About the CoreSense HE Project

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This is a brief note describing the recently signed **Horizon Europe CoreSense Project**. This project addresses the use of *advanced AI architectures* to improve the capability for situational understanding of *autonomous robots*. It is one of the nine projects approved in the Horizon Europe call HORIZON-CL4-2021-DIGITAL-EMERGING-01-11 of 2021 on *Pushing the limit of robotics cognition*.

While being an independent, European multipartner project, this project continues the long-term research line on *Autonomous Systems* (ASys) of the *Autonomous Systems Laboratory* of the UPM. The UPM CoreSense team includes also researchers from other UPM research groups on aerial inspection and electronics.

The project will start on October 1, 2022 and will be alive for four years.

1 CoreSense Project Content

1.1 About the project

Title: CoreSense: A Hybrid Cognitive Architecture for Deep Understanding

Abstract: Cognitive robots are augmenting their autonomy, enabling them to deployments in increasingly open-ended environments. This offers enormous possibilities for improvements in human economy and wellbeing. However, it also poses strong risks that are difficult to assess and control by humans. The trend towards increased autonomy conveys augmented problems concerning reliability, resilience, and trust for autonomous robots in open worlds. The essence of the problem can be traced to robots suffering from a lack of understanding of what is going on and a lack of awareness of their role in it. This is a problem that artificial intelligence approaches based on machine learning are not addressing well. Autonomous robots do not fully understand their open environments, their complex missions, their intricate realizations, and the unexpected events that affect their performance. An improvement in the capability to understand of autonomous robots is needed. This project tries to provide a solution to this need in the form of 1) a theory of understanding, 2) a theory of awareness, 3) reusable software assets to apply these theories in real robots, and 4) three demonstrations of its capability to a) augment resilience of drone teams, b) augment flexibility of manufacturing robots, and c) augment human alignment of social robots. In summary, we will develop a cognitive architecture for autonomous robots based on a formal concept of understanding, supporting value-oriented situation understanding and self-awareness to improve robot flexibility, resilience and explainability.

Partners: The consortium is composed of six partners from four EU countries:

Universidad Politécnica de Madrid - ES - Coordinator

Delft University of Technology - NL
Fraunhofer IPA - DE
Universidad Rey Juan Carlos - ES
PAL Robotics - ES
Irish Manufacturing Research - IR

Timespan: 2022-2026.

From UPM: There are three UPM research groups involved in this project:

- **Autonomous Systems Laboratory** (ASLab): Ricardo Sanz, Manuel Rodriguez, Esther Aguado
- **Computer Vision and Aerial Robotics** (CVAR): Pascual Campoy, Martín Molina
- **Centro de Electrónica Industrial** (CEI): Eduardo de la Torre, Andrés Otero

Project Manager: Ricardo Sanz, Departamento de Automática, Ingeniería Eléctrica y Electrónica e Informática Industrial. ETS Ingenieros Industriales; coordinator of UPM Autonomous Systems Laboratory.

1.2 Scientific and technical objectives

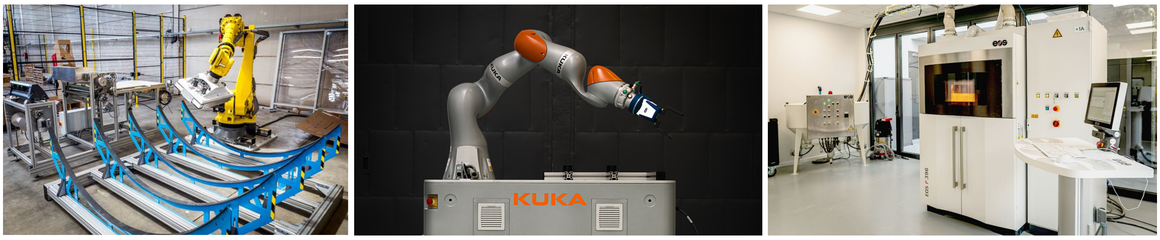
The project has four threads that span from a pure scientific aspect, to a real impact in the socienty and robotics community:

- A **theoretical** thread: Formulation of the *theory of awareness* based on a *systemic concept of understanding*.
- A **technological** thread: Implementation of a reference architecture and engineering toolbox for aware autonomous robots.
- An **application** thread: Use of the theory and the technical assets in the construction of autonomous robots, with increased capabilities to work without/with limited supervision, as well as the next generation of interactive robots, with greatly improved intuitive, safe and efficient cognitive, social and physical capabilities, to assist humans.
- An **impact** thread: Creation of an open-source community in the ROS ecosystem around the architectural software developed in the project.

1.3 Three real-world testbeds

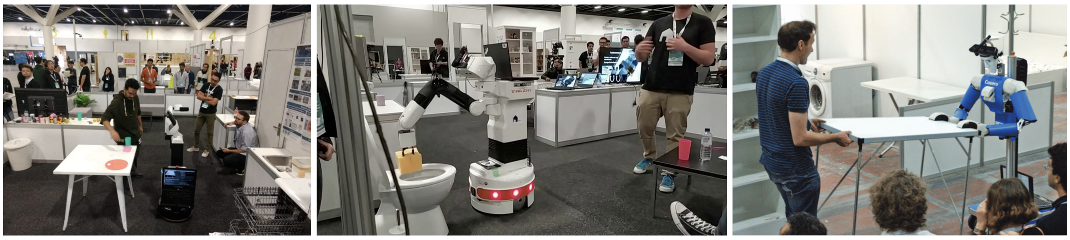
The ambition of the CoreSense technology is of *universality* —a mantra for us— and hence it shall be applicable to different systems. In this project we deploy it over four robotic systems organised into three tesbeds —social, aerial, manufacturing— because the call text requires demonstrating the technology in at least three scenarios. The project will apply the CoreSense technology in the testbeds to address three important problems in robotics: Resilience, flexibility and human alignment. The three testbeds are the following:

Manufacturing system testbed: In the manufacturing testbed we will address two scenarios: mobile manipulators and manufacturing of large parts. In them robots inserted in manufacturing cells will address the problem of flexible adaptation to changing production conditions relates with the locations for the robot, the tools needed, the need of learning new operations or the unexpected events related to finding defects in manufactured parts.



Inspection system testbed: A multiagent scenario with several drones to accomplish an industrial inspection mission will be used to test the resilience of the whole system. The main features of this testbed are: a) outdoor scenario suffering uncontrolled situations (e.g., wind gust) that are prone to produce failures, b) multirobot system that accomplish the mission in a distributed way c) a robotic system made of several drones that are able to high manoeuvrability and flexibility in task definition, but also prone to critical failures (e.g., crashes) and d) an industrial mission that do have inspection specifications to be accomplished.

Social interaction testbed: Robotics competitions are widely validated testbed in the scientific community [Behnke 2006]. They specify a typical scenario where scientific research can be contrasted and validated under identical conditions. The most important international competition is the RoboCup [Kitano 1997], which began with several leagues whose environment was robotic soccer but has evolved to disaster, rescue, or domestic scenarios. The validation scenario chosen for social interaction in this project is the RoboCup @Home [Wisspeintner 2009]. In this competition, a social robot must fulfil different tasks involving oral interaction, perception of people, environments, objects, navigation, and manipulation. We will demonstrate how the CoreSense cognitive architecture can solve these tasks effectively, with solutions that can be generated and exported to various environments where social and human capacity is crucial.



1.4 Project Organization

The project is organised into ten work packages and will have a duration of four years. Figure 1 shows the overall organization of the work. The ten work packages are as follows:

WP1 Understanding and Awareness Theory leadered by UPM develops the theoretical fundamentals.

WP2 Awareness Architecture leadered by TU Delft develops the systems architecture for awareness.

WP3 Cognitive Modules and Structures leadered by TU Delft organises the development of reusable components that implement the core architectural assets.

