SocRob@Home 2026 Team Description Paper

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Abstract. The SocRob@Home team from ISR/IST continues its long-standing participation in the RoboCup@Home Open Platform League, combining scientific research with competition-driven benchmarking. Building on recent podium results at RoboCup 2023 and 2024, the team focuses on advancing autonomous service robots capable of robust perception, adaptive navigation, and natural human interaction in domestic environments.

Current research spans multiple domains, including 2.5D navigation using 3D LiDAR data for safer and more efficient motion, reinforcement learning-based full-body navigation, and humanoid locomotion on uneven terrain. In perception, efforts concentrate on real-time people tracking through extensions of the SAMURAI model and multimodal data fusion, as well as robust object pose estimation for manipulation. Task planning research explores the integration of large language and vision-language models for multimodal reasoning, end-to-end action generation, and adaptive, context-aware interaction. Additionally, work in human–robot interaction applies neuro-symbolic reinforcement learning to model belief and intention inference in social navigation.

Together, these contributions aim to enhance autonomy, adaptability, and collaboration in real-world domestic robotics applications.

1 Introduction and Scientific Background

The SocRob@Home team has represented ISR/IST at RoboCup, the world's foremost event in artificial intelligence and robotics, since 1998. Originating from the SocRob (Soccer Robots or Society of Robots) research initiative, the team has participated in multiple RoboCup leagues, including Simulation, 4-Legged, Middle Size, and Robot Rescue, across numerous World Championships and regional events such as the Portuguese, German, and Dutch Opens (Figure 1).

Over more than two decades, SocRob@Home has involved over 100 students, from bachelor's to Ph.D. levels, fostering the integration of navigation, perception, and manipulation toward advanced domestic service robotics. Early milestones included participation in the RoCKIn Camps (2014–2015), where the

Fig. 1. Evolution of the SocRob@Home team and robotic platforms across major competitions, from early RoCKIn events to recent RoboCup@Home editions.

team earned the *"Best in Class for Manipulation"*[1] and *"RoCKIn@Home Benchmarking"* awards, and subsequent recognition at the German Open @Home League with the *"Most Appealing Robot"* award. These formative experiences established a foundation for the team's sustained presence in RoboCup@Home.

Since then, SocRob@Home has consistently reached the top tier of international competitions. At RoboCup 2018 in Montreal, the team advanced to the Bronze Cup finals[2], and in 2021, it contributed an open-source Petri net toolbox [1] to the virtual RoboCup, demonstrating multi-robot coordination under uncertainty[3]. More recently, SocRob@Home achieved second place at RoboCup 2023 in Bordeaux and third place at RoboCup 2024 in Eindhoven[4], earning the *GPSR Overbot Award* for best overall performance in service-oriented tasks.

Beyond RoboCup, SocRob@Home is a team involved in the European project *euROBIN*, a network of excellence in robotics AI that promotes collaboration and knowledge transfer across Europe (Figure 2). Within this framework, the team participated in the *First-Year Robotics Hackathon* (Seville, 2023) [2], featuring a complex multi-domain parcel delivery scenario, and in the *first euROBIN Coopetition* (Nancy, 2024), where leading institutions explored cross-domain transferability of robotic software and hardware. These activities complement the team's RoboCup@Home efforts by reinforcing principles of modularity, composability, and system integration [3].

At ISR headquarters, the team benefits from the ISRoboNet@Home testbed[5], a realistic apartment-like environment for benchmarking using an OptiTrack® system for accurate localization. SocRob@Home remains dedicated to advancing

1 `http://youtu.be/0STWX9SHo1I`
2 `http://youtu.be/P4QA02b6ihA`
3 `http://youtu.be/Pjq8B8gG35o`
4 `https://www.youtube.com/@socrob_home`
5 `https://isr.tecnico.ulisboa.pt/isrobonet/`

Fig. 2. SocRob@Home's participation in the euROBIN project, featuring the Robotics Hackathon in Seville (2023) and the first euROBIN Coopetition in Nancy (2024).

domestic service robotics and inspiring young researchers to address multidisciplinary challenges in AI, perception, and human-robot interaction.

The remainder of this paper is structured as follows: Section 2 outlines our research objectives and summarizes recent achievements, Section 3 presents the team members, and the appendix details the robotic platform prepared for RoboCup@Home 2026.

2 Research Focus

SocRob@Home's research targets the core challenges of domestic robotics, mapping, navigation, perception, manipulation, decision-making, and human-robot interaction, toward developing autonomous and socially aware service robots.

