RoboFEI@Home Team Description Paper for RoboCup@Home 2026: Korea Edition

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Abstract. The RoboFEI@Home team presents the New-Hera platform, our new service robot, for RoboCup 2026. Designed to assist individuals with limited mobility, this work addresses key challenges in human-robot interaction and domestic automation through a modular architecture that decouples high-frequency control from probabilistic AI inference.
To navigate dynamic environments, New-Hera integrates a lightweight base with an adjustable-height manipulator for precise object interaction. The software, fully migrated to ROS2, leverages the Nav2 framework and deep learning models to ensure deterministic navigation in crowded social spaces, safely navigating around dynamic objects like moving people, enabling adaptive manipulation, grasping objects from the floor to high shelves, and supporting offline-first speech, understanding commands without an internet connection.
This paper details our scientific contributions in point-cloud segmentation and user-centered design. Additionally, we highlight our impact on STEM education through the Brazilian Robotics Olympiad and our commitment to the community via open-source releases at `https://github.com/robofeiathome`.

1 Introduction

The RoboFEI@Home team presents its research and technical roadmap for the 2026 RoboCup@Home competition. This cycle marks a significant paradigm shift for our group with the full deployment of the New-Hera platform. While our previous work focused on stabilizing standard service tasks, our current research prioritizes three key scientific areas: deterministic navigation in crowded social spaces, adaptive manipulation in unstructured vertical workspaces, and offline-first natural language interaction.

Since its establishment in 2015, RoboFEI@Home has demonstrated consistent excellence in the league. Our approach to robust system integration was validated by achieving 1st place in the Open Platform League (OPL) at RoboCup 2022 in Thailand [1] and maintaining a consistent presence in the global top 10. Nationally, the team holds five titles in the Brazilian Robotics Competition and recently secured a podium finish in 2025. These achievements underscore the reliability of our software stack, which we have now migrated to ROS2 to address the increasing complexity of domestic service tasks.

This paper details the scientific advancements integrated into New-Hera to solve the 2026 Rulebook challenges, highlighting our contributions to user-centered design and semantic environmental perception.

2 Research focus and interests

The team's research incorporates diverse topics within service robotics, including dynamic and safe navigation in complex and unknown environments, vision-based object detection, and adaptive integrated behaviors. This focus directly aligns with real-world challenges regarding robotic applications in domestic environments. By operating the latest AI algorithms and robust frameworks, the team aims to enhance and develop technologies applicable to future service scenarios.

For the current cycle, the New-Hera project pivoted its research focus to leverage ROS2's determinism, identifying critical procedures to improve system reliability. Significant attention was devoted to the robot's navigation; the new lightweight base has enabled considerable progress in dynamic environments, which is critical for the Restaurant and Help Me Carry tasks that require navigating unknown, crowded spaces. Additionally, the integration of a prismatic joint at the manipulator's base expands the arm's reach for manipulation tasks like Storing Groceries. This hardware update enabled new studies in manipulation approaches, specifically focusing on improved motion planning and numerical Inverse Kinematics to manage the extended workspace of the 7-DOF arm.

Consistent with the Jesuit mission of Centro Universitário FEI, our research translates technical innovation into social utility, directly contributing to the UN Sustainable Development Goal 9 (Industry, Innovation, and Infrastructure). We leverage our advancements in adaptive kinematics and deterministic navigation to create robust assistive technologies for individuals with limited mobility. By engineering New-Hera as a modular and reliable platform for domestic automation, we aim to bridge the gap between cutting-edge academic robotics and the practical, daily needs of the elderly and people with disabilities, ensuring that our technical rigor drives tangible improvements in quality of life.

3 Approach to Solve RoboCup@Home Challenges

The 2025 development cycle focuses on addressing two primary causes of failure in domestic service robotics: kinematic limitations in unstructured environments and nondeterministic behavior in software state management. The New-Hera platform was engineered to solve these issues through a modular hardware architecture and a migration to a real-time, event-driven software ecosystem.

