RoboFEI@Home Team Description Paper 2023

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Abstract. HERA (Home Environment Robot Assistant) is a versatile robot developed by the RoboFEI@Home team for autonomous tasks in home environments. It excels in human-robot interaction and collaborates effectively with people. For RoboCup 2023, we have enhanced various packages, improving interaction methods, object manipulation, and social navigation. Image segmentation processes have optimized environment perception, enhancing manipulation and people recognition. This paper presents our research goals, team interests, hardware and software stacks utilized for solving @Home competition tasks. The team's software contribution can be found on `https://github.com/robofei-home`.

1 Introduction

The RoboFEI@HOME team is active since 2015, performing domestic tasks that require interaction with the environment, dealing with dynamic surroundings and coordinating different goals. Even before that, the RoboFEI team has competed in the Small Size League, since 2009, and in the Humanoid League, since 2013.

Their research focuses on human-robot interaction, considering human behavior, user modeling, and social navigation. The team strives for constant evolution, with a focus on enhancing the autonomy of the HERA robot. This Team Description Paper outlines their current and future research, achievements, competition participation, collaborations, and their approach to solving RoboCup@Home challenges.

To do such complex tasks, research is carried out in different contexts considering human behavior, user modeling, interaction design, and social navigation,

among others [1,2,3]. The research on human-robot interaction has been intensified with master and doctoral projects.

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2 Research focus and interests

RoboFEI@Home focuses on researching the interaction of robots with their environment, including objects and people. This field of study is vital for the development of service robots in emerging technologies like autonomous cars, robots, and smart houses. As a university specializing in engineering and computer science, RoboFEI@Home is actively engaged in research and development related to various areas such as mechanics, electronics, automation, robotics, materials, and computer science [4].

3 Team Achievements, Participations and Collaborations

We are a passionate team for RoboCup@Home and have actively participated in it since 2016, winning first place in the Open Platform League at the 2022 edition in Thailand. In the Brazilian Robotics Competition (partner RoboCup Brazil) we won first place five consecutive times. Early this year, we successfully participated in the RoboCup2023, France edition, coming within a few points of the medalists.

Hosting the Brazilian Robotics Competition, last year, allowed us to practice in our permanent @Home arena, improving our performance. Testing our technologies in a realistic environment presented new challenges and improved our manipulation, vision system, and navigation capabilities.

4 Approach to solve RoboCup@Home challenges

RoboCup@Home develops service robots for home applications and hosts the largest annual international competition. Robots are assessed based on their skills in Human-Robot Interaction, Navigation, Computer Vision, Object Manipulation, among others [5].

4.1 Robot Vision

The object detection system utilizes the YOLOv8 architecture implemented in PyTorch for accurate object detection. Synthetic data generation techniques are used to increase the dataset size efficiently. The Deep Salient Object Detection algorithm improves background removal by identifying the most significant object and generating a binary mask. This enables compositing the object onto

different backgrounds. These approaches effectively enhance object detection capabilities as demonstrated through rigorous experimentation. In the last year's RoboCup edition, an image segmentation technique using color extraction was implemented for the finals, for a fine adjustment in object manipulation. People recognition was also integrated, allowing the robot to memorize names and faces using the dlib library. These advancements reduce training time and enable a wide range of tasks involving people.

Fig. 1: A visual representation of the object detection system in action, showcasing its high accuracy in identifying and localizing objects.

4.2 Voice recognition

The team decided to use Google's Speech Recognition API. For this, a ROS package was developed that operates through an API set. They are online tools that work directly on Ubuntu. In addition, a comparison is made with generic sentences using the Hamming distance to recognize sentence variations. An integration with ChatGPT was also implemented in order to improve not only the speech recognition system but also the human-robot interaction techniques.

4.3 Manipulation

Our manipulator, developed by the mechanical team, is designed with a human arm-inspired approach, optimizing both domestic tasks and human-robot interaction. Extensive study of human anatomy and kinesiology led to a focus on key movements such as extension and flexion.

We have implemented new materials in the manipulator, utilizing 3D printing for complex-shaped parts and carbon fiber for flat parts. This results in improved strength-to-weight ratio and compact dimensions.

For control, we employ the Dynamixel Workbench package for simpler movements and direct kinematics. Moveit with inverse kinematics is responsible for trajectory planning and precise movements. To enhance manipulation safety and

optimization, we added OctoMap features (figure 2), enabling environment perception through the Zed camera. This integration ensures secure and accurate "pick and place" operations.

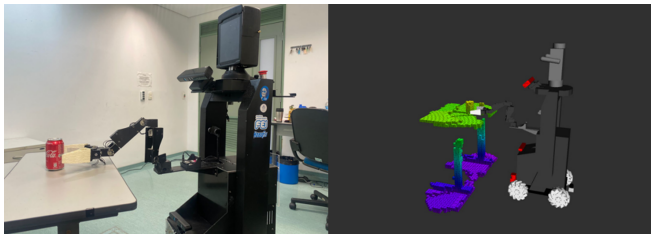

Fig. 2: Sensor interpretation using OctoMap in manipulation system.