Mapping, Localization, and Navigation: SocRob@Home's research in navigation focuses on human-aware and adaptive motion in domestic environments. Early work introduced a multimodal navigation framework that manages diverse interaction scenarios, including dynamic collision avoidance and human-guided tasks such as escorting and following. This approach integrates the concept of *Proxemics* to maintain socially appropriate distances from humans [4].

Building on this foundation, recent work explores a 2.5D navigation approach for robots equipped with 3D LiDAR sensors [5]. The method combines the efficiency of 2D path planning with the spatial awareness of 3D perception by dynamically projecting point clouds onto a 2D plane while adapting in real time to environmental and robot-body changes (Figure 3). Key contributions include a dynamic footprint updater, improved 3D-to-2D projections, and seamless integration with the ROS navigation stack. Experiments in multiple environments demonstrated superior safety and adaptability compared to traditional 2D and fixed-height 3D approaches.

Ongoing research advances toward *full-body navigation*, enabling concurrent base and manipulator motion in cluttered 3D spaces. The system aims to optimize task efficiency by planning base and arm movements jointly, allowing the robot to reach and manipulate objects while moving. A Deep Reinforcement

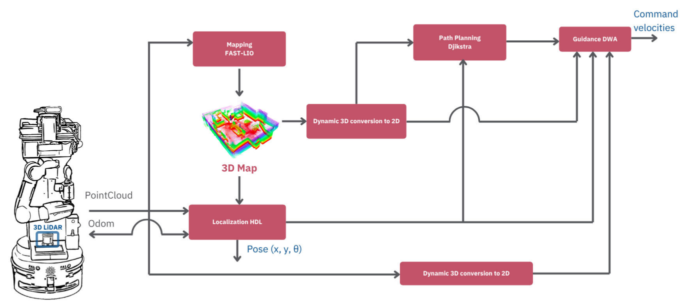

Fig. 3. SocRob@Home's 2.5D navigation approach merges 3D LiDAR perception with 2D path planning, using dynamic projections and adaptive footprints for safer and more efficient indoor navigation.

Learning (DRL) framework is being developed to coordinate these motions, enabling the robot to learn navigation strategies that maintain safe distances from obstacles and achieve optimal arm configurations during locomotion.

With the recent acquisition of the humanoid robot Booster T1, the team is also investigating stable bipedal walking over uneven, sloped, and stepped terrain. Using DRL-based training in simulation, the goal is to achieve robust and energy-efficient locomotion that generalizes across diverse terrains. Depth-based mapping supports precise foot placement and balance control, contributing to safe and natural movement patterns even in challenging environments.

Perception: Research in perception focuses on robust human and object understanding for service robotics tasks. In the area of people tracking and following, we are extending the capabilities of the SAMURAI model [6] to enable real-time person re-identification and tracking in dynamic domestic environments, demonstrating improved performance compared to previous approaches [7].

Ongoing work explores multimodal data fusion strategies to enhance long-term person tracking by integrating complementary cues and temporal consistency mechanisms. These methods aim to strengthen identity retention and robustness in complex, dynamic scenes.

This perception module is integrated with a Model Predictive Control (MPC) framework that governs pursuit and motion control, enabling smooth and adaptive navigation around humans. The MPC employs a fuzzy logic layer to dynamically adjust its objective weights, allowing context-aware behavior that adapts to environmental changes and target motion. To ensure safe and feasible trajectories, the workspace is modeled using polyhedral constraints applied at each prediction step, maintaining locally valid motion while supporting socially compliant navigation.

In parallel, we employ and integrate state-of-the-art 6DoF object pose estimation methods for manipulation and grasp planning, such as MegaPose [8], and point-cloud-based grasp detection frameworks. To support reproducibility and integration within ROS 2, the team provides open-source wrappers for Grasp Pose Detector (GPD)[6] and SAM2 real-time tracking[7].

Manipulation: To enable pick-and-place functionality, we have implemented a visual servoing approach [9] that facilitates the reaching and grasping of objects. This method utilizes an RGB-D camera mounted on the robot's head to continuously estimate the poses of the end effector and the target object. By calculating the positioning error between these poses, we employ a proportional controller to minimize this error. This approach effectively reduces calibration errors associated with both the camera and the arm joints, as both poses are represented in the camera frame.

