ANNEX 1 OPEN CHALLENGES DESCRIPTION

10 Calls for the 1st Open Call in 2023

WP1 - Robotic Manufacturing for a Circular Economy
WP2 - Personal Robots for Enhanced QOL and Well-Being
WP3 - Outdoor Robots for Sustainable Communities
WP4 - InterAct
WP5 - Learn
WP6 - Know
WP7 - Human-Centered Perspective

Title:
1_Perceiving and tracking of deformable objects
→ *multiple candidates*

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 pick single 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 :

- pick single items from a pile (basket or washing machine);
- grasp (and re-grasped the item such that it is flattened in the air without placing it on a surface (or alternatively stretch/flatten on a surface);
- identify the item, estimate shape. 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 fulfilment using at least eight different types of clothes;
- Validation of method on secondary robotic platform;
- Everything available on EuroCore.

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Title:
2_Dialog Management for Natural Human Robot Interaction
→ *several candidates*

General scientific and technical description:
We need software modules for a dialog management system to support intuitive human robot interaction. This involves automatic speech recognition and interpreting users' speech utterances to extract the underlying intent (e.g., to formulate a task or trigger a skill), mapping these intents to action plans or executable robot skills, and generating adequate speech responses by the robot. In addition, dialog management must maintain the current state of dialog in order to understand statements relating to previous utterances (e.g., "No, the green one" relating to "Bring me the cup") or enabling the robot to ask questions if instructions are unclear (e.g., "Should I bring you the green or the blue cup?"). The software module should take as input several configuration files to specify the action capabilities of the robots, the human and the scenario. The computation time should enable an online dialog between the robot and the human with "reasonable" delays (e.g., no awkward pauses). The software should be tested and validated with at least three of the euROBIN robots, in particular those of the WP2 teams (INRIA, KIT, DLR).

Endorsed by WP2, WP5

Objectives:
- Components for automatic speech recognition (audio to text), intent parsing (text to goal / robot skill), speech synthesis (text to audio);
- Dialog management allowing multiple bidirectional pairs of utterance / response, allowing the robot to ask questions for clarification or help;
- Allow novice users to enable the robot to understand new language utterances and integrate new robot skills (preferably without full re-training);
- Validate the modules 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 available on EuroCore.

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Title:
3_Visual perception: object recognition and 6D pose estimation for known objects
→ *multiple candidates*

General scientific and technical description:
We need to identify objects of interest in the different scenarios, from the visual perception (robot cameras, RGB-D or RGB). We may assume that the objects are known, i.e., we have the 3D model (mesh) of the object and a label for each object. From the camera input, we need to recognize the object in the image, localize it and estimate the 6D pose of the object. This 6D pose will be used by the robot to navigate towards the object (e.g., a chair, a door) and/or to plan a suitable grasping action (e.g., cup, fork, parcel, milk brick). For example, in Year 1 we will use this method to identify a door handle, navigate toward the handle and then grasp it, while in Year 2 we will use it to recognise cutlery and cups inside a dishwasher. The computation time for steps 3) and 4) must be compatible with an online robotics application (e.g., <100ms would be desirable). The perception models should be transferable between robots, even though they may utilize different types of sensors (e.g., stereo cameras or depth sensors). In this regard, the software should be tested with YCB objects and validated with at least three of the euROBIN robots, in particular those of the WP2 teams (INRIA, KIT, DLR).

Endorsed by WP2

Objectives:
- Provide a pipeline to allow a novice user to add new object models, train object models and use them for online object recognition (providing the label and the image area where the object is in the camera image) and online 6D pose (expressed in robot base coordinates) estimation from camera images;
- Provide a solution that can support the transfer of models between different robots with different sensor modalities (e.g., different cameras, different depth sensors);
- Validate the pipeline on at least 3 euROBIN robots.

