RoboFEI@Home Team Description Paper for RoboCup@Home 2025: CBR Vitória/ES Edition

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***Abstract*—The RoboFEI@Home team, active in the RoboCup@Home league since 2015, introduces New-Hera - a fully modular and lightweight service robot developed after retiring the legacy HERA platform in early 2025. New-Hera integrates an Intel NUC i7 and NVIDIA Jetson, ROS2-based architecture, modular electronics, and a block-structured mechanical design optimized for transport and upgrades. This paper presents the platform's evolution in manipulation, navigation, and human-robot interaction. Scientific contributions include user-centered design, motion analysis with OpenPose, and robust SLAM integration. A recent dataset for sound recognition, adapted from autonomous vehicle research, enhances service robots' awareness of alarms, voices, and ambient noise on embedded systems. Educational outreach and open-source resources remain core to the team's mission, available at https://github.com/robofeiathome.**

***Index Terms*—RoboCup Brazil, Robot Service, @home.**

I. Introduction

The RoboFEI@Home team has participated in RoboCup@Home competitions since 2015, developing service robots to address challenges in domestic environments through safe navigation, effective human-robot interaction (HRI), and reliable task execution.

After the 2024 season, the legacy HERA platform was officially retired. All efforts have since transitioned to the development of a new platform, New-Hera, which introduces a modular, lightweight, and scalable architecture better suited to current research demands and logistics constraints. Its compact and block-based mechanical structure improves portability and maintenance, key factors for travel and competition readiness.

Technically, New-Hera combines an Intel NUC i7 with an NVIDIA Jetson module, enabling the parallel use of high-performance computation and GPU-accelerated inference. The platform runs ROS2, supporting modern communication standards and improved modular integration.

The team's development approach is grounded in interdisciplinary collaboration, combining mechanical, electronic, and software engineering. This paper describes the evolution represented by New-Hera, detailing the platform's technical architecture, research contributions, and role in advancing the state of service robotics in national and international contexts.

II. Research focus and interests

The development of New-Hera reflects the RoboFEI@Home team's ongoing research in key areas of service robotics, including human-robot interaction (HRI), autonomous navigation, object manipulation, and vision-based perception in dynamic domestic settings. Our research focuses on building adaptive and socially-aware robots capable of operating in real-world scenarios.

Current efforts prioritize the integration of modular hardware and software using ROS2, enabling scalable development and faster adaptation to new functionalities. Navigation research centers on robust SLAM techniques and semantic mapping, allowing the robot to reason spatially and interact appropriately with humans and objects. In parallel, vision-based modules rely on deep learning and segmentation techniques for high-accuracy object detection, using real-time inference with GPU acceleration.

The manipulator design is also fully developed in-house, optimized for weight and reach, and integrated into the robot's architecture through custom control systems. Modularity extends to all hardware components, facilitating maintenance and upgrades, especially for deployment in educational and public environments.

Aligned with the Jesuit values of the Centro Universitário FEI, our work contributes to the United Nations Sustainable Development Goals (SDGs), focusing on accessibility, assistive technology, and inclusive solutions. The New-Hera platform is designed to support individuals with mobility limitations, enabling robots to assist in daily tasks with safety and autonomy. Our multidisciplinary approach (combining mechanical engineering, electronics, computer vision, and artificial intelligence) drives both technological advancement and social impact, contributing to the evolution of service robotics in Brazil. In August 2025, the RoboFEI@Home team participated in the RoboCup Asia-Pacific (RCAP) Beijing Masters, sharing expertise in service and humanoid robotics across various application contexts. The event gathered 16 international teams and 30 Chinese teams, fostering knowledge exchange and strengthening collaboration with multiple robotics companies in China.

III. Team Achievements, Participations and Collaborations

Since its establishment in 2015, the RoboFEI@Home team has consistently demonstrated excellence in service robotics competitions. The team has earned five first-place titles in the Brazilian Robotics Competition (CBR) and secured second place in the 2024 edition. On the international stage, RoboFEI@Home achieved first place in the Open Platform League at RoboCup 2022 in Thailand [1], consolidating its presence in the global robotics community.

Following the team's participation in RoboCup 2024, development efforts shifted entirely to New-Hera, which now represents the team's sole platform for research, education, and competition. The design of New-Hera is directly informed by the team's accumulated experience and competitive insights, resulting in a system optimized for logistics, modularity, and advanced robotics functionalities.

