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ANNEX 1 OPEN CHALLENGES DESCRIPTION

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1_Contextual Models to Interpret and Explain Errors

The possible host: DLR[1]

General scientific and technical description:

Humans do not only learn from their own mistakes but also from the mistakes of others. Similarly, it should be possible for robots to share information about errors made, and how it would have been able to avoid said errors. For this, a robot needs to first interpret and explain the errors it observed and derive corrective actions accordingly. This is not straightforward, especially if the observed error has a timely shifted causality. For example, if a robot is asked to pour water into a mug, it has to understand that an imprecise grasp may lead to spilt liquid in the subsequent pouring action. Furthermore, the descriptions have to be robot-agnostic. For example, while the imprecise grasp may be the cause of the spill, the error model should not blame the hand of the robot, but the orientation of the bottle in the hand. Only then can contextual models be transferred between robots. In this regard, we are looking for novel methods to represent error models that are explicitly developed with transferability in mind and have already been tested for at least two robots. The developed system is to be validated on at least two additional robots within the euROBIN Consortium.

Endorsed by WP2, WP5.

Objectives:

- Provide a contextual error model that is robot and task agnostic.
- Create explainable and interpretable error descriptions in the scenarios investigated within the competitions of euROBIN.
- Provide the means to integrate the software into the reasoning cycle of the robots.
- Optionally provide the means to yield corrective actions.
- Validate the method and the resulting causal models on at least 3 euROBIN robots.

Deliverables:

- Open software modules usable on different robot platforms such as those in WP2 (Personal Robotics).
- ROS compatible interface.
- Documentation and manual to configure and use the system with a specific robot platform and scenario.
- Everything is available on EuroCore.

[1] The Consortium reserves the right to change the host due to the results of the Open Call and the type of activities identified in the proposals.

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2_Knowledge graphs as tools for explainable data transfer

The possible host: University of Bremen, DLR, KIT[2]

General scientific and technical description:

In the rapidly advancing field of robotics, there is a pressing need for robots to collaborate and seamlessly transfer knowledge to become better in manipulation tasks, even when they do not share the same vocabulary of actions. To address this challenge, we are soliciting proposals that leverage knowledge graphs to facilitate the transfer of manipulation tasks between robots with varying action vocabularies. The primary objective of this call is to fund research institutes that have already developed solutions to address the explainability of robot actions by means of knowledge graphs or related methods. In this call, these models shall be adapted to enable robots with differing action vocabularies to communicate effectively about past, present, and future manipulation tasks based on a shared knowledge representation. The information shared may include goals, task properties, success criteria, or failure scenarios. Proposals should focus on transferring existing frameworks to achieve interoperability, knowledge transfer, and collaboration among robots.

Endorsed by WP2, WP5.

Objectives:

- Provide a comprehensive knowledge graph that serves as a common language for representing manipulation tasks, actions, objects, and relationships.
- Establish semantic mappings between actions from different robot vocabularies to enable seamless translation of task descriptions into the knowledge graph's language.
- Provide methods for translating and transforming manipulation tasks into the common language of the knowledge graph, accounting for variations in parameters and constraints.
- Implement the framework for executing translated manipulation tasks on receiving robots based on their native vocabularies.

Deliverables:

- Open software modules usable on different robot platforms such as those in WP2 (Personal Robotics).
- ROS compatible interface.
- Documentation and manual to configure and use the system with a specific robot platform and scenario.
- Everything is available on EuroCore.

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3_Electronic Task Board Benchmarking: sim2real transfer with ROS

The possible host: TUM[3]

General scientific and technical description:

Collecting data from real-world manipulation experiments is expensive. Electronic task boards provide a test bench for robots to work with sensorized real-world objects to assess the quality of their actions and to receive feedback about when their task is complete. This project focuses on making benchmarking with the electronic task board available to a wider community by implementing a ROS communication layer. Providing a ROS interface for the real-world task board would enable two important features:

(1) a digital twin of the task board to be synchronized with a real-world task board enabling the transfer of robot skills developed in a simulator to be tested directly in the real-world, and

(2) robot developers can directly communicate with the task board on a local network via ROS messages without connecting to the task board's web dashboard on the internet.