Deliverable:
- Manual and documentation of the pipeline and the software modules/libraries;
- Implementation in C++ or Python;
- Demonstration (video) of the pipeline with one of the robots of WP2;
- Everything is available on EuroCore.

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Title:
4_Defining robotic tasks sequence through imitation learning from videos / observation
→ *multiple candidates*

General scientific and technical description:
In the framework of Industry 5.0, which promotes human-machine cooperation for integrating human intelligence in the loop and combining human reactivity and adaptability with the precision, speed and reliability of robots, one the main challenge lies in the interaction between human and robots. The traditional code programming of robotic tasks has to be replaced by more intuitive ways for the operator to teach the robot, through user-friendly graphical interface, natural language or learning by demonstration. This last approach takes inspiration from humans' ability to learn new skills by observing other humans and trying to imitate them. In the same way, this approach is considered to allow robots to acquire manipulation skills from human demonstrations. While kinesthetic approaches are often considered for teaching by demonstration, the most intuitive method for a human to provide a demonstration is by performing the task himself and letting the robot observe him through a camera.

In this call, we focus on the automatic recognition of a sequence of manipulation tasks by watching an operator perform the demonstration.

Endorsed by WP1, WP2, WP5, WP6

Objectives: Demonstrate the ability to define a simple scenario of manipulation task (e.g., press blue button, take key, insert key) through video analysis of the operator gesture.

Deliverables:

- Dataset of video used for training;
- Algorithm/code with tutorial available in EuroCore;
- Methodology validated in terms of task sequence recognition;
- Transfer to ideally at least two euROBIN systems.

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Title:
5_Method for Collecting and Labeling Interactions between Human and Physical Robot with Internet of Things Devices and IMU Time-Series Data
→ *multiple candidates*

General scientific and technical description:
Improvements in robot motion planning have enabled robot system designers to deploy robots in direct proximity to humans. Some force sensitive, collaborative robots interact with the same objects as humans. However, they lack the same speed and dexterity as their human counterparts. Following the trend of making ordinary objects “smart” by equipping them with a microchip and monitoring sensors directly on the object over the internet allows designers to study the interactions between the object and the environment. An inertial-motion-unit (IMU) sensor detects the object’s acceleration and orientation and is one of the most common sensors used in internet of things (IoT) devices, e.g., mobile phones, wrist watches and medical devices, and generates an abundance of data over time.

This time-series data needs to be filtered and manually labeled to understand discrete manipulation events which is a time-consuming activity. Therefore, we propose to develop an automatic labeling method using IMU data from IoT devices to label when objects were picked up, turned over, and other manipulation movements. This method would greatly speed up the analysis of IoT IMU sensor data and would be used to study the behavior and efficiency differences between humans and robots when interacting with objects of interest. The initial study would investigate two IMU mounting locations. One IMU sensor would be placed on the actor either as a glove for a human or a bracket mounted at the end of a robot arm and the other mounted to the surface of the task board.

Endorsed by WP1, WP4, WP5

Objectives: Develop and validate a task board with an IoT IMU sensor that can label motion events as generated by a human or a robotic system. Example classifications for labels include the state of the actor when the sensor is worn by the actor, or from the progress of an ongoing manipulation task when the sensor is on the object (InterAct). Labels include orientation, in motion/idle, maximum acceleration, task progress and success indicators, etc. The data generated IMU devices can be used to supply training data for learning new interaction methods (Learn). Finally, the labeled data can be used by robot developers in the consortium to develop appropriate behaviors for their physical robot system to reflect the current labeled situation in the surrounding environment.

Deliverables:
- IMU Sensor andA mounting kit for (1) standard robot wrist flange, (2) operator glove, (3) task board;
- Algorihm/code with tutorial available in EuroCore as a code repository that provides labels to time-series data rendered onto a web dashboard visible to all consortium partners;
- Methodology validated using at least two euROBIN systems.

