the MoveIt API and is designed to be flexible and adaptable to a wide variety of motion planning scenarios. The result is an efficient, robust trajectory generation and execution system that can be standardized for use within the ACROBA ecosystem and potentially extended to the broader ROS community.

3.7 Integration/deployment - Basic Skill Set

Standardization aspect recommended by:	**SIGMA/BFH**	
Title of the standardization aspect	Basic Skill Set	
Short description of the standardization Aspect	Definition of a set of basic skills allowing to solve the most commonly encountered industrial tasks.	
Are there any standards addressing the identified aspect? (Yes/No)	No	
If standards exist	**List the standards (one per line)**	**Is this standard sufficient (Yes/No), If No describe content to be extended**
	N/A	N/A

Standardization strategy (detailed): Industrial robotics often requires repetitive tasks that can be broken down into a basic set of actions, both in manipulation and perception. As part of the ongoing development and testing within the ACROBA project, a Basic Skill Set has been partially defined and implemented. This set of core actions is being made available as ACROBA primitives/skills, aiming to simplify the deployment of robots across various industrial settings without requiring custom programming for each application.

Examples of Basic Skills that are part of this set include:

<u>Control Skills:</u>

- Grasping and manipulation: Skills to control grippers for picking, moving, and releasing objects.
- Path planning and execution: Skills for planning robot's paths and execute them.

<u>Perception Skills:</u>

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- Part detection and localization: Skills for identifying and locating objects within the workspace using vision systems or other sensors (e.g., object detection, pose estimation).
- Human detection and interaction: Skills to detect and track humans within the robot's environment using sensors (e.g., motion sensors, depth cameras). This could be useful in collaborative settings, where the robot needs to recognize and respond to human presence or movement.
- Part inspection: Skills to inspect parts for defects or quality control. This includes visual inspection (e.g., identifying surface defects) or dimensional inspection (e.g., verifying part measurements against specifications).

These basic skills are designed to be modular, enabling them to be combined to form higher-level tasks. Importantly, the standardization effort in ACROBA focuses on defining the names and parameters of each skill and primitive. This approach ensures that future developers can customize and extend the implementation while still adhering to a common interface and structure.

Although the Basic Skill Set has been partially developed and tested in the context of the ACROBA generic cell, the next step is to formalize this set as a standard, making it available to the wider ROS ecosystem.

3.8 Integration/deployment of non-safety-related functionalities

Standardization aspect recommended by:	**BIBA/IKOR**
Title of the standardization aspect	Optimization of safety-critical applications using non-safety-related functionalities
Short description of the standardization Aspect	Specification of a generic format/model for the integration of non-safety-related functionalities into a safe industrial application
Are there any standards addressing the identified aspect? (Yes/No)	Yes

If standards exist	**List the standards (one per line)**	**Is this standard sufficient (Yes/No), If No describe content to be extended**

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	IEC 61506	No

Standardization strategy (detailed): There is a need for a DIN specification dealing with a uniform approach, how supporting mechanisms to be deployed in safety-critical applications should be designed and implemented. Due to technical limitations, and functional and non-functional requirements, different solutions for enabling interoperability with safe applications (e.g. PLCs) have been developed.

Nevertheless, their deployment is still limited to specific applications, which should fulfil in advance predefined requirements (communications interfaces, databases, drivers, libraries, etc.).

The adopted approach in ACROBA consists of defining instructions in the form of rules. These rules are implemented using a JSON format following a predefined scheme (see rule-based toolkit, GitHub), The required DIN specification should focus on this aspect, A uniform framework for rules definition will enable the integration of such mechanisms into and their deployment in existing safety-related applications (process/robot control) in the future,

3.9 Integration - API for DRL and ROS

Standardization aspect recommended by:	**DEUSTO**	
Title of the standardization aspect	API for Reinforcement Learning libraries integration with ROS-enabled environments	
Short description of the standardization Aspect	A standard API for integrating ROS-enabled environments with reinforcement learning libraries via mapping of observation and actions spaces to ROS topics	
Are there any standards addressing the identified aspect? (Yes/No)	Yes	
If standards exist	**List the standards (one per line)**	**Is this standard sufficient (Yes/No), If No describe content to be extended**
	https://gymnasium.farama.org/ Gymnasium (previously OpenAI Gym)	No