Beyond competition, RoboFEI@Home plays a strategic role in STEM education. In 2024, the team coordinated four official events of the Brazilian Robotics Olympiad, promoting the RoboCup@Home league and engaging 356 students from 68 schools. The events supported teams in both Level 1 (children) and Level 2 (youth), encouraging early interest in science, engineering, and robotics.

The team also contributes to the international robotics ecosystem through open-source initiatives and scientific collaboration. Faculty and team members hold active roles in RoboCup committees, including the Executive and Organizing Committees for the 2025 edition in Salvador, Brazil. These contributions reinforce the team's commitment to scientific dissemination, community engagement, and technological leadership in service robotics.

IV. Hardware and Software Architecture

New-Hera is built upon a dual-computing system combining an Intel NUC i7 and an NVIDIA Jetson module. This hybrid architecture supports both CPU-intensive tasks and GPU-accelerated inference for real-time perception. The mechanical structure is lightweight and block-based, simplifying transportation, maintenance, and upgrades - key for competitive environments and field deployments.

The platform includes:

- Intel RealSense camera for depth perception.
- Dual 3D LIDARs for enhanced mapping and obstacle detection.
- Adjustable-height manipulator designed with a lead screw mechanism for vertical mobility.
- Custom electronics with modular wiring and accessible power distribution.

A. Robot NEW-HERA Hardware Description

The new version of the HERA robot is currently under development as of the TDP submission date, with the expectation of debuting in the RoboCup 2025 competition. Specifications are as follows:

Fig. 1. Current New-Hera Version

Source: RoboFEI Team, Centro Universitário FEI.

- Base: Mecanum Wheel Robot platform.
  - Sensors:
    - Lidar S2 or C9
  - Actuators:
    - 4 Omnidirectional wheels
- Chest: PeopleBot extension
  - Sensors:
    - Emergency switch
    - Bumpers
  - Actuators:
    - 7 DOF manipulator and height positioning
    - 1 Flexible gripper
- Head: Samsung Galaxy Tab S6 Lite
  - Sensors:
    - Intel RealSense D435i
    - Microphone - HyperX QuadCast S
- Control: Dell OptiPlex7000 and NVidia Jetson AGX Xavier.

B. Robot's Software Description

For NEW-HERA robot we are using the following software:

- OS: Ubuntu 22.04;
- Middleware: ROS2 Humble;
- Localization/Nav./Map.: SLAM;
- Face detection: Dlib;
- Face recognition: Dlib and Iris;
- People detection and tracking: Mediapipe
- Gestures/movement recognition: Mediapipe;
- Object recognition: YOLOV8 with Augmentation;
- Object manipulation: MoveIt2 and OctoMap;
- Speech recognition: DeepSpeech (offline) or a package Speech Recognition library (online);

- Speech synthesis: Flite (offline) or GTTs (online).
- Simulation environment: Gazebo inside a Docker Container

C. Cloud Services

NEW-HERA connects the following cloud services:

- Google API for voice recognition and synthesis.
- ChatGPT API for advanced natural language understanding and generation.

V. Approach to Solve RoboCup@Home Challenges

The RoboFEI@Home team's strategy to address RoboCup@Home challenges is centered on New-Hera, a modular and adaptive service robot designed for dynamic domestic environments. The platform integrates state-of-the-art components for perception, manipulation, navigation, and interaction, enabling it to perform complex tasks in real-world scenarios.

A. Navigation and Mapping

New-Hera employs ROS2's Navigation2 (Nav2) stack, integrating SLAM and path-planning algorithms optimized for dynamic indoor environments. Sensor fusion between LIDARs, cameras, and wheel encoders enhances localization accuracy and obstacle avoidance. Semantic mapping is also being explored to enable high-level spatial reasoning and context-aware behaviors during interaction tasks.

B. Manipulation and Object Handling

The manipulator is fully developed in-house and designed to be integrated seamlessly with perception and planning modules. Motion control is handled via the Dynamixel Workbench and MoveIt, while OctoMap provides 3D environmental awareness for safe and precise object manipulation. The adjustable height improves reach and adaptability to a variety of domestic surfaces and object sizes.

C. Perception and Vision Systems

Object detection is based on YOLOv8, integrated with PyTorch and accelerated via the Jetson module. Deep Salient Object Detection enhances segmentation in cluttered backgrounds, and custom synthetic datasets expand generalization to novel environments. The vision system supports both recognition and tracking, essential for delivery, cleaning, and inspection tasks.