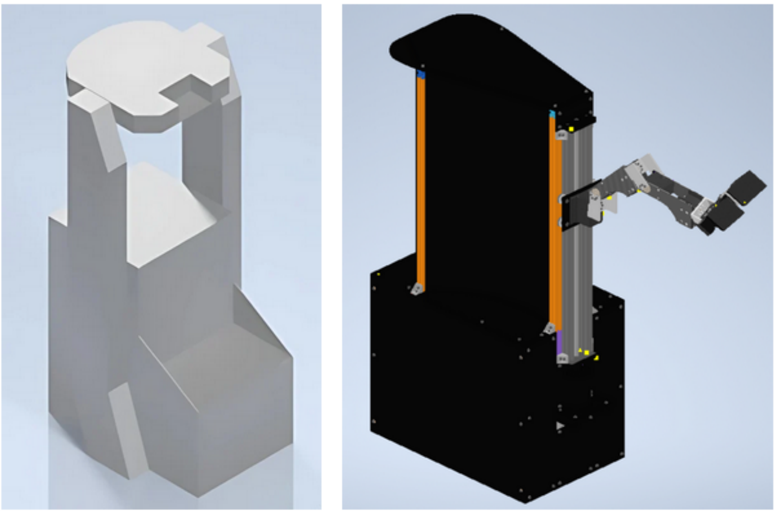

Fig. 1: Evolution of Hera's structure. Left - Old Hera's torso, with fixed height manipulator; Right - New Hera's torso, with vertical prismatic joint.

3.1 Adaptive Kinematics for Vertical Workspace Expansion

A recurrent challenge in the Enhanced General Purpose Service Robot (EGPSR) and Storing Groceries tasks is the variation in object placement height, ranging from floor level to high shelves. Fixed-base manipulators often suffer from singular configurations or unreachable workspaces in these scenarios. To mitigate this, we implemented a vertical prismatic joint at the manipulator's base, driven by a brushless 12V motor via a leadscrew mechanism, shown in Figure 2. Unlike static mounting, this variable-height topology dynamically expands the robot's reachable workspace volume without increasing the platform's footprint. This addition allows the robot to execute floor-level grasping and high-shelf placement with a single motion-planning strategy, significantly increasing success rates in the Storing Groceries task.

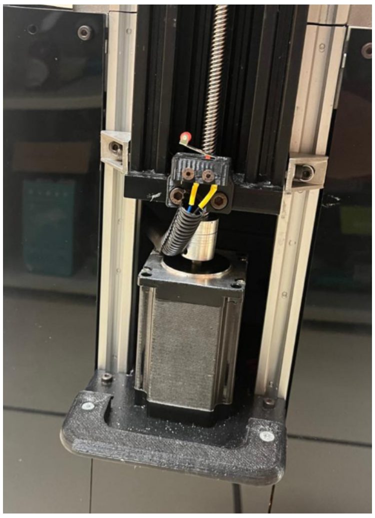

Fig. 2: New-Hera's leadscrew mechanism, previously using a step motor.

3.2 Deterministic Navigation in Dynamic Crowds

Navigating crowded environments, such as the Restaurant task, requires robust dynamic obstacle avoidance. We migrated the entire navigation stack to ROS2 to leverage its lifecycle management and real-time capabilities. Rather than relying on default behaviors, we customized the Nav2 framework to prioritize determinism. We implemented a multi-layered costmap approach in which semantic information (from vision) inflates cost values around detected humans distinct from static obstacles, ensuring socially compliant path planning.

To fully leverage the base's holonomic capabilities, we developed a custom plugin for the Nav2 DWB planner that prioritizes strafing over rotation in tight spaces. This implementation modifies the trajectory scoring function to heavily penalize rotational velocities when the robot is in close proximity to obstacles. This strategy effectively reduces the collision risks associated with the "turn-in-place" behaviors typical of differential-drive robots, ensuring safer maneuvering in narrow passages.