Standardization strategy (detailed): Extend the original standard Gymnasium API (previously OpenAI Gym API) to seamlessly accept ROS-enabled scenarios where ROS topics can be mapped onto a Gymnasium-compatible observation space, and ROS actions can be

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mapped onto a Gymnasium-compatible action space. Through this mechanism a ROS simulation/scenario featuring robotic arms, or other ROS-compatible robotic entities or electronics equipment can be easily adapted into a Gymnasium-compatible environment that can be trained using Reinforcement Learning libraries. This mapping will be carried out using configuration files via a standard syntax such as JSON.

3.10 Framework architecture – cognitive approach

<table>
<tr><td>Standardization aspect recommended by:</td><td colspan="2">SIGMA</td></tr>
<tr><td>Title of the standardization aspect</td><td colspan="2">Primitive/Skills/Task architecture</td></tr>
<tr><td>Short description of the standardization Aspect</td><td colspan="2">Task-level cognitive framework. Tasks can be decomposed in a sequence of blocks (skills, which are at a lower level composed by several primitives), that are goal-oriented, versatile and hardware agnostic.</td></tr>
<tr><td>Are there any standards addressing the identified aspect? (Yes/No)</td><td colspan="2">No</td></tr>
<tr><td>If standards exist</td><td>List the standards (one per line)</td><td>Is this standard sufficient (Yes/No), If No describe content to be extended</td></tr>
<tr><td></td><td>N/A</td><td>N/A</td></tr>
</table>

Standardization strategy (detailed): The ACROBA platform adopts a task-level programming paradigm, where tasks can be decomposed into a sequence of blocks, or skills, each addressing a specific cognitive capability. These skills are designed to be goal-oriented, versatile, and hardware-agnostic, allowing them to be used across a wide range of manufacturing tasks. Each skill is composed of primitives, which are basic and generic actions that directly interact with data or hardware through drivers, such as controlling actuators or sensors. This approach is similar to that found in other projects, such as SKIROS2 (GitHub), which also emphasizes decomposing tasks into modular and reusable blocks (skills and primitives). The ACROBA approach builds on this concept by introducing a three-layer cognitive framework, consisting of:

- Driver Layer: Handles direct communication with hardware drivers and sensors.
- Primitive Layer: Consists of low-level, generic actions or functions that interact with data and hardware.

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- Skill Layer: Composed of multiple primitives and can include other skills to perform higher-level tasks.

While this framework is currently being used in the ACROBA platform, it is not yet standardized across the broader ROS ecosystem. There is a strong potential to propose this architecture as a standard for decomposing robotic tasks into modular, reusable skills and primitives. This would offer a flexible and scalable approach to task programming that could be used across different robotic systems and applications.

By defining the cognitive framework and its components (drivers, primitives, and skills) in a standardized way, we can help ensure interoperability between systems, reduce the need for custom programming, and make it easier to integrate new hardware or software components. This modular, goal-oriented, and hardware-agnostic approach has the potential to greatly simplify task programming and coordination in robotic systems.

The next step could involve creating a formal ROS Enhancement Proposal (REP) to propose the standardization of the task-level cognitive framework, building on the principles outlined in ACROBA and other similar projects like SKIROS2.