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Title:
6_Multifunctional gripper design and tool changing mechanism for assembly
→ *single candidate*

General scientific and technical description:
Flexible robotic assembly requires a manipulation unit to accomplish versatile manipulation tasks instead of establishing an automation pipeline in which each sub-task is achieved by a dedicated system with fixed configuration. To achieve this, it requires the robot to have versatile tool use ability and be equipped with various tools for different tasks, for example, grasping a large variety of objects, manipulating different screws, nuts and bolts, etc. However, a flexible multifunction gripper and tool changing mechanism is usually not equipped with the robot system and how to design such a system to balance the trade off between versatility, complexity and costs is still an open problem. We propose to develop a multifunctional gripper with additional tool changing system to enable complex assembly using common lightweight and collaborative robots. The developed system should be based on recent advances in robot skill taxonomy and task analysis conducted within the framework of euROBIN, and to be validated on at least two real and challenging industrial use cases.

Endorsed by WP1

Objectives: Develop a multifunctional gripper with lightweight tool changing mechanism

Deliverables:

- A multifunctional gripper and tool changing mechanism design;
- Validate on two industrial use cases with two different robots from euROBIN, for example gearbox assembly, electronics disassembly.

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Title:
7_Ensuring high precision tasks with collaborative robots for flexible manufacturing
→ *multiple candidates*

General scientific and technical description:
Industrial robots are very efficient when performing repetitive tasks with high accuracy, and are ideally suited for high volume and rigid production lines. However, most of the industrial robots are physically separated from human workers by fences and require specific knowledge to program them. These constraints in terms of integration cost and low interaction with the operator are generally highlighted as the major causes of low adoption of robotics by SMEs or for manipulation tasks in general. Recently, collaborative robots have been more and more integrated in the industry, because they allow safe robot applications within the operator's proximity as well as intuitive programming by kinesthetic demonstration, making them easier to deploy to different tasks. However, these robots do not exhibit the same level of performance in terms of precision, payload or velocity as industrial ones, which slows down their acceptability for some industrial tasks.
In this call, we focus on demonstrating how collaborative robots can be deployed for realizing fine manipulation tasks with sub-millimeter accuracy in industrial or laboratory environments in the case where pure repeatability of the robot cannot be exploited due to a variation of the position of the object of interest.

Endorsed by WP1

Objectives:
Demonstrate the ability to reach a position with sub-millimeter accuracy with a collaborative robot. The target position is typically a given point (or a set of given points) of an object randomly placed in the workspace of the robot (e.g., screws on the lid of an electrical vehicle battery pack). The robotic system can be equipped with embedded or deported 2D/3D visual sensors.

Deliverables:

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

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Title:
8_Novel Control Methods for Cable Suspended Dual Arm Aerial Manipulators in Outdoor Scenarios: Towards Safer Human-Aerial Robot Interactions
→ *single candidate*

General scientific and technical description:
Aerial robotic manipulators (intelligent drones equipped with robotic arms) are capable of quickly conducting object grasping, transportation and delivery of small parcels in areas of difficult access for ground robots, avoiding traffic jams and other inconveniences of urban environments with high density of obstacles. However, the proximity of the aerial platform with the people, the vehicles, buildings and other obstacles should be avoided to reduce the risk of collision. In order to improve safety in the integration of the robot within urban environments, and particularly during the interaction with the human users (handover), a human-like dual arm system will be incorporated to the aerial platform in cable suspended configuration, similarly to a pendulum or swing, extending in this way the reach of the arms.

The scope of the proposed work is therefore the development and experimental validation of novel control methods for aerial robotic manipulators in suspended configuration. Besides drones, these methods can be transferred to other mobile platforms such as cranes, overhead cranes, or suspended structures that could be deployed by users in urban or rural scenarios for grasping and transportation in logistic applications. A dynamic model of the suspended dual arm robot should be firstly derived and validated in a simulator. The control methods should be able to achieve accurate end effector positioning and trajectory tracking, taking into account the dynamics of the cable suspended manipulator while exploiting the kinematic configuration of the arms. The main research and technological challenges are associated with the accurate position estimation and control outdoors, implementing these methods in a lightweight platform provided by the University of Seville.