3.3 Offline-First Perception and Interaction Architecture

To ensure autonomy in venues with unreliable network conditions, we architected an "offline-first" perception stack.

- **Vision:** We use a hybrid pipeline that combines YOLOv11 for bounding-box detection with MediaPipe for pose estimation. This architecture allows for rapid semantic segmentation of humans and objects directly on the edge device, minimizing latency during the "Follow Me" and perception tasks.

– **Auditory Redundancy:** For the GPSR task, relying on a single Automatic Speech Recognition (ASR) engine presents a single point of failure. We implemented a voting ensemble using FasterWhisper and RealTimeSTT. This dual-pipeline approach processes audio streams in parallel; a command is executed only if the semantic intent extracted by both engines matches, significantly reducing False Acceptance Rates (FAR) in noisy environments.

3.4 Distributed Hardware and Software Architecture

To support the computational demands of the algorithms described above without compromising navigation safety, we implemented a distributed architecture (Fig. 3, 4). The system is physically divided into two main computing units connected via Gigabit Ethernet:

1. Main Controller (Dell Optiplex 7020): Responsible for deterministic and high-frequency control loops. It hosts the ROS2 nav2 stack for navigation, MoveIt2 for manipulation planning, and the hardware interface for the Dynamixel motors (via hera_control). By keeping these nodes on an x86 CPU, we ensure that path planning and obstacle avoidance are not affected by GPU thermal throttling or resource starvation.
2. AI Accelerator (NVIDIA Jetson Orin Nano): Dedicated to probabilistic and heavy inference tasks. The hera_vision_system (YOLO/MediaPipe) and hera_speech (FasterWhisper) nodes run here. This separation allows the vision system to run at full frame rate (30fps) using CUDA cores without introducing latency to the robot's odometry or velocity commands.

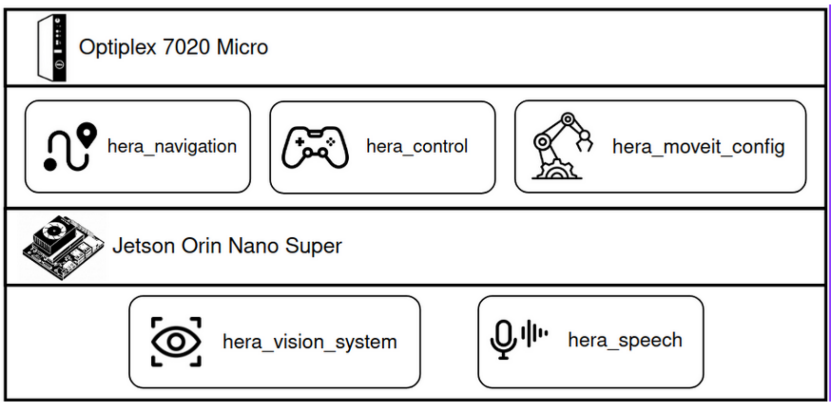

Fig. 3: New-Hera System Architecture. The diagram highlights the separation between the high-level control (Optiplex) and the AI perception layer (Jetson).