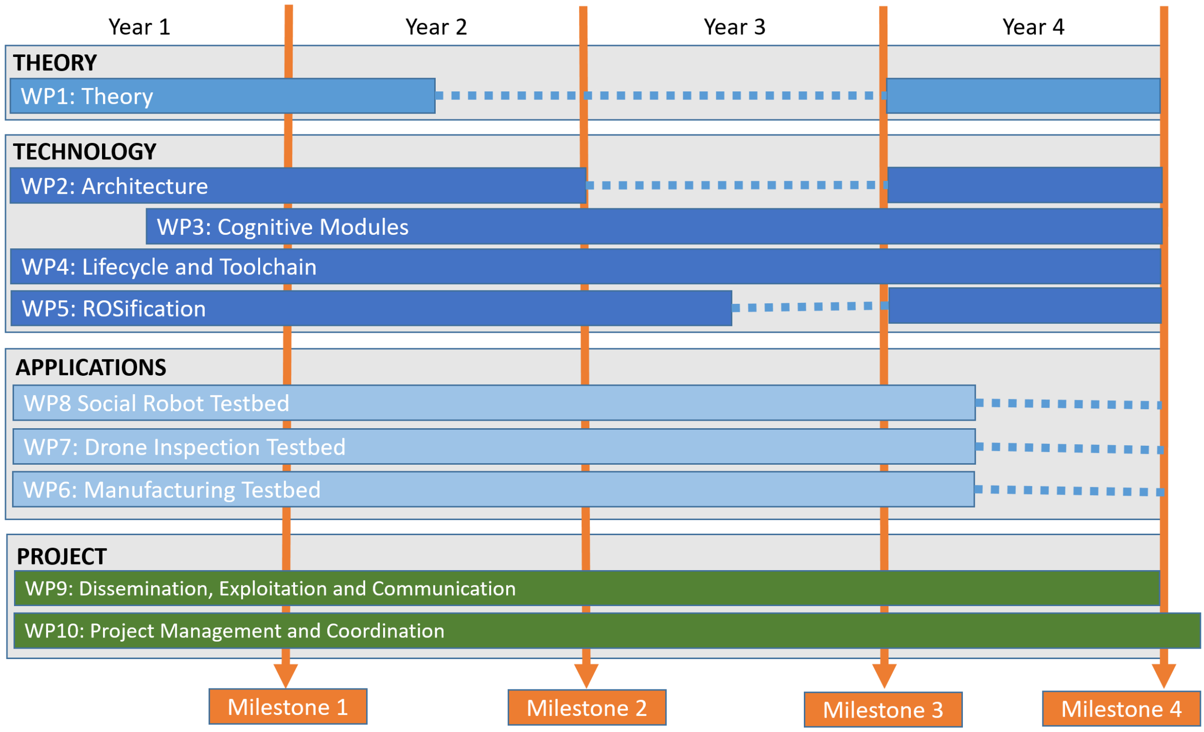


Figure 1: Overal organization of project activities.

WP4 System Lifecycle and Toolchain leaderd by Fraunhofer will develop engineering tools to support the use of assets in the construction of controllers for robots.

WP5 ROSification of Software Assets leadered by URJC will convert the project products into reusable assets for the ROS ecosystem.

WP6 Testbed: Manufacturing robots leaderd by IMR addresses the use of the architecture in fexibility improvement of manufacturing robots.

WP7 Testbed: Inspection drones leadered by UPM uses the arcitecture in the improvement of resilience in industrial inspection drones.

WP8 Testbed: Social robots leaderd by PAL ROBOTICS addresses the use of the architecture in explainability of robots interacting with humans.

WP9 Communication, Dissemination and Exploitation leadered by IMR coordinates project communication activities.

WP10 Project Management and Coordination is leadered by UPM.

Separation of concerns is a fundamental systematic engineering strategy and the way CoreSense approaches the problem of engineering autonomous, aware robots. The overall project methodology is a straightforward *model-based systems engineering methodology*, with the particularities of our project (we target both generic and concrete systems). This methodology is translated into a set of activities that generate the intermediate and final products of the project. The concrete flow of project activities is the following:

1. The concept of deep understanding will be formalised. Hierarchy, scalability, and vagueness will be addressed using granular representations.