The current iteration of the euROBIN task board has a MQTT interface and only communicates with a web server to update the web dashboard. A successful project would facilitate the transfer of offline simulated robot solutions to the task board to a real-world system made from an euROBIN robot platform and task board. This feature has been requested by the euROBIN partners.

Endorsed by WP1.

Objectives:

- Provide a communication interface to the electronic task board from a robot platform control program to collect feedback from onboard sensors and key performance metrics related to the experiment.
- Develop a modular software framework for extending the electronic task board to incorporate new task hardware elements without changing the base firmware, e.g. over-the-air updates.
- Synchronize a real-world task board with its digital twin implemented in a robot simulator for offline skill learning and development using ROS messages.
- Adoption and promotion of the electronic task board within the wider ROS community

Deliverables:

- Electronic task board firmware with ROS services and messages implemented to convey the task board's state.
- Documentation for implemented ROS services and messages including an API template for how to add new functionality, e.g. integrate new sensors on the task board, in the future.
- Simulation environment with modeled physics of the electronic task board and its associated task objects with a robot platform to perform the trial protocol. CAD files for the task board are available. The simulated robot platform should be selectable from at least two euROBIN robot platforms.
- Website with a guided walkthrough tutorial for new users to start up the simulated environment with the electronic task board and at least two euROBIN robot platforms.
- Everything available on the EuroCore repository.

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4_General Abstract Actuation Layer Architecture and Protocol Definition

The possible host: UTwente[4]

General scientific and technical description:
Robots typically have their dedicated actuator systems. Their capabilities are often directly exploited in the control architecture meaning that reusing the controller for another robot with its own actuator system is hindered. It requires a lot of reprogramming and knowledge of the particularities of the actuator system.

The aim of this project is to define an abstraction layer for actuators which will be general enough for different actuators, from standard force or velocity generators to variable impedance actuators. Physical actuators will have two electrical interfaces: a power supply where the physical energy will be drained from and a data digital one. Via the digital one, it will be possible to communicate with the actuator via a to be developed protocol. Such a protocol will not only be used in real time to give set-points to the actuator, but also to query its capability and structure. This will improve reusability at all levels. A specific functionality will also be implemented to make the actuators “energy-aware” so that passivity can be delegated at the level of the hardware.

The envisioned interface is a real-time API residing on the new firmware of an actuator. The actuator will not anymore be seen as a device with which we interface at the power level, but rather as a device having a power supply interface and a data channel. Via the Data channel and the API which will be described, it will be possible to query the actuator for its performances: maximum torque, variable compliance or not etc. In this way, the actuator can then be auto-configured via its API and then used as needed, as a standard torque or speed actuator, but also as a variable impedance actuator if the actuator can deliver such a service. The proposed interface would allow to create control modules which can adapt themself to the hardware which is used and would contribute enormously to a standardization and reusability of code.

Endorsed by WP4.

Objectives:

- Develop and validate an actuator abstraction layer and communication protocol allowing the central control code to be written in an actuator independent manner with as input the actuator capabilities with examples for different actuators, from standard velocity and torque based to variable compliance.

Deliverables:

- Algorithm/code with a tutorial available in EuroCore.
- Methodology validated using at least two euROBIN systems.

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5_Perceiving and tracking of deformable objects

The possible host: KTH[5]

General scientific and technical description:

Identifying and estimating the state of textile items (cloths, bedclothes, napkins, socks, etc). We may assume that these need to be manipulated prior to washing (to be put in the washer) or taken out from the washer (wet) and need to be stretched before hanging for drying. Scientifically, we need methods that perceive, model, track items under complex deformations and do this in real-time from RGB-D cameras (static, or on a robot arm).

Endorsed by WP5.

