RoboFEI@Home Team Description Paper for RoboCup@Home 2021

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Abstract. HERA (Home Environment Robot Assistant) is a robot developed by the RoboFEI@Home team. The project started in 2015 as part of the robotics projects led by the University Center of FEI in the Human-Robot Interaction area. The main goal is to support people in daily activities and is achieved through human-robot interaction and cooperation tasks. HERA counts with features that support in the development of the tasks, such as a significant amount of sensors that aid in the mapping of the environment, the navigation system, recognizing human silhouettes and faces, object formats and details, and a gripper, designed by the team, that allows the interaction of the robot with the environment. Throughout the text, the research goals and interests of the team will be presented, as well as the hardware and software stacks used in the development of the robot to solve the tasks of the @Home competition and some of the projects currently under development by the group. The article intends to cooperate with the sharing results on the specification of a service robot.

1 Introduction

Service robots consist of the combination of software and hardware systems that are designed to perform daily human-assisting tasks. There are several factors, the navigation system, robot vision, and voice recognition, required to accomplish the tasks with excellence. A service robot should be able to map and navigate through whichever location is assigned, to detect objects and humans, and recognize human commands.

In order to seek growth in advances in the service assistive robotics area, an international competition was established, known as the RoboCup@Home. Accordingly, an autonomous mobile robot is required to participate in the competition.

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The RoboFEI@Home team created HERA, a robot designed to perform human-robot interaction and cooperation tasks. At its core, HERA features a Mecanum Wheel robotic platform, with PeopleBot's chest level extension to aid interaction with humans and the environment [1].

HERA also counts with a series of sensors to aid map and navigate the environment, as well as recognize the human silhouette, faces of individuals and objects.

The Team Description Paper of the RoboFEI@Home is organized into 5 sections. The first section is the introduction, which includes a brief description of the area of study, the competition, and the team. The second section gives a detailed description of the RoboFEI@Home research focus and its history in other competitions. The third section presents the software applied to present a solution for the tasks stipulated by the RoboCup@Home Competition. The fourth section maps introduce the main projects of the RoboFEI@Home teams, describes their contribution to the RoboCup community, and their application to daily situations. The final section presents the conclusions and plans for improvement.

2 Research focus and interests

The main focus of the research conducted by the RoboFEI@Home is the interaction between humans and machines. This interaction can be observed in a great amount of technology emerging, such as autonomous cars, robots, and smart houses. The research in the field of human-machine interaction is highly influential to the development of service robots.

The RoboFEI@Home also contributes to the development of methodologies, techniques, models, and algorithms in the following topics: adaptive interfaces, brain-computer interfaces; planning; intelligent home and building automation; autonomous systems, and the internet of things (IoT).

2.1 Team Achievements, Participations and Collaborations

The first participation of the RoboFEI@Home in an @Home competition was during the Brazilian Robotics Competition 2015 (CBR, from Portuguese Competição Brasileira de Robótica), and ranked in third place. In 2016, the team managed to reach its first international competition. From this international experience, the team managed to gain a different view of the competition and different ways to improve. In the CBR@Home 2016, RoboFEI@Home managed to conquer the first place. Since 2016, the RoboFEI@Home has ranked in first place in the 2017, 2018, 2019 and 2020 edition. In the last edition of the Brazilian Robotics competition, 7 teams competed, which shows that even with the impacts caused by the pandemic, they were all able to participate. In the following year, the team participated in the RoboCup@HOME Competition, ranking in seventh place.

On account of the experience acquired by the members of the RoboFEI@Home team, they became involved in the organization of both competitions, CBR@Home and RoboCup@Home. In 2018, the CBR@Home's Chair is a RoboFEI@Home team member. In 2019 and 2020, some members of the team became part of the local and the international Committees.

The team participated in various scientific events, demonstrations, workshops, with the aim of publicizing the league locally, and demonstrating to people the importance and potential of social robotics.

3 Description of the approach used to solve RoboCup@Home challenges

HERA uses ROS Melodic Morenia, released in May 2018 [2]. In the next sections, the vision, speech and navigation systems used in the robot will be presented.

3.1 Robot Vision

In the RoboFEI@Home project we utilize a single input device, a Microsoft Kinect 2, to achieve face recognition, people detection and object detection. The freenect 2 [3] was used, with the objective of accessing the main functions of the Kinect in several platforms.

The team developed an approach to object detection based on the use of a convolutional neural network and the single-shot detector technique [4]. With this approach, a dataset containing a very large number of examples for each object is necessary, but the neural network is capable of greater generalization while reducing processing time. In this work, we use MobileNet v2 [5] as our neural network architecture of choice. We trained MobileNet v2 with the aid of TensorFlow Object Detection API in a custom-made dataset.

For the creation of the dataset used to train the API, the team developed a software for generating synthetic examples of the objects, which yielded satisfactory results for object detection. Objects are detected by the aforementioned method using the video feed from the Kinect camera and are later placed in the 3D environment, with relation to the robot, by finding each object's corresponding location in the point cloud, provided by the Kinect infrared sensor.