2. A general systems ontology will be developed to capture the essentials of dynamics, causality, and mereology in cognitive system modular structures.
3. The operational requirements of the testbed scenarios will be identified.
4. The CoreSense abstract architecture and ontology will be developed and captured in executable model form.
5. Tooling to support these processes will be developed.
6. The abstract architecture will be mapped to reusable assets adapted to testbeds needs. Testbed-specific ontologies will be elaborated. Testbed-specific architectures will be developed.
7. Reusable software assets for the architecture will be built for 1) the architectural core and 2) the testbeds-specific elements.
8. Reusable software assets for cognitive function implementations will be built using both transparent model-based and opaque brain-inspired approaches. Architecture-compliant functional modules will be developed. Function alignment between testbed scenarios will be driven by collaboratively developed, shared functional ontologies.
9. Testbed scenarios will be developed using the assets for the architecture and for the functional modules.
10. Testbed results will be evaluated to provide information for the architecture and functional modules consolidation. Evaluation will be done at two scopes: 1) The concrete testbeds themselves and 2) the broad domain of autonomous systems.

2 EC Programme Topic

This section describes the Horizon Europe workprogramme topic that this project is addressing. This information comes from the Funding & Tenders portal of the EC.

Topic: Pushing the limit of robotics cognition (AI, Data and Robotics Partnership)

Topic ID: HORIZON-CL4-2021-DIGITAL-EMERGING-01-11

Programme: Horizon Europe Framework Programme (HORIZON)

Call: Digital and emerging technologies for competitiveness and fit for the green deal.

Type of action: HORIZON-RIA — HORIZON Research and Innovation Actions

2.1 Topic description

Expected Outcome: New generation of AI-Powered Robotics: Enabling robots to have more profound impacts than they currently have, in powering them with a deeper kind of AI, endowing them with a better perception and understanding of the world (up to semantic and explainable representations), This would allow the next generation of autonomous robots, with increased capabilities to work without/with limited supervision, as well as the next generation of interactive robots, with greatly improved intuitive, safe and efficient cognitive, social and physical capabilities, to assist humans. In addition, depending on the focus of the proposal, the results are expected to contribute to at least one of the following expected outcomes

Smarter robots with improved capabilities, functionalities (including complex functionalities such as manipulation of delicate, irregular, dynamic or deformable objects, navigation in un-controlled and variable or challenging and harsh environments, and continuous human-physical interactions) and an increased level of autonomy over the current state of the art, necessary to address real-world problems, while ensuring safety and reliability. Smooth and trustworthy (including safety and reliability) human-robot collaboration through advanced reactivity and mutual understanding, and human-centric automated adaptation of robots in human-robot interactions.

Scope: Proposals are expected to develop technologies and systems that significantly enhance the cognitive ability of robots from the current state of the art to achieve greater levels of interaction and autonomy. Proposals will address as appropriate the following:

- Develop enabling technologies, both new and existing, that extend the current state of the art in robotics perception, cognition, interaction and action as well as develop novel or advanced tools for the design and configuration of robots and robot systems that speed up the process of integration thereby reducing the time taken to deploy robot solutions. To do so by addressing the modularity and composability of solutions both in the operational context of a wide range of action and interaction use cases. There is also a need to address concepts such as trustworthiness, privacy, security and ethics already at the technology design phase.
- Develop lifelong autonomous robotics able to tackle unknown situations and adapt in the long term in pushing the state of the art of AI-based robots that combine monitoring, learning, planning and acting in order to evolve in difficult environments over long period of time. Support from simulation tools could be considered, as appropriate. Increase robot acceptance by handling adequately both human and robotic actions, with human-centric, advanced behavioural and elaborated planning models, and adopting multidisciplinary approaches including SSH, as well as end-user involvement in the design of solutions addressing human factors and interaction. Gender and intersectionality dimension analysis should be a part of the proposals, where relevant.
- Push the limits of robotics interaction, adopting an interdisciplinary approach to integrate methods and techniques that allow the machines to engage in physical interactions with people or the environment, safely and intelligently, through specific enabling technologies: intuitiveness and responsive human-robot interfaces; integration of robot perception with natural and artificial intelligence; ability to physically, stably, dependably and safely interact with the environment, including users and surrounding people; development of advanced control tools fully integrating the human in the loop when performing a task; development of advanced control tools for dexterous and safe manipulation, assistance, and locomotion in diverse environments (ground, air, water, space, in-vivo and including safety critical and hazardous environments that are corrosive, explosive, nuclear or at extremes of pressure or temperature) and in general for improved performance of robots; energy autonomy and resilience to highly limited and imperfect communication networks in on-field applications.

Two types of proposals are expected, either focusing on higher level of autonomy, expecting less reliance on human supervision, or focusing on human-machine collaboration. In each case, improvement in the level of robotics cognition should be demonstrated through at least three real-world scenarios (including measurements of functional performance), showing also the potential added value of such improvement in such use-cases scenarios. Scientific and technological progress should be demonstrated by qualitative and quantitative KPIs, demonstrators, benchmarking and progress monitoring. Activities are expected to achieve TRL 4-5 by the end of the project

- The first type of proposals will further develop the level of autonomy in building on the latest developments in areas such as advanced perception, smart sensors, intelligent action and interaction, reasoning and learning, increased interpretation and understanding of the complex real-world environments (possibly involving human actions), anticipation of the effect of actions, adaptation and re-planning, graceful degradation, safety and security, etc. They will, as appropriate, further develop such components, and integrate them in an advanced robotics system, consider the balance of on-board vs off-board processes and the access and utilisation of external data and cloud resources to guide tasks and missions by adding external knowledge to internal reasoning and decision-making processes.

- The second type of proposals will further develop and integrate physical human-robot interaction, verbal/non-verbal communication as well as robot-environment/object interaction, embedding, as appropiate, safety, mutual understanding perception and interpretation of human actions, interaction situated in complex real-world environments and related motivations and social structures, joint goals, shared and sliding autonomy, ethical human-centric behaviour by understanding of physiological responses and emotions, etc. to reach truly smooth human-robot collaboration. This should as well integrate advanced control developments, and further develop them as necessary to guarantee the necessary speed for the required reactivity, ensuring natural, safe and smooth interactions with humans. Appropriate use should be made of data and knowledge accumulation from internal and external sources in order to guide reasoning and decision-making and the inclusion of explainability/transparency mechanisms appropriate to the use case. Such proposals should adopt a multidisciplinary approach and involve the necessary expertise in SSH, in particular in ethics and human-centric design to enhance trust and acceptability.

When possible proposals should build on and reuse public results from relevant previous funded actions. Proposals should make use of connections to the Digital Innovation Hub networks, particularly those in Robotics, Data and AI. Full use should be made of the common resources available in the AI-on-Demand platform, Digital Industrial Platform for Robotics, data platforms and, if necessary other relevant digital resource platforms. Communicable results from projects should be delivered to the most relevant of these platforms so as to enhance the European AI, Data and Robotics ecosystem through the sharing of results and best practice.

All proposals should also take into consideration trustworthy AI principles including respect of human dignity and agency, as appropriate, given the technology focus.

This topic implements the co-programmed European Partnership on AI, Data and Robotics. All proposals are expected to allocate tasks to cohesion activities with the PPP on AI, Data and Robotics and funded actions related to this partnership, including the CSA HORIZON-CL4-2021-HUMAN-01-02. Where relevant, synergies with other PPPs are encouraged.

Specific Topic Conditions: Activities are expected to start at TRL 2-3 and achieve TRL 4-5 by the end of the project.

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UPM ASLab CoreSense
An Hybrid Architecture for Deep Understanding