Objectives:

- This task involves resolving how to develop perceptual representations for manipulating clothing items out of a crumbled/unordered dry or wet pile. This is followed by stretching or straightening of items in the air or on a surface to facilitate identification (what kind of item it is) as well as potentially estimating the shape (mesh representations). The type of item allows sorting as well as the application of different hanging strategies to dry the cloth. From the shape, a reliable state estimation can be performed, for example, the position of landmarks or similar features. The system we consider is a dual-arm robot (moving base optional) as well as an RGB-D camera (can be static or actuated).

Thus, the goals are to :

- Develop perceptual techniques for tracking deformable objects to enable manipulating items from a pile (basket or washing machine).
- Develop perceptual techniques for tracking of deformable objects in grasping and re-grasped of item such that it is flattened in the air without placing it on a surface (or alternatively stretch/flatten on a surface).
- Develop perceptual techniques for identifying the item, estimating its shape, and alike, prior to, during and post-manipulation. The system is to be evaluated on at least 10 different items in dry and wet condition.

Deliverables:

- Document Method implementation in C++ or Python.
- Video of task fulfillment using at least eight different types of clothes.
- Validation of method on the secondary robotic platform.
- Everything available on EuroCore.

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6_Robotic fingertip with capacitive sensing for in-hand metallic object counting and pose estimation

The possible host: IMEC[6]

General scientific and technical description:

Industrial manufacturing tasks often require small metallic objects to be picked from cluttered bins and collected for assembly. It is crucial that the correct amount of parts is delivered to the assembly location or valuable time is wasted correcting the mistake. To automate this task, a robot should thus be able to count how many items it picked. Vision-based approaches greatly suffer from occlusion due to the robot itself. Adding tactile sensing to a fingertip could allow robots to perform this difficult task. However, when picking e.g. bolts from a cluttered bin, the bolt(s) may partially stick out from between the fingertips, which can confuse e.g. piezoresistive force sensors. Capacitive sensing offers two benefits:

(1) it strongly responds to metallics and

(2) its inherent proximity detection capability allows material outside of the fingertip to be detected. In addition to item counting, the fingertip should be able to estimate the pose of a single item. This way, the item can be accurately placed or inserted where needed.

Endorsed by WP4, WP5.

Objectives:

- Develop a robotic fingertip enabled with capacitive tactile sensing and integrate it with the Halberd platform so that it can be mounted on at least two euROBIN robot platforms.
- For interfacing, start from the open-source AIRO-Halberd platform (i.e., *Proesmans, R., & wyffels, F. (2023). Seamless Integration of Tactile Sensors for Cobots. Presented at the IEEE/RSJ 2023 International Conference on Intelligent Robots and Systems (IROS), Detroit, Michigan, USA.*).
- Collect visual and tactile data of part picking from cluttered bins and identify possible grasp results.
- Validate item counting and pose estimation capabilities and provide the constructed models for integration.
- Provide resulting machine learning models for integration in manipulation tasks, as well as provide the data collection, labeling and training code for easy extension to different parts.

Deliverables:

- Fingertip design with manufacturing guide and documentation.
- Software for sensor readout and inference of item number and pose.
- Robot-agnostic software pipeline for data collection and labeling.
- Everything available on EuroCore.

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7_Virtual robotic competition environment

The possible host: University of Bremen, IST-ID[7]

General scientific and technical description:

The rise of cloud robotics and simulation tools paves the way for advanced, cost-effective, and trustworthy robotic technologies. Events like RoboCup or VEX Robotics Competition spark the interest of budding researchers, showcasing the potential of robotics. Yet, due to resource constraints, hosting frequent robotic challenges becomes a challenging task, not to mention the extensive preparation required. In response to this challenge, the creation of a comprehensive virtual robotic competition platform is sought. This platform should be set within a virtual research building, ensuring a standardized environment where participants from all corners of the world can test and compete with their robotic designs.

Endorsed by WP2, WP6, WP8.