D. Human-Robot Interaction (HRI)

HRI modules combine speech recognition, gesture detection, and social navigation. The robot uses the Whisper API for voice command recognition, adapted for use on ROS2 with support for multiple accents and speech conditions. The system also includes behavior trees for task planning and reactive decision-making, enabling the robot to respond to human cues and environmental changes in real-time.

E. Modularity and Maintainability

The platform's modular approach extends to software and hardware, supporting rapid integration of new features. ROS2 provides scalable node management, and the mechanical design allows easy replacement of components. This ensures system longevity and flexibility across multiple research and competition scenarios.

VI. Current Research and Scientific Contributions

The RoboFEI@Home team remains committed to advancing service robotics through applied research, interdisciplinary collaboration, and open knowledge dissemination. All scientific contributions presented below are validated using the New-Hera platform, which serves as the team's unified testbed for experimentation and deployment.

A. User-Centered Design Practices for Human-Robot Interaction

This study focuses on enhancing usability and user experience (UX) in Human-Robot Interaction (HRI) through user-centered design (UCD) principles. Iterative evaluations were conducted to refine interaction modalities, dialogue models, and interface feedback mechanisms. Applied to New-Hera, the results have improved task comprehension and user engagement across voice and gesture-based commands [2].

B. Motion Analysis with OpenPose for Assisted Care

A motion tracking system based on OpenPose was integrated with ROS2 on New-Hera to analyze human joint movements in real-time. The system supports elderly care applications by monitoring mobility patterns and detecting abnormal motions. Its integration with the robot's perception stack enables adaptive positioning to optimize visual tracking during interaction [3].

C. Enhanced SLAM and Navigation with Sensor Fusion

New-Hera incorporates optical encoders, stereo cameras, and LIDARs in a fused architecture to improve localization accuracy and mapping density. Implemented within ROS2, this sensor fusion approach enhances navigation robustness in changing environments. The method supports obstacle prediction and path replanning in cluttered and human-populated spaces [4].

D. Object Segmentation with 3D Point Clouds for Manipulation

Advanced object segmentation using region- and edge-based techniques was developed to process point cloud data from the RealSense camera. These methods allow the robot to extract object contours and compute manipulation trajectories in real-time. On New-Hera, the segmented point clouds guide the in-house manipulator for safe and precise grasping in complex scenes [5].

E. Combining GPT Vision and YOLOv8 for Semantic Understanding

YOLOv8 and GPT Vision were combined to improve object recognition and contextual scene analysis. The integration enables New-Hera to detect and semantically interpret visual scenes, enhancing decision-making for tasks such as targeted object delivery, user interaction, and situational response. This combination demonstrates strong potential in extending the robot's autonomy and reasoning capabilities [6].

F. Environmental Sound Recognition for Context-Aware Service Robots

Environmental sound recognition (ESR) is a critical capability for autonomous systems operating in human-centered environments, as it complements vision and tactile sensing to provide a more comprehensive perception of context. While this research was originally motivated by autonomous vehicle applications, the underlying computational and operational constraints closely match those of service robots, such as New-Hera. Both platforms must process sensory inputs in real time, operate on embedded computing devices with limited resources, and respond promptly to events in dynamic and often noisy environments.

The main objective of the study was to develop and validate a dataset optimized for embedded sound recognition models, enabling robots to detect acoustic events that enhance contextual awareness during task execution and human-robot interaction. To this end, the authors extended the widely used UrbanSound8K (US8K) benchmark by tailoring it for autonomous decision-making in human-centric environments. The modification process involved merging classes irrelevant to autonomous decision-making into a new "background" class and adding a "silence" class curated from Freesound.org. The resulting dataset, UrbanSound8K for Autonomous Vehicles (US8K_AV), contains 4.94 hours of annotated audio, totaling 4,908 WAV files across six balanced categories: *car horn*, *siren*, *engine*, *human voice*, *background*, and *silence*.

The research methodology comprised three main stages:

1) **Dataset Curation and Labeling:** Re-assessment of US8K classes for their relevance to situational awareness in autonomous systems, followed by merging and creation of new classes.
2) **Model Training and Optimization:** Development and evaluation of lightweight convolutional neural network architectures designed for inference on embedded devices, with attention to latency, memory footprint, and robustness under varied noise conditions.
3) **Embedded System Evaluation:** Deployment of trained models on platforms comparable to service robots-specifically an NVIDIA Jetson and a Raspberry Pi 4-measuring classification accuracy, processing delay, and energy consumption during real-time operation.