3.11 Deployment of non-functional safe components

Standardization aspect recommended by:	**BIBA/IKOR**	
Title of the standardization aspect	Non-functional safe vision-based systems for safety-critical applications	
Short description of the standardization Aspect	Supporting safety in collaborative robotic applications using non-functional safe camera systems	
Are there any standards addressing the identified aspect? (Yes/No)	Yes	
If standards exist	**List the standards (one per line)**	**Is this standard sufficient (Yes/No), If No describe content to be extended**
	DIN EN 61508	No
	ISO 13849-1	No
	ISO/TS 15066	No
	IEC 62061	No
	ISO 10218	No

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Standardization strategy (detailed): Get in contact with the responsible ISO committees and propose the extension of the current standard with a section (chapter) for the deployment of non-safe sensors. Currently the idea of using a camera to stop or reduce the speed of the robot is considered acceptable from a safety point of view. As soon as the robot speed is to be increased, from production efficiency point of view, such decisions are not allowed to be executed when it comes from (or is based upon) non-functional safe hardware/software components, such as non-certified camera systems. The ACROBA solution is based upon the integration of a vision-based sensor. This would prevent the use of ACROBA to ensure safe collaborative applications. The recommended concept (See D2.5/D3.5) considers this aspect by isolating all the non-functional components (hardware and software) from the safety layer of the whole application. The adopted approach in combination with additional (required) mechanisms for plausibility check and verification (DIN EN 61508) needs to be validated by related standardization working groups. The adoption of this approach could be allowed by regulations to support the integration of novel technologies (hard- and software-based) and avoid time-consuming validation procedures. The responsibilities for the integration of such mechanisms need to be assigned to appropriate application stakeholders (Integrator, Safety, experts, process engineer…). This will enable the use of non-functional safe components and their related capabilities in safety-critical applications. The approach adopted for vision-based systems (widely used at lab-scale) will be replicated for other sensor systems such as the motion capturing systems.

3.12 Modelling - Process flow

<table>
<tr><td>Standardization aspect recommended by:</td><td colspan="2">BFH</td></tr>
<tr><td>Title of the standardization aspect</td><td colspan="2">Process and tasks modelling</td></tr>
<tr><td>Short description of the standardization Aspect</td><td colspan="2">A technique/approach for process/tasks flow modelling in industrial environments using high level language</td></tr>
<tr><td>Are there any standards addressing the identified aspect? (Yes/No)</td><td colspan="2">No</td></tr>
<tr><td>If standards exist</td><td>List the standards (one per line)</td><td>Is this standard sufficient (Yes/No), If No describe content to be extended</td></tr>
<tr><td></td><td>N/A</td><td>N/A</td></tr>
</table>

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Standardization strategy (detailed): In general, task description can be done through Scripting language or Behavior Trees. However, there is currently no standard for scripting languages nor Behavior Trees (BT) libraries. BT libraries even have different implementation and follow different standards. There is no high-level description language available neither.

In the ACROBA platform, the process flow modelling relies on a visual programming language, which consist of dragging and dropping user defined blocks. This language is based on BPMN (Business Process Model and Notation) from the Object Management Group® Standards Development Organization (OMG® SDO). BPMN has become the de-facto standard for business processes diagrams.

A REST API between the TaskPlanner and the GU, allows for the creation and update of a task description. The graphical process flow is then stored in an internal high-level representation with information on the skill flow and parameters. This high-level task representation is done in the standard JSON format and used as the standalone internal representation of a task. It is transformed on the fly at runtime in a behavior tree.

3.13 HRC – Risk assessment considering human factors and behavior

Standardization aspect recommended by:	**BIBA**	
Title of the standardization aspect	Extension of risk assessment procedure with additional Human factor–related issues.	
Short description of the standardization Aspect	Working out an extended risk assessment procedure including steps related to risk reduction through human-factors-related mechanisms to ensure safety and human-centricity in parallel.	
Are there any standards addressing the identified aspect? (Yes/No)	Yes	
If standards exist	**List the standards (one per line)**	**Is this standard sufficient (Yes/No), If No describe content to be extended**
	ISO 10218	**No**
	ISO 13849-1	No
	ISO/TS 15066	No
	IEC 62061	No