4.4 Robot Navigation

An autonomous robot, to be able to navigate alone, needs the ability to map where it is, define its position in space and decide the best achievable route. For this to be possible, sensors that capture external environments are used, and this information is transformed into interpretive data so that the robot chooses the best route. When it is in an unknown location, the robot must map the environment where it is located, and at the same time define its position in space. This technique is known as Simultaneous Location and Mapping (SLAM). In navigation, the robot has the ability to choose the best possible route and avoid obstacles using parameters where the smallest path error is corrected instantly.

5 Current Research

5.1 Inteligent Battery Managment

Our research in the electronics field is more focused on the development of intelligent systems to optimize battery planning. By analyzing a database, it would be possible to calculate the current consumed in a given process and select the most effective battery to meet the demand. Among the available options, lithium-ion batteries (li-ion), lithium-ion polymer batteries (li-po) and lead acid batteries stand out.

This approach would enable a more accurate and efficient choice of batteries, taking into account factors such as storage capacity, lifetime, cost and energy efficiency. This smart system would ensure a more accurate and efficient selection of batteries, optimizing energy use and contributing to the development of technologies that rely on high-performance batteries.

5.2 Manipulation using point cloud

By segmenting objects into point clouds, service robots can accurately identify and delineate objects in their surroundings. This capability is especially relevant for manipulation, allowing robots to know where an object begins and ends, enabling safer grasping and more careful interaction with the environment.

This technology gives robots a richer understanding of the space in which they operate, enabling them to select the best strategies to manipulate objects efficiently, avoid unnecessary collisions and minimize the risk of damage to the environment and themselves. Through this advanced technology, these machines can adapt more easily to dynamic environments, offering high-performance solutions in a variety of applications, from domestic tasks to healthcare services.

6 Conclusion

The RoboCup@Home competition is a challenging event that requires robots to perform a variety of tasks related to home assistance. This Team Description Paper describes the main strategies and technologies used by robot HERA to win first place in the last year's edition: RoboCup@Home 2022 (Open Platform League), focusing on the organization of tests and rapid implementations of technologies for validation. This, added to our constant use of the arena built at the university, enables us to validate our solutions quickly and make necessary adjustments to optimize our performance.

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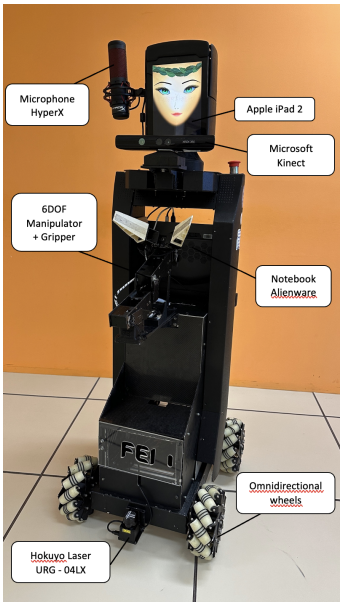

Robot HERA Hardware Description

Robot HERA has been designed for human interaction in the domestic environment. Specifications are as follows:

- Base: Mecanum Wheel Robot platform.
  - Sensors:
    - Hokuyo URG - 04LX
  - Actuators:
    - 4 Omnidirectional wheels
- Chest: PeopleBot extension
  - Sensors:
    - Emergency switch
    - Asus Xtion
  - Actuators:
    - 6 DOF manipulator
    - 1 Flexible gripper
- Head: Apple Ipad 2
  - Sensors:
    - StereoLabs ZED2
    - Microsoft Kinect
    - Logitech c920 webcam
    - 2 microphones - HyperX QuadCast S
- Control: Notebook Gamer Alienware m15 R7 i7.

Robot's Software Description

For our robot we are using the following software:

- OS: Ubuntu 20.04;
- Middleware: ROS Noetic;
- Localization/Navigation/Mapping: SLAM;
- Face detection: Haar cascades;
- Face recognition: LBP Algorithm;
- People detection and tracking: OpenPose
- Gestures/movement recognition: Wave! and NITE;
- Object recognition: MobileNet v2 + SSD on Synthetic Data;
- Object manipulation: Moveit! and OctoMap;
- Speech recognition: DeepSpeech (offline) or a package based on the Speech Recognition library (online);
- Speech synthesis: Flite (offline) or GTTs (online).
- Simulation environment: Gazebo inside a Docker Container

External Devices

HERA robot relies on the following external hardware:

- JBL Charge 5
- Nvidia Jetson Xavier NX.

Cloud Services

HERA connects the following cloud services:

- Google API for voice recognition and synthesis.