The experiments demonstrated that optimized ESR models could run in real time on resource-constrained hardware without external GPU acceleration. Accuracy was consistently high for critical event classes such as *siren* and *human voice*, even when tested under noisy or mixed-background conditions. The low inference latency observed on both Jetson and Raspberry Pi confirmed feasibility for immediate decision-making in field deployments.

In the context of RoboCup@Home, integrating US8K_AV into New-Hera's perception stack substantially enhances the robot's contextual reasoning capabilities. By detecting auditory cues-such as a smoke alarm, an approaching vehicle, or a person calling for help-the robot gains an additional modality for interaction and decision-making, reducing reliance on vision alone. This multimodal awareness can improve performance in tasks involving search and rescue, user assistance, and safety monitoring, aligning directly with the league's goals of advancing service robotics for domestic and public environments. Importantly, the dataset and associated models have been released as open-source resources, enabling other teams to reproduce, adapt, and extend this approach [7] (https://doi.org/10.1038/s41597-025-05446-2).

Beyond the competition setting, this research has broad applicability in multiple domains of service robotics. In **domestic environments**, ESR allows robots to identify events such as doorbells, kitchen timers, or the sound of a child crying, enabling timely responses and proactive assistance to residents. In **hospitals and healthcare facilities**, robots equipped with sound recognition can detect patient calls, medical equipment alarms, or unusual noises that indicate emergencies, supporting healthcare staff in critical situations. Within **universities and public buildings**, the technology can help robots respond to fire alarms, announcements, or auditory cues in crowded areas, improving safety and coordination. In **industrial or corporate settings**, ESR can assist in monitoring machinery sounds for predictive maintenance or alerting to abnormal acoustic patterns. Across these contexts, the integration of ESR fosters more natural, safe, and effective human-robot interaction, making autonomous systems more context-aware, responsive, and socially integrated.

VII. Future Vision

The continuous evolution of new robotic platforms is essential to maintain competitiveness and relevance in a rapidly changing technological landscape. Market trends indicate a growing demand for robots capable of operating in multiple contexts, with high levels of integration and adaptability to different mobile bases, whether commercial or custom-built.

Our internal research focuses on the design of upper modules that can be quickly integrated with various mobile robotic bases, ensuring structural, electronic, and software compatibility. This approach allows the same perception and interaction architecture to be deployed across multiple platforms, accelerating development cycles and reducing costs.

In parallel, we are conducting studies on the application of humanoid robots in the RoboCup@Home tasks, investigating how their physical and interactive capabilities can expand the scope of performed activities. Research on the integration of non-humanoid service robots with humanoid robots is a

strategic direction, as it enables combinations that merge the mechanical robustness and payload capacity of traditional mobile platforms with the dexterity and natural interaction offered by humanoid robots.

This synergy between different robotic typologies reinforces our commitment to exploring hybrid and adaptable solutions, aligned with both market demands and the technical and scientific challenges present in competitions and real-world applications.

VIII. Conclusion

The RoboFEI@Home team continues to advance the field of service robotics through the development of New-Hera - a unified, modular, and adaptive platform designed to meet real-world challenges in domestic environments. With the retirement of the HERA platform in early 2025, New-Hera now serves as the exclusive foundation for research, competition, and educational outreach.

New-Hera integrates high-performance computation, modular electronics, and scalable mechanical design. It supports advanced capabilities in navigation, object manipulation, perception, and human-robot interaction. The transition to ROS2 and the use of embedded AI have enabled greater flexibility, maintainability, and responsiveness across all subsystems.

Scientific contributions validated on New-Hera include vision-based interaction, 3D object segmentation, motion analysis, multimodal perception, and environmental sound classification. These efforts reinforce the team's commitment to accessible, socially impactful robotics solutions. The newly published US8K_AV dataset exemplifies this approach, expanding robot awareness in auditory contexts.

The team also remains dedicated to robotics education and open science. Through national outreach initiatives and participation in RoboCup@Home and CBR, the RoboFEI@Home team fosters innovation and talent development in Brazil and beyond.

All source code, datasets, and development resources are publicly available at: https://github.com/robofeiathome.

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