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Standardization strategy (detailed): The potential strategy is trying to get into DIN/EN/ISO working groups of mentioned standards for contributions. The contribution consists of taking in consideration human factors and behaviours (trust, workload, ergonomics, safety awareness, well-being, ...) and related assessment techniques (real-time ergonomic assessment, real-time health/workload monitoring, well-being analysis) in existing risk assessment procedures and guidelines to enable human-centricity and determine the safety level based on the severity, the frequency of exposure and the possibility to manage the hazard to an acceptable level by reducing risk through the integration of these factors. The extension of traditional risk assessment procedures with additional steps/mechanisms is recommended. The existing guidelines don't focus on these factors and do not recommend related mechanisms as safety measures. The trend for agile manufacturing, at research level, is to perform an in-process risk assessment using enabling technologies (hardware and software tools) supporting the prediction of human intention and resulting hazards/risks. The integration/recommendation of real-time workload, fatigue, and ergonomics assessment measures becomes essential.

3.14 Flexibility – Data set

Standardization aspect recommended by:	**BFH**	
Title of the standardization aspect	Data set for skill input	
Short description of the standardization Aspect	A generic strategy enabling the flexibility to use any standard for the input data	
Are there any standards addressing the identified aspect? (Yes/No)	No	
If standards exist	**List the standards (one per line)**	**Is this standard sufficient (Yes/No), If No describe content to be extended**
	N/A	N/A

Standardization strategy (detailed): Advanced industrial tasks are composed of various different skills, which generally rely on a complex set of parameters. There are different dataset categories which could be specified:

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- Common data: data shared across multiple skills, and generally the ACROBA platform generic skills.
- Skill specific data: data unique to a given robotic skill. In the ACROBA platform, these concern the user defined skills developed for a particular use case.

In both cases, the data types rely on the ROS Standard, and data input parameters are defined via ROS messages. In the ACROBA platform, we use a MongoDB as a central repository to store datasets: standardized formats for inputs and outputs (e.g. CSV, JSON, URDF etc.) could be thus used. Two strategies can then be used:

- During the process design, a user can either specify directly parameters or map data stored in the central DB to skills input parameters for more complex cases.
- Process directly input data in some robotic skills for the more complex scenarios.

These strategies allow for flexibility to use any standard for the input data at the skill level. Skills usually cover many different needs and different purposes. It is thus important to have this flexibility.

3.15 Interoperability – ROS Interface of new skills and primitives

<table>
<tr><td colspan="2">Standardization aspect recommended by:</td><td>DEUSTO</td></tr>
<tr><td colspan="2">Title of the standardization aspect</td><td>ROS Interface for new primitives or skills</td></tr>
<tr><td colspan="2">Short description of the standardization Aspect</td><td>Definition of the invocation interface, message formats for new skills that may be standardized for the community</td></tr>
<tr><td colspan="2">Are there any standards addressing the identified aspect? (Yes/No)</td><td>Yes</td></tr>
<tr><td>If standards exist</td><td>List the standards (one per line)</td><td>Is this standard sufficient (Yes/No), If No describe content to be extended</td></tr>
<tr><td></td><td>ROS
https://www.ros.org/</td><td>No</td></tr>
</table>

Standardization strategy (detailed): Extensions to ROS are proposed through a REP (ROS Enhancement Proposal). A REP is a design document providing information to the ROS community or describing a new feature for ROS or its processes or environment. New primitives or skills created under ACROBA that may be of interest to the general robotics

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research community, can be proposed for standardization under the REP process. The development of these new skills must be formalised following the software development standards set out in the ROS documentation. These standards specify precisely how to define communications messages to be transmitted using the standard protocols used in this platform mentioned above.

3.16 Interoperability – Trajectory representation

Standardization aspect recommended by:	**DEUSTO**	
Title of the standardization aspect	Format of Transformation Frames representing trajectories	
Short description of the standardization Aspect	Working out an approach for the representation of the Transformation Frames (TFs) format.	
Are there any standards addressing the identified aspect? (Yes/No)	No	
If standards exist	**List the standards (one per line)**	**Is this standard sufficient (Yes/No), If No describe content to be extended**
	N/A	N/A

Standardization strategy (detailed): Trajectories are commonly represented by a sequence of transformation frames (TFs) in robotics and other applications. TFs provide a concise and efficient way to represent the position and orientation of an object at a given time. To facilitate data exchange and interoperability between different systems, it is important to standardize the format of TFs representing trajectories. The trajectory data should be represented using the geometry_msgs/Transform Stamped message type. This message type provides a structured way to represent a single TF, including information about the translation, rotation, and timestamp. The TF data should be represented in a specific coordinate frame. This frame should be clearly identified in the header of the TransformStamped message. The strategy consists of:

- Identify key decision-makers and influencers: Target your lobbying efforts towards individuals and organizations that have the power to influence the adoption of standardization.