For people detection we are using OpenPose [4], the first real-time multi-person system to jointly detect human body, hand, facial, and foot keypoints on single images. Together we are using Wave! for gesture recognition. The robot performs a face recognition using Haar Cascade.

3.2 Robot Navigation

When the robot is in an unknown location, it must know the environment where it is located, mapping and at the same time defining its position in the space. This technique is known as Simultaneous Localization and Mapping (SLAM). In the navigation, the robot has the capacity to choose the best possible route and avoid possible obstacles. For this to happen, it determinates parameters where there is the slightest path error and the robot is constantly correcting it.

3.3 Manipulator

In reason of the simulated competitions, our manipulator has been changed. It has the same number of degrees of freedom (DOF) contained in a human arm, with the purpose of obtaining a great similarity to real movements using the anthropomorphic principle.

The prototype was built using CAD tools, which allowed the study of the kinematics of movements and functional requirements, and if any member failed during the simulation, the project would be redesigned. This way, creating an iterative development process, with the intention of improving the prototype, as show on figure 1.

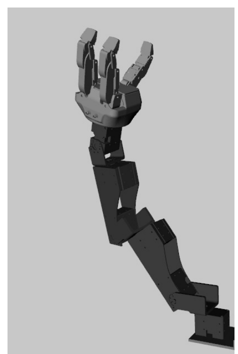

Fig. 1: Manipulator developed for robot HERA.

The gripper has changed substantially from the physical robot's current form. The physical gripper relies on applying enough pressure to the object to keep it in its grasp. Although, this method would not work in a simulated environment, since the virtual objects' hitbox could collide with the gripper's, causing a flick, that sends the item flying away from the manipulator. The virtual robot now utilizes a gripper that hugs the object and locks it into place like a human hand would, with sensors on the inner part of each finger. These sensors measure the amount of force that is being applied to the object, thus, making it easier to manipulate different kinds of items.

4 RoboFEI@Home Projects

This section describes current research and projects under development for the robot.

4.1 Learning rules for social navigation

This project is to develop a social navigation model on environments with multiple contexts focused on naturalness, sociability and comfort. Ontological Information (knowledge) is expected to be used in a learning system of social norms and rules in this process as focus of research. The work seeks to accomplish collaboration at the research areas of artificial intelligence, navigation, and social interaction through social navigation.

Navigation problems will be explored on environments of multiple contexts, and varied complexity rating; artificial intelligence, combining advanced pattern recognition and developing intelligence with common sense; human social dynamics understanding and moral rules that can be totally integrated with human social life showing empathy and social behavior; as well as ethics and security precautions.

Applicability in the real world: The research of this project is based on the mapping of existing social navigation models to develop a generic and modular model using semantic knowledge through the robot's ontologies of the environment, people and their relationships, to learn social behaviors related to navigation. The advantage of this type of application is that the robot can use existing knowledge about the environment in which it is inserted (people, objects and places) to learn new knowledge (behavior). Using ontology, it will be possible, for example, to learn social norms and rules in simulated environments and to use this learning in real environments.

Results As preliminary results of this research, a selection of the navigation methods used on the HERA robotic platform was made, focusing on social navigation metrics such as comfort and naturalness. In these results, it was observed that the robot manages to follow some aspects of social navigation in a satisfactory way, however it is still possible to make relative improvements, mainly in human comfort and sociability. Currently, comparative studies are being carried out between state-of-the-art methods for learning of social navigation and the method developed in the RoboFEI laboratory.

5 Conclusion

Since 2015, when RoboFEI@Home started competing, the team's research on service robots has improved substantially. Both the software and hardware has been evolving since then. At CBR@Home 2020, where the team won the fifth title, both, the new simulated robot and the synthetic dataset generation tool for object detection, showed a good performance and were crucial to win the contest. The research being conducted by the team shows development in areas of interest for home assistance robotics, with some of the projects already showing positive results in competitions. As future works, the aim is to improve the performance in tasks of people and gestures recognition, using new technologies, as well as the development of a modular structure, to facilitate the transport and maintenance of the robot.

Fig. 2: The two versions of our robot, physical and simulated.

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Robot Technical Specifications

Hardware Description:

- Base: Mecanum Wheel Robot platform.
  - Sensors:
    - Hokuyo UTM-30LX-EW.
  - Actuators:
    - Omnidirectional wheels.
- Chest: PeopleBot extension.
  - Sensors:
    - Emergency switch.
    - Asus Xtion
  - Actuators:
    - 6 DOF manipulator + 1 DOF gripper.
- Head: Apple Ipad 2.
  - Sensors:
    - Microsoft Kinect 2;
    - Logitech c920 webcam;
    - 2 RODE VideoMic GO directional microphones;
- Control: Zotac Mini-PC i5 7500T CPU.

Software Description:

- OS: Ubuntu 18.04;
- Middleware: ROS Melodic Morenia;
- 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!;
- 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