Objectives:

- Facilitate the advancement and understanding of robotics via simulated challenges.
- Provide a consistent and standardized virtual environment for all competitors.
- Foster the development of inventive robotic designs.
- Broaden participation by eliminating geographical and resource-based barriers.

Deliverables:

- A sophisticated virtual competition environment, such as MuJoCo, Bullet, Isaac Sim or Gazebo.
- Varied robotic agents designed for compatibility within the virtual environment.
- An automated scoring system for transparent and unbiased evaluations.

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8_Very Low Weight and Compliant Gripper for Aerial and Ground Robotic Manipulators

The possible host: University of Seville, IMEC[8]

General scientific and technical description:

Object grasping is one of the most basic and relevant tasks conducted by robotic manipulators, presenting a significant complexity when the variety of objects to be grasped is wide in terms of shape, weight, or flexibility. In the field of aerial robotic manipulation, in which object grasping is conducted while flying or operating in high altitude workspaces, the very low weight feature (in the range of a few tens or hundreds of grams) is an additional constraint that makes the design and development of grippers particularly challenging due to the limited payload capacity of drones and the dynamic coupling between these and the onboard robotic arms.

The use of soft materials on the fingertips and flexible elements like springs or elastomers in the transmissions, along with the integration of sensors providing tactile feedback, are key features that contribute to replicate the dexterity of human hands, which can be considered as the best general purpose gripper. In this sense, the transferability of human manipulation skills to aerial or ground robotic manipulators can be more easily achieved when the gripper replicates certain mechanical and sensing features. Therefore, the main goal of this call is the design, development and validation of a very low weight gripper (100 – 200 grams) that can be integrated as an end effector in a dual arm aerial manipulation robot from the University of Seville and in a lightweight industrial arm from the Vrije Universiteit Brussel (embodiment transfer) and that allows to replicate the sensing and manipulation skills of human hands (task transfer). The gripper should be energy efficient and provide fast actuation, implementing for example a compliant bi-stable mechanism with two stable equilibrium positions so the grippers tend to be open or closed when no force is applied, providing passive accommodation to the shape of the object. The gripper prototypes will be integrated and validated experimentally in the platforms provided by both euROBIN partners.

Endorsed by WP3, WP4.

Objectives:

- Understanding the requirements of gripper design for aerial and ground manipulators.
- Choice of appropriate components and materials for the mechanical design.
- Development of gripper prototypes and preliminary testing.
- Integration of prototypes on dual arm aerial manipulation robot from the University of Seville and on lightweight industrial manipulator from IMEC.
- Realization of experiments in outdoor scenarios on flight with the aerial robot or in ground testbed with an industrial arm for validating the developed system.
- Publication of research results in international conferences or journals.

Deliverables:

- Technical documentation, including drawings, 3D models, schemes and diagrams, as well as source code to be shared in the EuroCore repository.
- Data logs and reports from the experiments.
- Videos validating the developed prototypes and its integration in the aerial and ground manipulators.
- Research paper(s) to be submitted to international conferences or journals.

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9_Mixed indoor/outdoor wheeled-legged autonomous navigation in structured environments

The possible host: IIT[9]

General scientific and technical description:

The Centauro robot is a fully torque-controlled hybrid wheeled-legged platform, endowed with a humanoid bi-manual upper body. Inside the euROBIN project, it shall be used to deliver tools to a human co-worker. Navigation in mixed indoor/outdoor environments represents a challenging task due to several factors, e.g., (i) the diverse performance of attained by different perception sensors in indoor w.r.t. outdoor scenarios, (ii) the need to select the most appropriate locomotion mode (wheeled, or legged) to negotiate steps/stairs or other forms of non-flat terrain; (iii) the presence of narrow passages that could require the robot to reshape its support, therefore sacrificing stability for a slimmer footprint; (iv) the need to understand the semantics of the scene in order to, e.g., utilize crosswalks to cross a street, or more, in general, to comply with specific rules or paths; and others.