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- Develop a compelling case for standardization: Clearly articulate the benefits of the standardization, such as improved interoperability, reduced development costs, and enhanced data quality.
- Build relationships and coalitions: Engage with stakeholders from diverse backgrounds and perspectives to build support for standardization.
- Participate in relevant discussions and forums: Actively participate in industry events, conferences, and online discussions to raise awareness of standardization.
- Provide evidence and data to support your claims: Back up your arguments with data, research, and case studies that demonstrate the value of standardization.

3.17 Communication – FIWARE protocol

Standardization aspect recommended by:	**DEUSTO**	
Title of the standardization aspect	Communication features for the FIWARE protocol	
Short description of the standardization Aspect	New generic message format definition for specific information transmission.	
Are there any standards addressing the identified aspect? (Yes/No)	Yes	
If standards exist	**List the standards (one per line)**	**Is this standard sufficient (Yes/No)**
	FIWARE https://www.fiware.org/	No
	IEC/SC 65E Devices and integration in enterprise systems,	No

Standardization strategy (detailed): In modern manufacturing plants, a direct and sufficiently fast flow of information between production plants and offices or production control rooms is necessary. In this scenario, real-time communication as understood in the context of industrial production is not necessary, but the main objective is to have a reliable information transfer of general production data, e.g. machine or robot status, manufacturing events or statistics of manufactured components.

In order to achieve these objectives in a reliable way, an established industry standard such as FIWARE is adopted. For the integration of this protocol into the platform, the ROS FIROS communication node, provided directly by the FIWARE standardization consortium, is used.

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Information regarding this standard can be found in https://www.fiware.org/wp-content/uploads/2020/06/FF_iHubs_GuideforApplicants.pdf

3.18 Communication – ROS Protocol

Standardization aspect recommended by:	**BFH**	
Title of the standardization aspect	Communication Protocol ROS	
Short description of the standardization Aspect	Propose standardization of generic messages (msgs) if they do not exist to be considered by ROS developers.	
Are there any standards addressing the identified aspect? (Yes/No)	Yes	
If standards exist	**List the standards (one per line)**	**Is this standard sufficient (Yes/No), If No describe content to be extended**
	ROS https://www.ros.org/	No

Standardization strategy (detailed): Extensions: Integration of ROS2 drivers for different robots. The current version of the ACROBA platform uses the first version of ROS but is designed to be ported to ROS 2 when necessary. Regarding communications, the original version of ROS is based on the TCP/IP standard, implementing the protocol called ROSTCP.

In the case of the second version of ROS, the standard protocol on which ROS2 communications are based has been changed, using DDS in this new version.

Both TCP/IP and DDS are protocols with their corresponding standardizations, so it can be considered that communications at the plant level follow or will follow one of these two established standards.

With respect to the communication messages implemented in the ROS platform, they are formally defined in the platform documentation. However, it is possible to define the necessary messages to be transmitted, assuming that they will be transmitted at a low level following the standard protocols mentioned above.

In the case of the development of a new driver for a robot or machine, the developed code must follow a test plan specified by the developer and implement the necessary communication messages in case such messages are not already defined in ROS.