Additionally, leveraging RGB-D input, we have developed a second method that incorporates a closed-loop feedback reinforcement learning algorithm. By utilizing camera observations and the robot's positional data, this method executes ideal grasping tasks. The robot can either transition the end effector to a pre-grasping stage, which can then be refined using the aforementioned visual servoing approach, or directly pick up the object if necessary. This closed-loop feedback mechanism also enhances performance in dynamic environments.

Decision-Making & Task Planning: We have developed a lightweight, end-to-end robot control pipeline (Figure 4) that leverages Large Language Models (LLMs) to translate natural language instructions directly into executable robot actions [10]. Unlike traditional architectures that rely on separate Natural Language Understanding (NLU) and planning modules, this pipeline integrates reasoning and execution within a single model. To ensure onboard autonomy, we fine-tuned a compact LLM that runs directly on the robot, removing the need for external APIs or cloud-based processing.

The system is designed to be resilient to Automatic Speech Recognition (ASR) errors by integrating multiple transcription hypotheses directly into the LLM prompt, allowing the model to reason over alternative interpretations of the user's utterance. Furthermore, the pipeline incorporates information from a semantic map that stores details about all previously perceived objects and their attributes. This map is continuously updated as the robot explores its environment, enabling the model to ground its reasoning in up-to-date contextual knowledge and produce more reliable and adaptive task plans. All components of this work, including the codebase, trained models, and datasets, have been released as open source to promote transparency and reproducibility.[8]

In collaboration with Oracle®, we have also explored an in-context learning approach that exploits the capability of larger LLMs to learn from examples without requiring expensive fine-tuning. This framework employs Retrieval-Augmented Generation (RAG) techniques to dynamically retrieve relevant examples and contextual information for the current task. As a result, the system

[6] `https://github.com/socrob/grasp_detection_ros2`
[7] `https://github.com/socrob/sam2_realtime_ros2`
[8] `https://github.com/socrob/llm_gpsr`

can recall past interactions, integrate new user feedback, and continuously refine its responses over time.

Our ongoing research investigates several directions to expand the reasoning and adaptability of language-driven robotic systems. These include the integration of visual-language models to enable multimodal understanding, mechanisms for real-time user feedback that allow interruption and adaptation of running plans, methods for enabling an LLM to recognize and potentially expand the limits of its own action space, and techniques that enhance the model's reasoning capability by allowing it to simulate the outcomes of potential actions before execution.

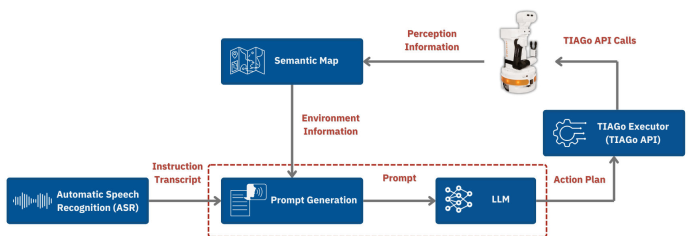

Fig. 4. Task planning pipeline. From command to execution.

Human-Robot Interaction: Our current research in human-robot interaction focuses on enabling service robots to infer, track, and reason about the beliefs, desires, and intentions of humans and other agents during collaborative tasks. Using deep representation and reinforcement learning methods, we aim to equip robots with the capacity to act and adapt socially in dynamic, partially observable environments.

In such settings, navigation and cooperation alongside humans require reasoning under uncertainty and consideration of others' hidden mental states. While egocentric navigation can be modeled as a Markov Decision Process (MDP), social navigation extends naturally to a Partially Observable MDP (POMDP), where agents must estimate and update beliefs about others' intentions. Drawing inspiration from Theory of Mind and Epistemic Planning, our approach combines neuro-symbolic, model-based reinforcement learning with a perspective-shift mechanism for belief estimation. This framework leverages recent work on Influence-Based Abstractions (IBA) to support structured multi-agent reasoning in socially aware navigation [11].

3 Team Members

Abdullah Alamer: PhD student developing diffusion-based tactile manipulation methods that combine vision and touch sensing for delicate object handling.

Afonso Certo: PhD student researching multimodal reasoning with visual-language models, aiming to extend LLMs' action spaces and simulate outcomes for improved decision-making.

André Silva: Research Engineer working on visual servoing for precise control of robotic manipulators.

António Morais: MSc student developing full-duplex human–robot interaction, enabling robots to listen, speak, and reason simultaneously for more natural, context-aware communication.