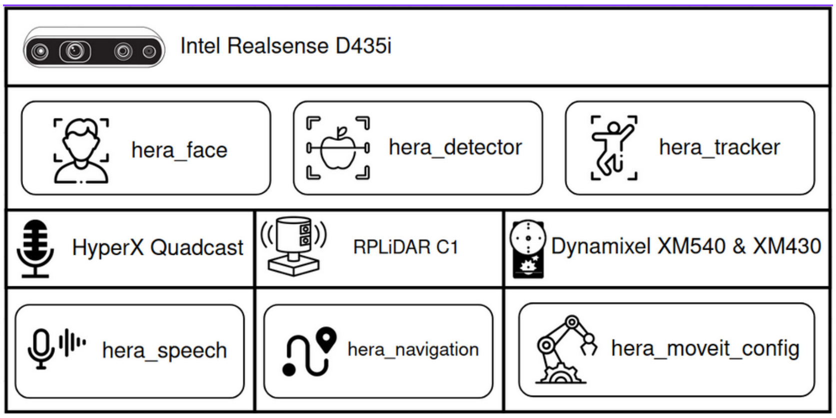

Fig. 4: New-Hera Sensor Architecture. The diagram presents the sensor integration (RealSense, RPLidar C1, and Microphone) via specific ROS2 lifecycle nodes.

This architecture ensures that even if the vision system hangs or lags due to complex scene processing, the robot maintains safe reflexive behaviors (obstacle braking) via the independent navigation stack.

Beyond physical hardware separation, the system leverages the ROS2 Lifecycle (Managed Nodes) architecture. Unlike standard ROS1 nodes that start computing immediately upon launch, our critical drivers (Lidar, Camera, Motor Controller) are initialized in an 'Unconfigured' state. A global 'System Manager' node is responsible for transitioning these drivers to 'Active' only when all hardware checks pass. This prevents the "zombie state" behavior where a robot attempts to navigate before its sensors are fully calibrated, a common issue in competition startups.

4 Current Research and Scientific Contributions

4.1 User-Centered Design Practices for Enhanced Human-Robot Interaction

The critical role of User-Centered Design (UCD) in the development of service robots is addressed in this work, particularly regarding the enhancement of usability and User Experience (UX) within Human-Robot Interaction (HRI). Motivated by the increasing integration of robots into daily human environments, the necessity of intuitive and accessible designs that go beyond technical functionality is emphasized to ensure user satisfaction. The application of usability engineering principles is explored, iteratively involving users in the design process to refine robot interfaces and behaviors.

The study was conducted by analyzing existing usability frameworks and adapting them to the unique demands of HRI, focusing on real-world scenarios where robots interact with diverse users. It is demonstrated that integrating

UCD practices significantly improves the usability of service robots, facilitating seamless interactions and task execution [2] (`https://doi.org/10.29327/v-brahur-vi-brasero.869332`).

These principles have been directly integrated into New-Hera's interface design for the 2026 season. By implementing the refined interaction protocols derived from this study, the robot now provides clearer multimodal feedback during the Receptionist task, significantly reducing user confusion and improving task completion rates in non-expert trials.

4.2 Ambient Sound Perception Applied to Social Robotics

The adaptation and validation of the US8K_AV environmental-sound dataset for mobile service robots is addressed in this contribution, specifically focusing on the recognition of safety-critical and social acoustic events. Motivated by the need to enhance situational awareness in indoor environments, the necessity of real-time audio recognition systems capable of operating on resource-constrained hardware is emphasized.

A rigorous four-stage data-engineering workflow is explored, iteratively evaluating the original UrbanSound8K dataset to merge low-relevance classes and incorporating a 'silence' class to improve idle-state discrimination. The study was conducted by rebalancing the dataset into ten non-overlapping folds and benchmarking classical Machine Learning models on a robot-mounted processor. It is demonstrated that this optimized framework significantly improves the robot's ability to identify events such as sirens and dog barks, facilitating more responsive behaviors [3] (`https://www.nature.com/articles/s41597-025-05446-2#Abs1`).

This optimized framework is now fully deployed on New-Hera's edge computing unit, enabling the robot to interrupt its navigation stack upon detecting safety-critical sounds (e.g., fire alarms). This capability ensures immediate pausing of tasks in emergency scenarios, enhancing the platform's safety compliance during the Help-Me-Carry and Restaurant tasks.