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3.19 Security

Standardization aspect recommended by:	**ROBOCOAST**	
Title of the standardization aspect	Security rules / container	
Short description of the standardization Aspect	Integration between the platform and the modules in a way that it protects the trade secrets	
Are there any standards addressing the identified aspect? (Yes/No)	Yes	
If standards exist	**List the standards (one per line)**	**Is this standard sufficient (Yes/No), If No describe content to be extended**
	N/A	No

Standardization strategy (detailed): Extensions based on best practices: Definition of secret levels for containers, to protect IP. To keep trade secret level security. Important for commercialisation. Best practises to safeguard software code are: 1) Minimize the container image 2) Use compiled binaries 3) use tools to obfuscate binaries, variables and control flow 4) Encrypt sensitive files 5) use Docker's secret management feature, or third-party solutions like HashiCorp Vault 6) Limit Access and permissions 7) License checking and DRM 8) implement integrity checks or tamper-detection 9) Dynamic loading of sensitive components.

4 Conclusion and future works

During the lifetime of the ACROBA project, several findings have been identified. These are mainly related to technical limitations faced by the project partners for the development of the ACROBA objectives. Many of them have been addressed through the development of novel techniques/approaches. These developments can be optimized and best transferred to the market through the adoption of the identified standardization aspects. According to the aspects, the main contributions are related to interoperability, modelling and integration. In addition, the project activities have shown that ensuring HRC-related issues/requirements are limiting/hindering the adoption/integration of novel techniques based upon non-functional safe approaches, especially when a TRL6/7 is expected. The certification process is time consuming and requires the involvement (consortium partner, associated partner) of a certification body from the beginning of the project.

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These identified standardization aspects, once implemented, will reduce costs, anticipate technical requirements, and increase productive and innovative efficiency. For the implementation of these aspects, additional effort (time, budget) is required after the ACRBA project lifetime. After the project's completion, it is expected that the Joint Venture will continue to consider the established strategy and monitor any standards that may emerge in the future.

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ACROBA
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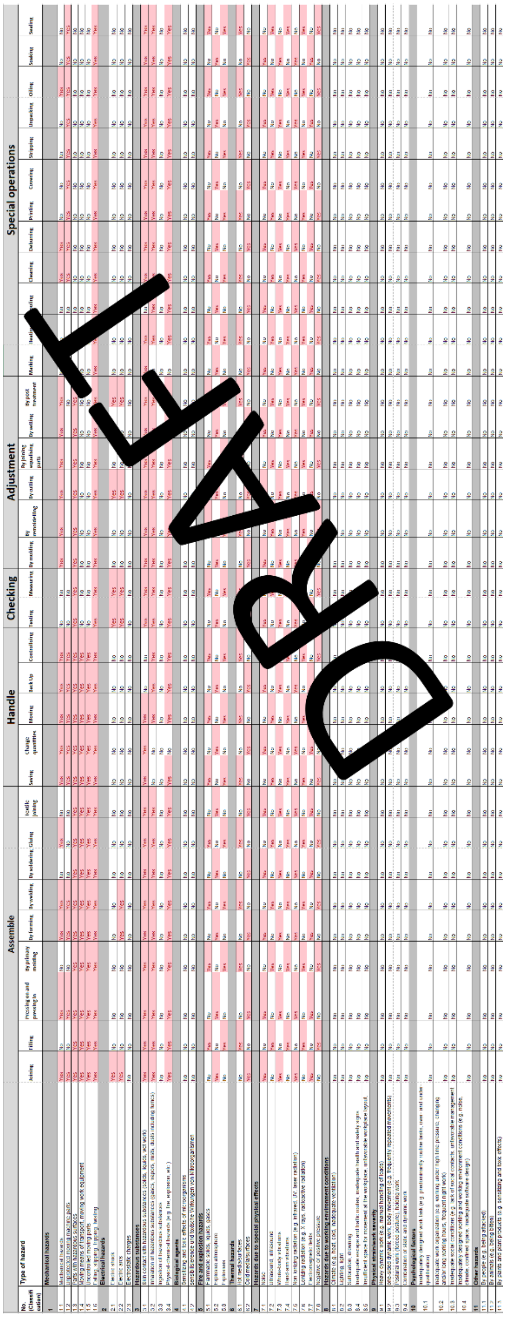
BIBA