Beatriz Pimenta: BSc student working on speech recognition for natural and reliable human–robot interaction.

Catarina Caramalho: MSc student working on the robot's APIs and graphical user interfaces (GUIs).

Duarte Santos: MSc student developing policies for stable bipedal walking over uneven terrains in humanoid robots.

Gabriel Nunes: Laboratory technician responsible for the design, assembly, and maintenance of electrical, electronic, and mechanical components.

Inês Sousa: MSc student working on a data-fusion approach to robust person re-identification in social robotics.

João Botas: MSc student developing the robot's graphical interface and API for improved usability and system integration.

Kevin Alcedo: PhD student addressing human-robot interaction challenges using deep representation learning and reinforcement learning methods to enable robots to reason about human beliefs and intentions in joint tasks.

Pedro Lima: Faculty member involved in robot competitions since the earliest editions of RoboCup and the European Robotics League. He is the project coordinator.

Rodrigo Coimbra: MSc student developing a reinforcement learning-based full-body navigation system to control service robots in 3D environments.

Rodrigo Serra: Research Engineer focusing on people-following and perception-based tracking methods. He contributed to the design of the euROBIN Coopetition framework, which blends RoboCup's competitive spirit with collaborative goals of transferability and knowledge exchange. He is the current team leader.

Rui Bettencourt: PhD student working on full-body navigation techniques for wheeled mobile robots that coordinate manipulator motion during locomotion over uneven terrain.

Teresa Nogueira: MSc student developing a Model Predictive Control (MPC) module for navigation in dynamic environments.

Vítor Fonseca: BSc student currently exploring the capabilities of Visual Language Models (VLMs), such as ChatRex, to reason about scene understanding.

4 Conclusion

Participation in RoboCup 2026 will provide a realistic testing ground for the MSc and PhD research developed by team members. This opportunity not only validates ongoing work but also fosters the generation of new ideas and challenges for future research, while contributing to the advancement of the robotics community.

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SocRob@Home TIAGo Robot Hardware Description

The SocRob@Home platform is a customized version of the TIAGo robot developed by PAL Robotics (Figure 5), adapted for advanced perception, manipulation, and human–robot interaction research. The main mechanical specifications are:

- **Base:** Differential-drive with maximum speed of 1 m/s.
- **Torso:** Lifting mechanism with 350 mm stroke at 50 mm/s.
- **Arm:** 7-DoF manipulator with 2.8 kg payload.
- **End-effector:** Robotiq 2F-140 gripper.
- **Head:** 2-DoF pan–tilt mechanism.
- **Laptop tray:** Dual-slot tray supporting up to 5 kg.
- **Dimensions:** Height 110–145 cm, base footprint 54 cm.
- **Weight:** 72 kg.

Fig. 5. Customized SocRob@Home TIAGo robot.

Additional onboard devices:

- 8 W speaker and **RODE VideoMic NTG** microphone.
- Head-mounted **Azure Kinect** and wrist-mounted **Intel RealSense D405**.
- 7 inch **ELO touchscreen** (800×480 px).
- Dual-band Wi-Fi antennas (802.11 b/g/n/ac) and **Asus RT-BE88U** router.
- Inertial measurement unit and three ultrasonic sensors (0.03–1 m range).
- Front and rear **Hokuyo** laser range finders (0.02–5.6 m range).
- **Unitree 4D LiDAR L1**.
- 720 Wh battery.
- Onboard computer: Intel i5 CPU, 8 GB RAM, 250 GB SSD.

Robot Software Description

The robot runs a fully ROS 2-based software stack:

- **Platform:** Ubuntu 22.04 with ROS 2 Humble.
- **Localization:** Adaptive Monte Carlo Localization (AMCL).

- **Navigation:** ROS 2 Nav2 stack.
- **Speech recognition:** OpenAI Whisper.
- **Speech synthesis:** Acapela Text-to-Speech engine.
- **Perception:** Segment Anything Model 2 (SAM2) and YOLOv8 for object and person segmentation.
- **Manipulation:** ROS 2 MoveIt framework with visual servoing integration.
- **Task planning:** YASMIN ROS 2 library and an LLM-based planning module.

External Devices

The robot is complemented by the following external hardware:

- **NVIDIA Jetson Xavier NX** for accelerated vision inference.
- Two 15 inch laptops (Intel i7 CPU, 16 GB RAM, 512 GB SSD, NVIDIA RTX 3050 GPU).
- 200 W high-capacity laptop power bank.