4.3 Intelligent Interaction for Social Robot Navigation

The challenges of Social Robot Navigation (SRN) in shared environments are addressed in this article, focusing on the need for robots to demonstrate social competence beyond mere obstacle avoidance. Motivated by the lack of formal design methodologies for robotic interfaces, the development of multimodal and adaptive interaction strategies grounded in an extension of the Modelling Language for Interaction as Conversation (MoLIC) is emphasized.

A novel framework that incorporates embodiment and Theory of Mind models into the robot's control architecture is explored to manage dynamic interactions. The study was conducted by validating the proposed framework through comparative experiments in real-world scenarios, contrasting adaptive approaches with static social interfaces. It is demonstrated that explicit interaction modeling significantly enhances the legibility of the robot's intentions and the user's perceived safety [**?**].

For the 2026 competition, this interaction model has been integrated into New-Hera's local planner behavior tree. The robot now utilizes multimodal cues (gaze direction and LED signaling) to broadcast its navigational intent before executing trajectories, successfully mitigating the 'freezing robot' deadlock often observed when navigating through crowds in the Restaurant task.

5 Conclusion

In conclusion, the RoboFEI@Home team presents a comprehensive technical roadmap for the 2026 season, underpinned by the full deployment of the New-Hera platform. The transition from a static architecture to a modular, kinematic-adaptive system represents a significant leap in our capability to address the unstructured challenges of the RoboCup@Home rulebook. By resolving critical bottlenecks such as non-deterministic navigation in crowded spaces and kinematic singularities during floor-level manipulation, New-Hera stands as a validated platform ready for real-world application.

Beyond our technical achievements, the team remains steadfast in its commitment to societal impact and educational outreach. Through our volunteer work organizing the Brazilian Robotics Olympiad, we actively foster the next generation of engineers by translating high-level research into accessible knowledge for children and youth. This continuous cycle of learning and teaching ensures that our innovations extend beyond the laboratory, inspiring a broader interest in STEM fields across Brazil.

References

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4. RoboCup@Home. `http://www.robocupathome.org/`. Accessed on: Oct, 10th 2024.
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New-Hera Robot Hardware Description

Fig. 5: New-Hera Platform

The New-Hera platform debuts in RoboCup 2026 featuring a modular acrylic architecture. Specifications are as follows:

Base

- **Type:** Holonomic Mecanum Platform
- **Weight:** 14.8 kg (32.6 lbs)
- **Sensors:** 2x RPLiDAR C1, Ultrasonic, Infrared
- **Actuators:** 4x High-Torque Motors

Torso

- **Type:** Custom Acrylic Frame
- **Weight:** 12.7 kg (28.0 lbs)
- **Sensors:** Emergency Stop, Physical Bumpers

Manipulator

- **Type:** Custom 6-DOF Arm + Prismatic Joint
- **Weight:** 10.8 kg (23.8 lbs)
- **Vertical Travel:** 0.6m (Leadscrew)
- **Materials:** Carbon fiber links, Flex gripper
- **Actuators:** 1x Brushless (Lift), 6x XM540 (Arm), 2x XM430 (Gripper)
- **Sensors:** Force/Torque feedback, Microswitch

Head

- **Display:** Samsung Galaxy Tab S6 Lite
- **Sensors:** Intel RealSense D435i, HyperX Mic
- **Actuators:** 2x Dynamixel XM430 (Pan/Tilt)

Control Units

- **CPU:** Dell OptiPlex 7020 Micro
- **GPU:** NVIDIA Jetson Orin Nano

Software Description

Distributed ROS2 Architecture:

- **OS:** Ubuntu 22.04 LTS
- **Middleware:** ROS2 Humble
- **Nav:** Nav2 Stack (SLAM/AMCL)
- **Vision:** YOLOv11, MediaPipe, Dlib
- **Manip:** MoveIt2 + OctoMap
- **HRI:** Whisper, PiperVoice

Cloud Services

External APIs (Redundancy):

- **NLP:** ChatGPT API (OpenAI)
- **Backup Voice:** Google Speech API

Repository:
`https://github.com/robofeiathome`