The candidate will implement a software pipeline that combines existing robot capabilities (such as: support polygon reshaping, driving, and stepping motions), as well as onboard perception and localization systems, to autonomously generate a feasible connecting path between given points. The resulting global plan will be executed with the help of a local planner, with the aim to compensate for mapping/localization inaccuracies, as well as the presence of dynamic obstacles.

Endorsed by WP3.

Objectives:

- Design a simulated environment as close as possible to the scenario that the robot will face in the envisioned use case challenge within the WP3 scenario of the euROBIN project.
- Develop and tune perception modules for robust environment understanding that is critical for the mobility planning pipeline and the overall decision-making process.
- Develop the global and local planning pipeline starting from the existing tools.
- Validate the performances of the developed pipeline in both indoor and outdoor scenarios.

Deliverables:

- Source code of the developed/implemented methods to be included in the EuroCore repository.
- Publications to international conferences or journals.
- Experimental/Simulation data logs from the validation trials.

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10_ Intelligent Human Agent Simulation for Social Robot Navigation

Host: LAAS-CNRS[10]

General scientific and technical description:

Robotic simulators play a significant role in the development and evaluation of new frameworks and architectures before their deployment onto real robots. With ever-increasing robots in human environments, it is necessary to include humans in robotic simulators for testing and verification of the algorithms. Many robotic simulators already offer human agents or avatars considering these demands. Nevertheless, these agents are often scripted or use naive approaches to move and react to the robot. For example, PedsimROS[11] uses social forces to simulate crowds, and SEAN 2.0[12] uses behavioral graphs to simulate semi-crowded environments with groups and pedestrians. Although these works have good collective behavior, the individual agent uses only a naive reactive model. In this context, we propose to enrich human agent behaviours in simulators, particularly for socially aware navigation. The main idea is to develop a software package that is agnostic to the type of simulator (as much as possible) and can generate various human behaviors while reacting rationally (or realistically) to other humans and robots they meet in the environment. There are already some initial implementations[13] and we plan to enrich the behaviours, add new ones, and create new benchmarking scenarios. For benchmarks, we also plan to provide online calculation and storage of various evaluation metrics. Further, we aim to provide simpler ways of scripting elaborative scenarios involving these agents and the robot, taking advantage of recent developments in large-scale natural language models (LLMs), which were not part of the earlier approaches. The developed framework will be integrated and tested in various robotic simulators and will be made available in EuroCore.

Endorsed by WP7.

Objectives:

- Develop intelligent and rational human agents in simulation for benchmarking socially aware robot navigation.
- Provide scalable and simulator agnostic architecture to achieve this.
- Provide API to interface this software with various kinds of simulators.
- Develop simpler ways to script navigation scenarios using natural language models.

Deliverables:

- C++ and Python based software packages for intelligent human agent simulation, data logging (including metrics) and scripting scenarios.
- APIs to connect with major open source robotic simulators like Gazebo and Webots.
- ROS and ROS2 interfaces for the package.
- Documentation of the code and the usage.
- The package will be made available on EuroCore.

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10 The Consortium reserves the right to change the host due to the results of the Open Call and the type of activities identified in the proposals.
11 https://github.com/srl-freiburg/pedsim_ros
12 Tsoi, Nathan, et al. "Sean 2.0: Formalizing and generating social situations for robot navigation." IEEE Robotics and Automation Letters 7.4 (2022);
13 Favier, Anthony, et al. "Simulating intelligent human agents for intricate social robot navigation." RSS Workshop on Social Robot Navigation 2021; Pérez-Higueras, Noé, et al. "HuNavSim: A ROS 2 Human Navigation Simulator for Benchmarking Human-Aware Robot Navigation." arXiv preprint arXiv:2305.01303 (2023); Hauterville, Olivier, et al. "Interactive Social Agents Simulation Tool for Designing Choreographies for Human-Robot-Interaction Research." Iberian Robotics Conference 2022.

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