Endorsed by WP3, linked to WP4 and WP7

Objectives:
- Problem formulation, system identification, and design of system architecture;
- Derivation of dynamic model and development of simulator;
- Controller design and simulation of cable suspended robotic manipulator;
- Implementation of control methods;
- Realization of experiments in outdoor scenarios for validating the developed system;
- Publication of research results at international conferences or journals.

Deliverables
- Simulation of the aerial robotic manipulator in ROS/gazebo, MATLAB/Simulink;
- Source code of the developed methods to be shared in the EuroCore repository;
- Data logs and reports from the experiments;
- Videos with demonstrations of the system;
- Research paper(s) to be submitted to international conferences or journals.

Title:
9_Urban navigation with wheeled-legged robots
→ *multiple candidates*

General scientific and technical description:
The scope of the work is to develop navigation methodologies for wheeled-legged robots for urban navigation. As a platform, we are using a quadrupedal system with actuated wheels capable of going high speed, stepping across obstacles and stairs, or overcoming rough terrain. Local control and motion planning algorithms offer versatile waypoints following in different settings.
In euROBIN, these machines are used as carriers for logistics applications, i.e., to move payloads from a start to a goal location. In order to deploy the system in an urban environment, we have to develop a navigation pipeline that accounts for the system's mobility, is able to handle dynamic obstacles such as pedestrians or cars, and can include a semantic understanding to navigate on sidewalks, to cross streets appropriately, or to use doors to enter buildings.
In this project, the researchers have access to a diversity of sensory information collected by the robot (lidar point cloud, RGB cameras in driving direction, multiple stereo cameras around the vehicle), they can leverage existing SLAM infrastructure, and build upon an established simulation pipeline (NVIDIA issac / omniverse). The algorithms will be implemented on the ANYmal with wheels platform, a robust, field-hardened systems with powerful onboard computers and ROS API.

Figure 1

Endorsed by WP3, linked to WP5, WP6

Objectives:
- Problem formulation;
- Dataset and software infrastructure analyst to identify the right set of tools, e.g., data labelling for supervised learning algorithms;
- Implementation of semantic-based urban navigation;
- Implementation of dynamic obstacle detection and avoidance;
- Test in simulation (if desired);
- Test and validation in real-world experiments;
- Publication of research results at international conferences or journals.

Deliverables:
- Software for semantic-based navigation and dynamic obstacle avoidance;
- Videos with demonstrations of the system;
- Research paper(s) to be submitted to international conferences or journals.

Title:
10_Massively parallel simulation and learning algorithms
→ *multiple candidates*

General scientific and technical description:
Discovering relevant behaviours through a learning process may require sample-greedy exploration processes. This raises issues when applied to robots due to their operating costs and to the damages it may result in. Combining experiments on a real robot with an exploration in simulation can alleviate this issue. Massively parallel simulations based on tools like JAX or Isaac Gym allow to drastically accelerate exploration processes and open new avenues for learning in robotics, where interactions may be sparse. The goal of this call would be to propose robot simulations and learning algorithms modules that can fully exploit the potential of these massively parallel libraries.

Endorsed by WP5

Objectives: -

Deliverables:
- Open source libraries in C++ or Python;
- Example of use in the context of at least one of the euROBIN use cases and two systems;
- Everything available on EuroCore;
- Define the description format for the task environment and the conversion for different platforms (USD, URDF and MJCF);
- Implement a method to generate a digital twin for a specific scenario (e.g., replenishment or set the table);
- Implement modules to apply learning algorithms on parallel instances of the digital twin;
- Implement methods to rate and visualize the effectiveness of the algorithms;
- Test and validation in real-world experiments;
- Publication of research results at international conferences or journals.

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