Annexes

Mapping of assembly tasks with potential hazards



No. (Classification)	Type of hazard	Joining	Filling	Pressing on and pressing in	By primary molding
1	**Mechanical hazards**				
1.1	Mechanical hazards	Yes	No	Yes	No
1.2	Unprotected moving machine parts	Yes	No	Yes	No
1.3	Parts with hazardous surfaces	Yes	Yes	Yes	Yes
1.4	Moving means of transport, moving work equipment	Yes	Yes	Yes	Yes
1.5	Uncontrolled moving parts	Yes	Yes	Yes	Yes
1.6	Falling, slipping, tripping, twisting	Yes	Yes	Yes	Yes
2	**Electrical hazards**				
2.1	Electric shock	Yes	No	No	No
2.2	Electric arcs	Yes	No	No	No
2.3	Electrostatic charges	No	No	No	No
3	**Hazardous substances**				
3.1	Skin contact with hazardous substances (solids, liquids, wet work)	Yes	Yes	Yes	Yes
3.2	Inhalation of hazardous substances (gases, vapors, mists, dusts including fumes)	Yes	Yes	Yes	Yes
3.3	Ingestion of hazardous substances	No	No	No	No
3.4	Physical-chemical hazards (e.g. fire, explosion, etc.)	Yes	Yes	Yes	Yes
4	**Biological agents**				
4.1	Sensitizing and toxic effects of microorganisms	No	No	No	No
4.2	sensibilisierende und toxische Wirkungen von Mikroorganismen	No	No	No	No
5	**Fire and explosion hazards**				
5.1	Flammable solids, liquids, gases	No	Yes	No	Yes
5.2	Explosive atmosphere	Yes	No	Yes	No
5.3	Explosives	No	Yes	No	Yes
6	**Thermal hazards**				
6.1	Hot media/surfaces	No	Yes	No	Yes
6.2	Cold media/surfaces	Yes	No	Yes	No
7	**Hazards due to special physical effects**				
7.1	Noise	Yes	No	Yes	No
7.2	Ultrasound, infrasound	No	Yes	No	Yes
7.3	Whole-body vibrations	Yes	No	Yes	No
7.4	Hand-arm vibrations	No	Yes	No	Yes
7.5	Non ionizing radiation (e.g. infrared, UV, laser radiation)	Yes	No	Yes	No
7.6	Ionizing radiation (e.g. X rays, radioactive radiation)	No	Yes	No	Yes
7.7	Electromagnetic fields	Yes	No	Yes	No
7.8	Negative or positive pressure	No	Yes	No	Yes
8	**Hazards due to working environment conditions**				
8.1	Climate (e.g. heat, cold, inadequate ventilation)	No	No	No	No
8.2	Lighting, light	No	No	No	No
8.3	Suffocation, drowning	No	No	No	No
8.4	Inadequate escape and traffic routes, inadequate health and safety signs	No	No	No	No
8.5	Insufficient space for movement at the workplace, unfavorable workplace layout	No	No	No	No
9	**Physical strain/work severity**				
9.1	Heavy dynamic work (e.g. manual handling of loads)	No	No	No	No
9.2	one-sided dynamic work, body movement (e.g. frequently repeated movements)	No	No	No	No
9.3	Postural work (forced posture), holding work	No	No	No	No
9.4	Combination of static and dynamic work	No	No	No	No
10	**Psychological factors**				
10.1	Inadequately designed work task (e.g. predominantly routine tasks, over- and under-qualification)	No	No	No	No
10.2	Inadequate work organization (e.g. working under high time pressure, changing and/or long working hours, frequent night work)	No	No	No	No
10.3	Inadequate social conditions (e.g. lack of social contacts, unfavorable management)	No	No	No	No
10.4	Inadequately designed working and working environment conditions (e.g. noise, climate, confined space, inadequate software design)	No	No	No	No
11	**Other hazards**				
11.1	By people (e.g. being attacked)	No	No	No	No
11.2	By animals (e.g. being bitten)	No	No	No	No
11.3	By plants and plant products (e.g. sensitizing and toxic effects)	No	No	No	No

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